Appendix K

GEOTECHNICAL CONSTRAINTS AND ENDORSEMENT (CARDNO PTY LTD)

Our Ref: 82219047-0011: IGP
Contact: Ian Piper

15 October 2019

Northern Construction & Manager and Wakefield Ashurst Developments
11 Shoreside Row
Murrays Beach NSW 2281

Attention: Lewis Bird

Cardno (NSW/ACT) Pty Ltd
ABN 95 001 145 035

Unit 1
10 Denney Street
Broadmeadow NSW 2292
Australia

Phone +61 2 4965 4555
Fax +61 2 4965 4666

GEOTECHNICAL ENDORSEMENT OF DRAWINGS
LOTS 2, 3, 4, 5, 7 & 8 D.P. 1240365,
LOT 3 D.P. 1090495
CENTRAL PRECINCT, NORTHERN SECTOR, WALLARAH PENINSULA

For the purpose of geotechnical endorsement, the following documents related to the construction of a new subdivision at the above mentioned address, have been supplied by ADW Johnson and reviewed by Cardno:

- Concept Engineering drawings by ADW Johnson (Project No – 239475(N), Discipline: CENG, Rev: E, dated 15.10.2019, Drawing Numbers: 001-004, 101-111, 201-232, 251-253, 331-332, 501-516, 601-603); and
- Geotechnical Reports prepared by Cardno (NSW/ACT) Pty Ltd titled “Preliminary Slope Stability Assessment. Central Precinct, Northern Sector – Wallarah Peninsula. 82218007-002.2”, and “Report on Geotechnical Constraints. Central Precinct, Northern Sector – Wallarah Peninsula. 82218007-003.2” both dated 11 September 2019.

Review of the concept engineering drawings indicate that the recommendations proposed to address stability and other geotechnical constraints identified in the above reports have been adopted and reflected in the drawings.

Limitations

Cardno have provided consulting services for this project in general accordance with current professional and industry standards. The review of plans does not include checking of the actual civil, structural and other infrastructure designs and is limited to whether recommendations of the geotechnical report are adopted in the design drawings.

Cardno cannot provide unqualified warranties nor do we assume any liability for the design, any site conditions or changes to the design or site that are not observed or known.

The reports by Cardno, as mentioned earlier, have been relied on for the purpose of this endorsement.

A geotechnical consultant or qualified engineer should inspect footing and excavations to confirm conditions assumed in the geotechnical reports. If subsurface conditions encountered during construction differ from those given in the reports, further advice should be sought without delay.

This letter and any associated documentation were prepared solely for the use of Northern Construction & Manager and Wakefield Ashurst Developments & Lake Macquarie City Council. Any reliance assumed by other parties on this report shall be at such parties own risk.

Yours sincerely,

Abid Ali
Geotechnical Engineer

Ian Piper
Technical Services Manager, Geotechnical

for Cardno
Direct Line: +61 2 4940 5525
Email: abid.ali@cardno.com.au

Enc: Concept Engineering drawings by ADW Johnson

Report on Geotechnical Constraints

Central Precinct, Northern Sector - Wallarah Peninsula

82218007

Prepared for

Wakefield Ashurst Developments & Northern Managers & Construction Pty Ltd

4 October 2019

Cardno

Contact Information

Cardno (NSW/ACT) Pty Ltd
ABN 95 001 145 035

Unit 1
10 Denney Street
Broadmeadow 2292
Australia

Phone +61 2 4965 4555
Fax +61 2 4965 4666

Document Information

Prepared for	Wakefield Ashurst Developments & Northern Managers & Construction Pty Ltd
Project Name	Central Precinct, Northern Sector - Wallarah Peninsula
File Reference	82218007-003.2
Job Reference	82218007
Date	4 October 2019
Version Number	2

Author(s):

Inglis Brien
Geotechnical Engineer

Effective Date 11/09/2019

Approved By:

Ian Piper
Principal Technical Officer

Date Approved 11/09/2019

Document History

Version	Effective Date	Description of Revision	Prepared by	Reviewed by
0	06/02/2018	Draft Issues for Client Comment	IB	IGP
1	19/07/2019	Amended Draft Issue to Client	IB	IGP
2	11/09/2019	Final Issue	IB	IGP

Table of Contents

Appendices

Tables

1 Introduction

Wakefield Ashurst Developments & Northern Managers & Construction Pty Ltd (WA & NMC) commissioned Cardno to undertake a geotechnical investigation of the Central Precinct North Sector - Wallarah Peninsula. The work was commissioned by Mr Lewis Bird of WA & NMC and investigation has been undertaken under the terms and conditions outlined in Cardno proposal dated 27 June 2017 [1].

The subject site comprises Lots 2, 3, 5 & 8 of DP1240365, part Lots 4 & 7 of DP1240365 and Lot 3 DP1090405 as per the client supplied drawings below and shown in Site Overview Plans in Figure 1 of Appendix A:

- Drawing title “Northern Sector Overall Service Locations”, council “LMCC”, drawing reference: 239475(N)-ESK-062”; and
- Drawing title “Concept Engineering Plans, Stage 1, Central Precinct, Northern Sector, Wallarah Peninsula”, council “LMCC”, drawing reference: 239475(N)-CENG-500-599.

It should be noted that Lot 1 of DP226060, Lot 131 of DP604167 & Lot 76 of DP775644 currently owned by Lake Macquarie City Council & Hunter Water are included within the overall site boundary however are not part of the proposed residential development.

The above listed lots form the subject site of the current investigation. Based on current data the proposed development within these lots are likely to comprise a mixture of development types, including residential, commercial and community park space.

This report has been prepared in conjunction with a preliminary slope stability report under a separate cover, *Cardno Report Ref. ‘82218007-002.2 – Preliminary Slope Stability Assessment, dated 11-09-2019* [2].

1.1 Objective

This report aims to identify potential geotechnical constraints within the proposed development and provides detailed recommendations for remediation of the identified constraints. The report also aims to facilitate the planning and preliminary design throughout the early stages of development, including vegetation clearing and bulk earthworks. The level of geotechnical investigation undertaken and discussed is considered suitable to provide preliminary input to support the development application. It should be noted that detailed investigation will likely be required for specific geotechnical design elements subsequent to bulk earthworks.

1.2 Scope

The following has been undertaken to achieve the objective outlined above:

- Review of previous studies in the area, data from previous investigations, regional geological mapping, historical photographs and LIDAR data;
- Mapping of the sites significant geotechnical features that influence the design of the proposed development;
- Site walk over to assess surface conditions and constraints;
- Intrusive geotechnical site investigation including drilling of boreholes and test pitting to assess the subsurface profile to confirm previous investigations;
- Laboratory testing to assess the geotechnical and chemical properties of the sites subsurface material; and
- Interpretation of data and analysis.

2 Document Review

As part of the desktop review, existing geotechnical data relevant to the current investigation has been sourced from the client. The documents have been summarised below and the observations, results and recommendations from the below reports can be seen incorporated and appropriately referenced within this report.

> **Coffey 2012 – Wallarah Peninsula Indicative Pavements & Geotechnical Constraints** [3]

The purpose of the Coffey 2012 report was to provide preliminary pavement designs and comments on unusual geotechnical constraints to assist a previous potential sale of portions of the Wallarah Peninsula. No field investigation was undertaken specifically for the purpose of this study, however previous investigation results were utilised in order to provide suitable comments and recommendations.

The report includes detailed descriptions of regional geological setting and the various constraints across the site including; shallow sandstone outcrops, slope stability issues, previous mining impacts, uncontrolled fill, in-place weather coal outcrops, underground mine workings, swampy conditions and mine subsidence.

Recommendations provided within this report predominately pertain to likely pavement design and composition which will be addressed following development approval in subsequent reports.

> **Coffey 2010 – Abandoned Mine Assessment – Murrays Beach (Adjacent Development)** [4]

The purpose of the Coffey 2010 report was to provide an assessment of constraints due to past coal and clay pit mining activities in the Murrays Beach development area. The report also provided anticipated Mine Subsidence Board (MSB) development conditions as well as strategies to mitigate hazards associated with the abandoned mine workings.

The report although not directly related to the Mawson's development which is located further to the east although the report presents useful information that can be extrapolated to findings in the adjacent area currently under investigation.

> **RCA 2008 – Geotechnical Constraints Assessment – Northern Precinct (South)** [5]

The purpose of the RCA 2008 report was to assess the geotechnical suitability of the site for residential development and provide detailed geotechnical constraints, mapping and urban development guidelines.

The report includes a summary of previous land use, landforms, soil erosion impacts, soil landscape units, regional geological setting, subsurface conditions, ground water conditions and site constraints.

The report also includes recommendations for the treatment of cut and fill slopes, slope stability issues, erosion management, material re-use, preliminary pavement thicknesses and general structures recommendations including residential footing & retaining wall recommendations and general recommendations pertaining to water retaining structures.

Investigation included the excavation of numerous test pits and bores, Dynamic Cone Penetrometer (DCP) testing, constant head permeameter testing and Benkelman Beam testing of the Old Pacific Highway & Scenic Drive pavements within the development.

Recommendations in the report can be summarised below:

- Where shallow underground mine workings are present, provide large lots to allow a building envelope to be situated on the best possible location in combination with excavation and re-compaction of goafed ground where shallow workings are present.
- Perform additional geotechnical investigation and contamination sampling of overburden pertaining to old borrow pit areas to better define the depth and nature of materials to determine suitable earthworks methodology.
- Undertake development in accordance with a suitable erosion and sediment control plan in conjunction with the rehabilitation of existing disturbed surfaces associated with the open cut mine and clay borrow pit areas.
- Undertake suitable slope remediation in areas determined to have a moderate or greater risk level classification and undertake development in accordance with good hillside practice in areas of very low to low risk level classification.

- Undertake further investigation of existing pavements throughout the development to assess the suitability of the pavements for rehabilitation.

> **RCA 2007 – Desktop Assessment of Ground Improvement of Swansea Open Cut** [6]

The purpose of the RCA 2007 report was to assess the viability of ground improvement methodologies such as dynamic compaction and impact rolling in reducing the volume of conventional excavation and re-compaction earthworks whilst achieving final landform surface appropriate for high level residential foundations, pavements and services. No field investigation was undertaken specifically for the purpose of this study, however previous investigation results were utilised in order to provide suitable comments and recommendations

The report includes recommendations for the treatment of the Swansea Open Cut mine spoil that include a combination of conventional excavation and replacement methods to guidelines detailed in AS3798 and alternative compaction methods such as partial excavation and replacement, dynamic compaction and impact compaction rolling of the uncontrolled filling material. The report also recommends that where alternative methods are adopted a trial to confirm the viability of the treatment is performed prior to adopting the method over a large area.

> **SKM 2005 – Swansea Open Cut Redevelopment – Preliminary Geotechnical Report** [7]

The purpose of the SKM 2005 report was to present results from preliminary geotechnical investigation undertaken of the former Swansea Open Cut Coal mine. The investigation and report aimed to define the as-mined rock head surface within the open cut, determine the extent, thickness, composition and degree of compaction of the spoil and debris, investigate potential contaminates and combustible material and other deleterious matter present in the mine spoil and lastly assess the options for pit reconstruction and rehabilitation for residential development.

At the time of investigation, preliminary contamination testing was undertaken of mine spoil materials and assessed against relevant EPA (1998) guidelines which indicated that the land was suitable for industrial, recreation and residential land uses.

Recommendations for remediation of the mine spoil include reinforcement with geo-synthetic mats, grid and tendons, recondition spoil in controlled fill embankments. It is also recommended that benching, recutting selective high wall removal and buttressing be performed along sections of the high wall identified to be at high risk of rock fall or instability in combination with standoff distances of up to 30m and restricting public access to the steep exposed faces of the box cut.

The report also details opportunities for the re-use of filling material associated with the box cut, it is recommended to expand the low wall stripping and perform partial removal of the high wall to generate large volumes of granular spoil for use as fill material throughout the remainder of the development. It is also recommended to strip and reconstructed fill benches associated with the Northern Spoil Dump with surplus materials to facilitate residential development.

> **SKM 2002 – Wallarah Peninsula Geotechnical Review (Desktop Study)** [8]

The purpose of the SKM 2002 report was to provide a subjective assessment of ground conditions within the Wallarah Peninsula project area. No field investigation was undertaken specifically for the purpose of this study, however previous investigation results were utilised in order to provide suitable comments and recommendations.

The report includes a summary of geotechnical constraints and remedial recommendations while referencing; published maps, unpublished Mineral Resource reports and coal exploration logs, mine workings plans provided by the MSB, aerial photographs from Department of Lands and the Roads and Traffic Authority (RTA), unpublished geotechnical reports from the RTA and results from walkover surveys.

Recommendations for the Old Swansea Open Cut mine located on the subject site include the removal of re-compaction of mine spoil, re-cutting, benching and buttressing of the existing high wall.

> **RCA Australia 2008 – Environmental Site Assessment and Remedial Action Plan** [9]

An environmental site assessment was conducted, and remedial action plan prepared, for the Former Landfill Site by RCA Australia (RCA) in September 2008. The study area comprised Lot 2 DP337960 and Lot1 DP344160. The investigation included assessment of potential contaminants that might be present within spoil piles. The investigation comprised a field investigation and review of previous investigation undertaken be SKM.

Results from the additional investigations indicated HIL A (standard residential) exceedances in analytes Benzo(a)pyrene (2 total), Sum of reported PAH (1 total), Toluene (1 total), Zinc (1 total) & Lead (8 Total) and HIL E (parks, recreational open space and playing fields) exceedances in Zinc (1 total), Lead (2 total), Benzo(a)pyrene (1 total), Toluene (1 total) & Sum of reported PAH (1 total).

Perched groundwater sample data recovered from the wells when compared to the groundwater investigation levels (GILs) for 95% protection of aquatic ecosystems ANZECC and ARMCANZ Guidelines – 2000, indicated elevated concentrations of some metals including cadmium, chromium, copper, iron, lead and zinc. TPH and total phenols were also elevated above the adopted GILs, although results indicated that there had been no impact on the down gradient surface water.

Asbestos fibres were not detected in surface soil samples, although fragments of asbestos containing materials were detected across the site surface and within fill materials. Soil gas monitoring returned non-detectable readings for methane and CO2 at all locations.

The report concluded the following:

- The presence of soil contaminants, including PAH and lead, pose long-term human health risks for potential site occupants.
- Impacts on perched groundwater within the landfill are minor and have been shown not to impact on down gradient surface water.
- Remediation by encapsulation with the footprint of a proposed recreation area was the preferred remediation strategy. This would require excavation of impacted materials on the proposed residential footprint and relocation to the recreational footprint, before capping.

3 Site Description

The site is situated south of Swansea, with the Pacific Highway and the Wallarah interchange to its west, Wallarah National Park to its south and proposed development areas to its north and north-east. The site is located within regionally steep terrain comprising predominately undeveloped eucalypt woodland, with local topography characterised by large ridgelines/spurs generally trending southwest to northeast ranging from 10 – 20 degrees. The steep slopes to the north of the development generally fall to the southwest towards a central valley area. The central valley floor area is defined by a large natural drainage path extending northwest from a man-made dam in the centre of the site. The valley floor area comprises gentle slopes of less than 5 degrees.

During current site investigation impacts from previous land use were noted and are summarised below:

- Previous open cut mining operations associated with large high wall excavation faces and deep areas of overburden fill and numerous stockpiles predominately associated with Lot 2 of DP1240365 in the north eastern portion of the site.
- Mine subsidence and old entries to underground workings located in the south-eastern corner of Lot 5 of DP1240365, extending into Lot 7 of DP1240365.
- Past clay and gravel borrow pit areas contained within the central and western portions of Lot 5 of DP1240365.
- Old Swansea Landfill area within Lot 3 of DP1240365 comprising a combination of general household rubbish, building materials and excess soil and rock excavation material from the Wallarah interchange construction project.
- Cut and fill embankments within Lots 3 & 5 of DP1240365 associated with the Old Pacific Highway and Scenic Drive road pavements where pavement condition was observed in a poor condition at the time of investigation. Tension cracking was observed developing within the pavement particularly in areas commonly referred to as the ‘Swansea Bends’. Detailed comments & recommendations regarding the stability of the road embankments can be seen summarised below.
- A small rural dam constructed between 1965 and 1971 of unknown condition was present within the central portion of the site intercepting the main drainage gully as previously discussed.

Further detail on the above geotechnical restraints and recommendations for future remediation of these areas can be seen detailed in Section 7 and areas identified can also be seen in Figures 2, 3 & 4 attached in Appendix A.

Additional minor impacts throughout the site include various power line easements and buried telecommunication services, minor impacts associated with a previous residence on Lot 5 of DP1240365 and significant amounts of fly tipping throughout the site predominately associated with the Old Pacific Highway & Scenic Drives road alignment. These various impacts are briefly described throughout the relevant sections within this report, however do not form detailed recommendations as part of this assessment.

It should be noted a review of a number of historical aerials was undertaken as part of the site assessment. Review of the aerials revealed much of the site had previously undergone clearing to facilitate part of the activities detailed above. A Site Plan detailing previously disturbed land within is illustrated in Figure 5 in Appendix A and also attached in Appendix D along with the relevant historical ariels.

During site investigation, much of the vegetation across the site was observed to comprise predominantly semi-mature trees and thick underbrush and grass, with some baron areas of previous disturbance throughout the site associated with site activities such as open cut mining, clay pit mining and landfill where trees had not yet re-established.

Drainage over the site is predominately via surface runoff, with most ridge slopes being generally well drained with low lying areas associated with the valley floor containing poorly drained heavy clays. Erosion has been noted across the site and predominately confined to areas where human activity has left surficial soils exposed such as the old clay pit areas or open cut coal mine area. No evidence of bank or gully erosion was noted along the central drainage gully or over other vegetated slopes across the site, although some significant scour erosion was noted along earthen access tracks throughout the site.

4 Investigation Methodology

4.1 Current Investigation

The fieldwork was undertaken from the 24th of July to the 26th of September 2017 and was undertaken by an experienced Geotechnical Engineer from Cardno. Fieldwork conducted can be summarised below:

- Numerous site walkovers and visual inspection by a Geotechnical Engineer from Cardno which included site mapping, photography and logging of significant site features;
- Drilling of twenty-three (23) boreholes using a truck mounted scout drilling rig. Drilling was advanced using a combination of rotary air drilling and diamond core drilling techniques. The boreholes predominately targeted areas previously impacted by underground and surface mining activities.
- Disturbed bulk samples, rock core and environmental samples of natural materials and bedrock were collected for subsequent analysis and engineering logs quality control.

Boreholes and various geotechnical restraints were located by the use of GIS software and borehole locations are shown overlain on the relevant aerial imagery shown in Figure 6 in Appendix A. Subsurface conditions are summarised in Section 6 and are detailed in Engineering Logs attached in Appendix B, along with explanatory notes.

4.2 Previous Investigations

Previous intrusive field investigation as described in Section 2 was undertaken by various consultants including Robert Carr & Associates (RCA) and Sinclair Knight and Mertz (SKM) during past development application processes on behalf of Lensworth Wallarah Peninsula (previous owner) and Stockland's (previous owner).

Previous field investigations and testing undertaken by RCA detailed in report ref. 'Geotechnical Constraints Assessment', dated 30-06-2008 [5] comprised;

- Site walkover and mapping;
- Excavation of 17 test pits and 2 pavement bores using a track mounted excavator;
- Dynamic Cone Penetrometer (DCP) testing;
- Seven constant head permeameter tests in hand drilled bores; and
- Benkelman beam deflection testing of existing pavements.

Previous field investigations and testing undertaken by SKM detailed in report ref. 'Preliminary Geotechnical Report', dated 06-04-2005 [7] comprised;

- Excavation of 40 test pits using backhoe fitted with 300mm excavation bucket;
- Drilling of 9 boreholes using a truck mounted Edson 3000 rig, advanced using 125mm solid flight augers;
- Standard Penetration Testing (SPT) to assess subsurface strength and consistency properties;
- Collection of 10 Disturbed bulk samples for subsequent laboratory analysis including Particle Size Distribution testing, Atterberg Limit testing & California Bearing Ratio testing; and
- Collection of 10 soil samples for chemical laboratory analysis for preliminary contaminate analysis of mine spoil.

Boreholes, test pits / bores and hand auger locations from previous investigations are overlain on the relevant aerial imagery along with current investigation locations in Figures 6 in Appendix A.

5 Published Data

5.1 Site Geology

Reference to Gosford-Lake Macquarie 1:100 000 Geology Map, Geological Series Sheet 9131 Ed1 1995 [10] indicates that the site is situated within the Munmorah Conglomerate & Wallarah Coal Seam formations of the Narrabeen Group from the Early Triassic period, which is known to comprise conglomerate, pebbly sandstone, grey to green shale and residual soils derived from the weathering of these rocks. The above mentioned formations are known to overly Teralba Conglomerate of the Moon Island Beach Subgroup, which are a part of the Newcastle Coal Measures from the Late Permian period. The Teralba Conglomerate formation is known to comprise conglomerate, tuff, siltstone, claystone, black coal and residual soils derived from weathering of these rocks.

The following geological summary referenced from Coffey's 2012 report *'Wallarah Peninsula Indicative Pavements & Geotechnical Constraints*' [3] provides a detailed description of the underlying geological formations/units across the site:

- Munmorah Conglomerate; comprising sandstone and pebbly sandstone with occasional shale beds, located in the vicinity of t Mawson's Lookout and high wall areas of the Swansea Open Cut, material weathers to a residual sandy clay / clayey sand.
- Wallarah Coal Seam; 8.5m thick seam comprising three distinct splits, upper split, middle split and lower split. Splits are typically separated by tuffaceous siltstone and shale, material weathers to oxidised coal (carbonaceous silt/clay) and tuffaceous siltstone to high plasticity residual clay soils.
- Teralba Conglomerate; comprising conglomerate with minor sandstone beds at shallow depth, weathers to sandy gravelly soils with varying proportions of clay, located on along the valley floor areas to the west of the old pacific highway at the Wallarah interchange and inside the main gate of the existing development.
- Great Northern Seam; comprising thin coal and carbonaceous layer, weathers to localised high plasticity clay. Seam is poorly developed in the area, known to increase in thickness some distances to the west. Location at ground surface at about RL 60m along the steep upper slopes of the Coastal Village Precinct.
- Eleebana Formation (Awaba Tuff); comprising tuffaceous siltstone with sandstone and conglomerate up to 20-25m thick. Exposures seen only in the Coastal Village Precinct.
- Chain Valley Seam; comprising a coal seam approximately 1.0 – 1.5m thick. Some minor exposures located in the Coastal Village Precinct.
- Bolton Point Conglomerate; comprising sandstone with pebbly sandstone and conglomerate of approximately 30m thick. Exposures found in lower part of the Coastal Village Precinct and along coastal cliff lines.
- Fassifern Coal Seam; comprising coal and claystone of significant thickness. Exposed at the base of coastal cliff to the east of the Coastal Village Precinct.

5.2 Site Soil Landscape Mapping

Reference is made to the soil landscape maps derived from The Office of Environment and Heritage, Electronic Soil Profiling Maps (eSPADE) V2.0 [11] detailing soil landscape units across the site. The Awaba Soil Landscape (9131aw) of the Gosford – Lake Macquarie area is the predominant soil landscape across the subject site, with the other predominate soil landscape mapped as **Disturbed Terrain** (9131xx). The elevated areas in the central northern portion of the site are also included in the Awaba Soil Landscape although of the Awaba Soil Landscape - Variant A (9131awa). Detailed descriptions of the soil landscapes can be seen in the below Table 5-1.

Table 5-1 Soil Landscape Properties

Unit	Landscape	Soils
Awaba - 9131aw	Rolling low hills on predominately coarse-grained sediments of the Narrabeen Group and the Newcastle Coal Measures in the Awaba Hills.	Shallow Lithosols on Steep Slopes, Shallow to moderately deep Soloths and Yellow Podzolic Soils on gentler slopes. Known high erosion hazard and localised mass movement risk.
Awaba - 9191awa (Variant A)	Areas, defined as Variant A, are moderately inclined to steep slopes, otherwise landscape is similar to that of the Awaba 9131aw soil landscape.	Shallow Lithosols on Steep Slopes, Shallow to moderately deep Soloths and Yellow Podzolic Soils on gentler slopes. Known high erosion hazard and localised mass movement risk.
Disturbed Terrain - 9131xx	Level plain to hummocky terrain, extensively disturbed by human activity, including complete disturbance, removal or burial of soil.	Highly Variable. Known limitations include mass movement hazard, steep slopes, foundation hazard, poor drainage and erosion hazards.

Notes to table:
Derived from The Office of Environment and Heritage, Electronic Soil Profiling Maps (eSPADE) V2.0 (www.environment.nsw.gov.au/eSpade2Webapp#)

5.3 Published Site History

Detailed site history describing the various impacts from past human activity has been presented in previous geotechnical reports from various consultants such as RCA, SKM and Coffey Geotechnics. A general summary of investigation, results and recommendations of the relevant reports can be seen detailed in Section 2. Reference should be made to the below reports for further information on site history concerning the Swansea Open Cut Mining Operations & the underground mining operations of the various Wallamaine Collieries impacting the site:

- RCA 2007 – Desktop Assessment of Ground Improvement of Swansea Open Cut [6];
- RCA 2008 – Geotechnical Constraints Assessment – Northern Precinct (South) [5];
- SKM 2002 – Wallarah Peninsula Geotechnical Review (Desktop Study) [8]; and
- SKM 2005 – Swansea Open Cut Redevelopment – Preliminary Geotechnical Report [7].

Reference should be made to the below reports for further information on site history concerning clay and gravel pit mining impacting the site:

- RCA 2008 – Environmental Site Assessment and Remedial Action Plan [9]; and
- SKM 2002 – Wallarah Peninsula Geotechnical Review (Desktop Study) [8];

6 Investigation Findings

6.1 Subsurface Conditions

6.1.1 Natural Subsurface Conditions

The natural subsurface profile encountered across the site throughout boreholes and logged exposures during the current investigation and previous site investigation can be generally summarised as follows:

- Shallow sandy / gravelly residual CLAY soils were observed in elevated and steep areas throughout the development within majority of boreholes during current investigation. The material was predominately observed to be dry to moist at the time of investigation. Moisture generally increased with increases in depths. Residual clays were observed to grade to a combination of weathered sandstone and conglomerate rock types at relatively shallow depth from approximately 0.1 – 1.5m below ground level (BGL) at the majority of locations. Previous investigations performed by other sub consultants indicated similar subsurface profiles where residual soils where overlying Munmorah and Teralba Conglomerate rock types, with the shallow overlying clay soils typically extending less than 1.0m in depth. The shallow residual clay soils were observed to be very stiff to hard in consistency at the time of investigation.
- Deep residual high plasticity silty clay / clay soils encountered during previous investigations were predominately contained within areas previously described as the valley floor areas. Clay soils associated with the central valley floor area were thought to have weathered from the underlying coal, siltstone and tuffaceous claystone bedrock of the Wallarah Coal geological formation. Residual clay soils were also observed to be very stiff to hard in consistency at the time of investigation.

Although not encountered during current or previous investigation it is expected that a significant layer of colluvium comprising sand, gravel and silt deposits would be encountered on the lower side slopes and along the base of the central valley floor and natural drainage gully.

The subsurface profiles encountered in the boreholes during current investigation are presented in the engineering logs attached in Appendix B together with explanatory notes. Engineering logs for previous site investigation can be seen in relevant past geotechnical reports as referenced in Section 2.

6.1.2 Uncontrolled Filling

The disturbed subsurface profile encountered throughout the Swansea Open Cut area and old clay and gravel pit borrow areas throughout the site has been observed to vary slightly with composition, predominately due to the nature of the extraction activities.

Uncontrolled filling / spoil in the open cut area predominately comprise clay, sand and gravel mixtures with minor oversized sandstone and conglomerate rock were observed up to approximately 0.6m in diameter. The filling is noted to be impacted by minor amounts inferior clay material, about 8% by volume, waste coal, coaly mudstone and carbonaceous shale, volumes have been estimated to be around 1% of the total spoil volume and very large sandstone boulders, of 0.6-4.0m maximum dimension, about 1% of total spoil volume.

Filling associated with former clay and gravel borrow areas was observed to comprise clay and gravelly clay with minor amounts of organic material. Filling was generally free of oversize material and waste coal products.

Current investigation was limited to only one borehole location (BH022) within the open cut mine spoil and the relevant engineering log can be seen attached in Appendix B. It should be noted however, conditions observed during current investigations were consistent with previous site investigations as detailed in geotechnical reports described in Section 2.

6.1.3 Rock Profile

The natural bedrock profile encountered during current site investigation across the site throughout boreholes and logged exposures can be generally summarised as follows:

- **UNIT M** – Weathered Munmorah Conglomerate comprising of interbedded pebbly sandstone, sandstone and siltstone. Rock was predominately observed to be extremely weathered to slightly weathered and of very low to medium strength based on point load test results. This unit was encountered close to the ground surface from 0.1-0. 3m and was observed to extend to depths of up to and greater than 18.0m, depending on site elevations; overlying

- **UNIT W** – Weathered tuffaceous siltstone, coal and shale encountered below the Munmorah Conglomerate at the majority of locations, predominately comprising of three distinct splits the Upper, Middle and Lower Wallarah Coal seams. Splits were generally found to be separated by tuffaceous siltstone and shale. Tuffaceous siltstone and shale was generally found to be distinctly to slightly weathered of low to medium strength. The unit was encountered at various depths ranging from 4.6m BGL to depths of up to 16.0m, depending on site elevations; overlying
- **UNIT T** – Weathered Teralba Conglomerate comprising distinctively blue-grey conglomerate and minor siltstone / sandstone beds. Conglomerate was generally found to be slightly weathered to fresh of medium to high strength. The unit was encountered at depths greater than 18.0m in the majority of locations although it was encountered at around 1.8m in one location (BH007) in the base of previous gravel borrow pit along the central western boundary of the site.

It should be noted that during investigation numerous voids were encountered in the subsurface profile predominately located within Units M & W associated with the underlying mine workings of the Wallamaine Colliery. Voids were noted to be due to partial roof collapse, intact mine workings and partial goafed workings and void sizes varied from 0.1m to approximately 2.0m. Subsurface profiles including records of encountered voids can be seen detailed in the engineering logs attached in Appendix B together with explanatory notes.

Voids were consistent with the mine tracings as can be seen in Figure 4 in Appendix A and were generally encountered in areas where significant surface subsidence features were observed. It should be noted that no observations of potholing or subsidence was present throughout the remainder of Lot 5 of DP1240365 which is also consistent with the mine tracings.

6.2 Field Observations

During fieldwork undertaken from the 24th of July to the 26th of September 2017 field observations were made as part of a site walkover. A summary of relevant field observations is detailed below:

- Significant disturbance was observed from past open cut mining operations within Lot 2 of DP1240365 which comprised large high wall excavation faces, deep areas of overburden fill and numerous stockpiles. Exposed excavation faces generally comprised of sandstone and pebbly sandstone / conglomerate of the Munmorah Conglomerate formation overlying exposed coal from the upper Wallarah split noted at some locations. Numerous areas of the exposed high wall showed signs of instability, with a number of small and large rock falls noted along the section. Significant volumes of filling were noted within the box cut, comprising clays, gravels and sands with minor components of coal and oversized material. The filling surface was hummocky and irregular and numerous stockpiles were noted throughout the area.
- Mine subsidence and old entries to underground workings were noted within Lot 7 of DP1240365 known to be associated with the Wallamaine Colliery in the south western corner of the site. Mine subsidence comprised numerous pot holes, open cracks and linear depressions. It should be noted that subsidence features were not observed outside the previously mined areas as shown in Figure 4 and only a limited area along the boundary of Lot 5 was impacted by subsidence features.
- Former clay and gravel borrow pit areas were noted within the central and western portions of Lot 5 of DP1240365 and identified by the presence of significant disturbance, minor erosion and previously stockpiled spoil material. Both former clay and gravel pit areas observed signs of minor erosion due to the lack of vegetation and regrowth in the areas, exacerbated by the various access tracks traversing through the areas.
- An area of significant disturbance was observed in the central portion of the site (Old Swansea Landfill), and is known to comprise a combination of general household rubbish, building materials and excess soil and rock excavation material from the Wallarah interchange construction project. The site was identified by a large area predominately devoid of large vegetation adjacent the ‘Old Swansea Bends’. Some minor to moderate erosion was present in this area due to the lack of vegetation and poor drainage of the stockpiled material.
- Some minor tension cracking was observed within a large section of the Old Pacific Highway road pavement, assumed to be caused from long term creep of the road embankment. Overall pavement condition was observed to range from poor to moderate throughout the site with large potholes forming throughout various areas of pavement, likely exacerbated by a lack of maintenance and illegal trafficking of the previously closed roads.
- A small rural dam, expected to be associated with the operation of previous clay pit extraction was observed to intercept the main drainage gully in the central portion of the site. The basin was observed to

be in reasonable condition however the construction of the basin is not known. Some scour was observed in the bank, where the dam had been recently overtopped with an estimated depth of 300mm.

> Signs of a previously demolished residential development were noted in the south eastern portion of Lot 5 of DP1240365. A concrete driveway was still present in this location however, barely visible due to dense grasses and vegetation growth adjacent the structure. A concrete water tank was also noted close to the old residential site.

Impacted areas as described above can be shown in Figures 2, 3 & 4 attached in Appendix A.

6.3 Groundwater

Groundwater was encountered in two boreholes (BH005 & BH017) during the current investigation was present within the highly fractured Wallarah Coal seam profile. It is expected that the highly fractured Wallarah Coal seam is acting as a confined aquifer and as such may observe heightened groundwater levels following periods of extended wet weather.

During site walkover, areas of ponded water were observed along the central valley floor area and drainage gully. Where periods of sustained wet weather are encountered it is likely that a large area of the valley floor area will become saturated and remain saturated for an extended period of time. The remainder of the site has been observed to be well drained and as such it is unlikely that water will become perched for any significant amount of time.

6.4 Previous Geotechnical Laboratory Results

Laboratory testing of uncontrolled fill / spoil associated with the old Swansea Open Cut mine was performed by SKM in 2005 in report ref. 'Preliminary Geotechnical Report', dated 06 April 2005 [7] and comprised numerous Particle Size Distribution (PSD) testing, Atterberg Limits testing and California Bearing Ratio (CBR) testing. The results of the relevant testing can be seen in Section 6.4.1 & Section 6.4.2 below.

6.4.1 PSD & Atterberg Limits Testing

The results of the Particle Size Distribution (PSD) and Atteberg limits testing undertaken on representative spoil from the old Swansea Open Cut mine are encountered during previous SKM investigation are summarised below in Table 6-1 with report sheets attached in Appendix C.

Table 6-1 Summary of PSD & Atteberg Testing Results

Location	Depth (m)	Material description	LL (%)	PL (%)	PI (%)	%Passing 2.36mm	%Passing 0.075mm
OC 19	0 – 2.4	Clayey Gravelly SAND	26	17	9	68	27
OC 20	0 – 1.2	Gravelly Clayey SAND	30	18	12	74	45
OC 23	0 – 1.3	Sandy Clayey GRAVEL	31	18	13	69	38
OC 24	0 – 3.5	Gravelly Clayey SAND	31	17	14	76	41
OC 25	0 – 2.2	Gravelly Clayey SAND	27	16	11	73	32

Notes to table:
LL – Liquid Limit
PL – Plastic Limit
PI – Plasticity Index

6.4.2 California Bearing Ratio & Material Density Test Results

The results of the laboratory shrink swell tests undertaken on representative spoil from the old Swansea Open Cut mine encountered during previous SKM investigation are summarised below in Table 6-2 with the report sheets attached in Appendix C.

Table 6-2 Summary of CBR & Material Density Testing Results

Location	Depth (m)	Material Description	SOMC (%)	SMDD (%)	CBR (%)
OC 19	0 – 2.4	Clayey Gravelly SAND	13.5	1.89	10
OC 20	0 – 1.2	Gravelly Clayey SAND	15.5	1.82	11
OC 23	0 – 1.3	Sandy Clayey GRAVEL	14.5	1.85	10
OC 24	0 – 3.5	Gravelly Clayey SAND	15.5	1.82	9

Location	Depth (m)	Material Description	SOMC (%)	SMDD (%)	CBR (%)
OC 25	0 – 2.2	Gravelly Clayey SAND	13.0	1.89	13
OC 26	0 – 3.1	Clayey Gravelly SAND	13.5	1.85	-
OC 28	0 – 3.0	Clayey Gravelly SAND	11.5	1.94	-
OC 33	0 – 2.7	Clayey Gravelly SAND	13.0	1.89	-
OC 35	0 – 1.8	Clayey Gravelly SAND	13.0	1.90	-
OC 38	0 – 1.6	Clayey Gravelly SAND	14.0	1.87	-

Notes to table:
SOMC – Standard Optimum Moisture Content
SMDD – Standard Maximum Dry Density

6.5 Current Geotechnical Laboratory Results

Point load testing was undertaken on selected rock core samples obtained from BH01. The results of the axial and diametric point load testing undertaken are presented in Appendix C.

The results generally indicated that sandstone of the Munmorah Conglomerate encountered within BH01 was generally of very low to medium strength. Results from recovered core samples of siltstone & shale from the Wallarah Coal formation indicated rock strengths of generally very low to low strength.

7 Comments and Recommendations

7.1 Summary of Geotechnical Constraints & Remediation Recommendations

A summary of geotechnical constraints described within this report is provided below along with recommendations for possible remediation techniques for these distinct areas.

7.1.1 Old Swansea Open Cut Mine Spoil

The extent and composition of the Old Swansea Open Cut mine has been extensively described during current and previous investigations. The mine spoil is known to comprise clay, sand and gravel mixtures with minor oversized sandstone and conglomerate rock, which has been observed up to approximately 0.6m in diameter. It is also noted to contain small amounts, by volume, of inferior materials such as clay, waste coal products and large boulders greater than 0.6m.

SKM during investigations in 2005 [7] have estimated total spoil volumes to be around 700,000 cubic metres of material with maximum depths estimated to extend up to 10m BGL with an average depth of fill of between 3-6m BGL. During investigations, SPT testing indicated that the spoil was generally medium dense, uniform and deficient of large boulders. The spoil was also estimated to have in-situ bulk densities of approximately 1.4 -1.6 tonnes per cubic metre. Material encountered throughout investigations has been reasonably uniform as demonstrate by laboratory results seen in Section 6.4, and observed relatively high MDD values as such it is expected that compaction of the spoil would be readily achievable.

Limited contamination assessment undertaken by SKM – 2005 did not identify any gross contamination in accordance with the then relevant NSW EPA Guidelines (1998).

It is recommended to undertake remediation of the uncontrolled filling area. Several methods have been considered, including remove, recondition and replacement of the spoil, dynamic & impact compaction and piling of the proposed structures. However, to maximise the beneficial outcomes of the proposed residential development it is proposed to undertake removal and replacement of the spoil. It should also be appreciated that minor areas of previous mine workings may be present at the interface of the former open cut boundaries. If encountered, these areas would be treated by excavation and replacement with controlled fill.

It is also recommended to undertake removal and replacement as it would allow an alternative classification to Class P following construction and would reduce the risk of differential settlements within the fill area.

Earthworks procedure for the removal and replacement of spoil within the Old Swansea Open Cut Mine should include the following:

- Removal of any existing vegetation, topsoil, slopewash / colluvium, organics or deleterious materials from the areas where fill is to be placed. Any other unsuitable material including foreign matter should be removed from the fill areas.
- Fill materials containing vegetation including tree stumps, roots, root fibres or other organic matter should be removed from site.
- Fill should not comprise material with particle sizes of greater than 200mm or 2/3 of the compacted layer thickness.
- Benching of the slopes where fill is to be placed with slopes steeper than 8H: 1V will be required.
- Placement of fill in uniform horizontal layers with compaction of each layer to a minimum dry density ratio of 95% standard compaction (AS 1289-5.5.1) at moisture contents in the order of 85-115% of SOMC or ±2% but generally as close to SOMC as practical.

A notable area of deep uncontrolled filling associated with the previous mining activities comprises the northern edge of the Open Cut. The area is defined as a large area of uncontrolled filling, battered at approximately 35 degrees and up to 12m high has been identified as a high-risk area.

Detailed recommendations for the remediation of this area can be seen in Cardno Report ref. 82218007-002.2 ‘Preliminary Slope Stability Assessment’, dated 11-09-2019 and can be summarised as seen below:

- Removal of vegetation across the slope;
- Removal and replacement of the uncontrolled fill back to underlying natural profile; and/or
- Removal of filling followed by the construction of a series of retaining walls and batters.

7.1.2 Old Swansea Open Cut High Wall

As previously described in Section 6.2, investigations performed by Cardno and other consultants have identified a large semi-continuous exposed high wall face, associated with pervious coal extraction operations in the Old Swansea Open Cut mine. Wall heights have been observed to be in the order of 25-30m within some areas, most notably Mawson's Look Out and the high wall at the base of the DMR Hill in the central eastern portion of Lot 1 of DP1240365 (outside the area under investigation). The remaining section of the high wall located to the west within the development extent was observed to have an average height of approximately 3-10m high, with some portions of the wall having existing spoil buttressed against them.

Notable rock falls were observed, predominately contained within sections of the high wall associated with the Mawson's Look Out area. The volume of falls has been estimated to range from one cubic metre to up to 50 cubic metres. The rock fall debris were observed to not extend more than 20 metres from the base of the exposures, although given the presence of a number of tension cracks and undercutting of the overlying sandstone layers, it is assumed that the process will continue without remedial treatments.

It should be noted that portions of the Mawson's high wall face cross the site boundary into LMCC owned land as seen in Figure 7-1 below. Remedial works would be recommended to the entire batter face, including the portions within LMCC land, for future use of the lookout. However partial treatment within the subject property can be undertaken to reduce the risk to an acceptable level for the proposed development. Detailed recommendations for the remediation of the Mawson's Lookout high wall exposure are detailed in Cardno Report ref. 82218007-002.2 'Preliminary Slope Stability Assessment', dated 11-09-2019 and summarised below:

- Buttressing portions of the high wall with spoil;
- Selective face treatments;
- Significant regrade of lower portions of the high wall; and/or
- Construction of an earthen or mulch berm a minimum of 15m from the toe of the existing slope of at least 1.5m high.

Figure 7-1 Area of High Stability Risk Crossing Common Boundary

As detailed above, it is expected that the sections of the high wall where heights are less than 10m, partial or complete removal will be undertaken during bulk earthworks. Partial or complete removal of the high wall throughout areas with similar wall heights is expected to reduce any minor stability issues associated with

these sections. Where partial or complete removal is not considered suitable, it is recommended to buttress exposed slopes with site won fill during site regrade.

It is expected following the treatment of Mawson's Look out high wall as detailed above, partial or complete removal of the lower portions of the high wall and some minor regrade of the low wall during bulk earthworks would generate an additional 200,000 cubic metres of crushed rock. It is anticipated that the material would be suitable for use as lot fill or select for the various future internal road pavements.

7.1.3 Moderate Slope Stability Risks

Further areas of slope stability risks have been identified within Cardno Report ref. 82218007-002.2 'Preliminary Slope Stability Assessment', dated 11-9-2019 and summarised below:

- Steep natural upper ridge slopes located across the site, comprise predominately densely vegetated slopes of approximately 14-26°. Risks associated with these areas include small rock falls, creep or debris flows following periods of wet weather. Due to the steep nature of these areas, it is recommended that development within these areas be avoided, however where development is proposed treatments could include the following:
  - The construction of engineered building platforms formed during regrade / bulk earthworks along with a combination of deep foundations suitably extended into the underlying bedrock; or
  - Installation of a rock catch fence or earthen berm up gradient of areas proposed for residential development.
- Road embankments associated with the Swansea bends where open tension cracks have been observed. It is recommended that reconstruction and/or reinforcement of these embankments are undertaken.
- Valley side slopes comprising steep fill batters associated with the former landfill site comprising slopes of up to 4m high and 25 degrees. Recommendations provided include the construction of retaining walls, removal and replacement of the fill or reconfiguration of the landfill area.

7.1.4 Underground Mines & Surface Subsidence

During site investigation, underground mine workings were observed within Lot 1, 5 & 7 of DP1240365 as previously detailed. Estimated depth to cover ranges from around 10m to 30m under the crest of the DMR hill within Lot 1 (outside of the investigation area). Workings observed in the south of the site within Lots 5 and 7 contain an estimated depth to cover of approximately 5 to 15m. Significant subsidence features have been observed in the areas impacted by underground mine workings during current investigation as previously mentioned in Section 6.2 and during previous investigation by other consultants.

Cardno have undertaken detailed investigation to determine the extent and to also characterise the workings in the southern area of the site, investigation findings can be found detailed in Section 6. Observations during site investigations has identified open cracks of approximately 2.0m wide and up to 50m long with numerous linear depressions up to several metres, predominately located outside the current investigation area within Lot 6 & part of Lot 7. Investigations also indicated that workings contained within Lot 1, Lot 5 and Lot 7 were relatively shallow with average depths of approximately 6m and progressively increasing in depth towards the south.

Given the shallow depth of cover to underground workings within Lot 5 and Lot 7, it is expected that there is considerable risk of additional pothole subsidence forming and as such the area would require significant remediation to render the area suitable for residential development. Due to the relatively shallow depth of cover encountered, it is recommended that excavation, removal and re-compaction of underground workings be performed during the bulk earthworks stage. Excavation and re-compaction of goafed ground should be performed in accordance with AS 3798-2007 *Guidelines on Earthworks for Commercial and Residential Developments* [12]. It should be noted that Lot 1 has been included above as there a potential for minor sections of workings from Wallamaine colliery No 4 to be present at the interface in the Swansea open cut footprint. It is intended that if still present the removal of the existing fill in the open cut footprint will allow conformation of the presence of any minor areas of old working that can be addressed by earthworks.

Options such as piled foundations founded beyond the depth of workings or grouting of the underlying workings could be considered, although to maximise the beneficial outcomes of the proposed residential development it is recommended to adopt the removal and replacement option.

The area considered suitable for complete workings removal and replacement can be shown as the area within Lot 5 and Lot 7 impacted by underground workings, as illustrated in Figure 4, attached in Appendix A. Where workings extend beyond the areas indicated on the attached plan, excavation should be performed to

ensure all working mapped or unmapped are removed entirely from within the Lot. Excavation should be undertaken under the supervision of a suitably qualified geotechnical engineer to ensure the satisfactory removal of all workings is undertaken.

Further assessment of the viability of future development within the areas outside the current investigation limits would be required, however options for removal of workings or grouting are expected to be suitable to render further areas suitable for development.

7.1.5 Former Clay and Gravel Borrow Pit Filling

During current and previous investigations two areas have been identified to be impacted by former clay and gravel borrow pit mines, areas are indicated in Figures 2 in Appendix A. The areas are defined by significant disturbance, minor erosion and various amounts of uncontrolled filling / spoil stockpiled throughout the impacted areas. The spoil is known to comprise clay and gravelly clay with minor amounts of organic material. Filling was observed to be generally free of oversize material and waste coal products. Maximum pit depths were noted to be relatively shallow (approximately 3-4m in depth) with stockpiles within the same order. Given the relatively small area impacted by the former clay and gravel pit mines it is recommended to remove, recondition and replace all material that are identified as uncontrolled fill during proposed bulk earthworks.

During bulk earthworks / site regrade, fill should be placed and compacted in accordance with AS 3798-2007 *Guidelines on Earthworks for Commercial and Residential Developments* [12].

Earthworks procedure should include the following:

- Removal of any existing uncontrolled filling, stockpiles, topsoil, slopewash / colluvium or deleterious materials from the areas where fill is to be placed. Any unsuitable material including foreign matter should be removed from the fill areas.
- Fill materials containing vegetation including tree stumps, roots, root fibres or other organic matter should be removed from site.
- Fill should not comprise material with particle sizes of greater than 200mm or 2/3 of the compacted layer thickness.
- Benching of the slopes where fill is to be placed with slopes steeper than 8H: 1V will be required.
- Placement of fill in uniform horizontal layers with compaction of each layer to a minimum dry density ratio of 95% standard compaction (AS 1289-5.5.1) at moisture contents in the order of 85-115% of SOMC or ±2% but generally as close to SOMC as practical.

7.1.6 Old Pacific Highway Embankment & Steep Natural Slopes

A slope stability assessment has been performed as part of its own assessment by Cardno which comprises a review of previous studies in the area, data from previous investigations, regional geological mapping, historical photographs and LIDAR data, geological mapping to record lithology and geological structure and to identify potential failure mechanisms using conventional field methods and analysis of the risk based approach outlined in AGS Landslide Risk Management paper [13]. Detailed investigation and recommendations for the remediation of the various site slopes can be seen in Cardno Report ref. 82218007-002.2 ‘Preliminary Slope Stability Assessment’, dated 11-09-2019.

The risk of slope stability has been assessed using a semi quantitative classification system that assesses risk to property published by the Australian Geomechanics Society Sub-Committee on Landslide Risk Management which was published in the Journal and News of the Australian Geomechanics Society Volume 42 No 1 March 2007, titled ‘Practice Note Guidelines for Landslide Risk Management 2007’ [13].

The preliminary slope stability assessment has identified numerous areas that pose currently unacceptable risks to property without appropriate remediation. The areas identified within the report are as follows:

- The exposed high wall at the eastern end of the Old Swansea Open Cut mine including the Mawson’s Lookout high wall.

  The Northern edge of Open Cut / Mine Low Wall – Steeply battered of unknown depth and compaction;
- Road fill embankments along the Old Pacific Highway alignment with steep batters of typically 26-30° up to 5m high;
- Steep natural upper ridge side slopes with typical gradients of approximately 14-26°; and
- The Landfill and construction material filling from Wallarah interchange.

Recommendations for the remediation of such areas has been described in more detail within the Cardno Report ref. 82218007-002.3 'Preliminary Slope Stability Assessment'.

During previous investigations performed by RCA – 2007 [5] it was indicated that road embankments along the Old Pacific Highway alignment, predominately associated with the 'Swansea Bends' and steep terrain slightly to the south of the bends, were identified as an area observing signs of instability. During field investigation open longitudinal cracks with vertical displacements along the outer pavement edge were observed along a large section in the vicinity of the Swansea Bends, which was confirmed during current investigations performed by Cardno.

Following inspection, it is assumed the failure mechanism impacting the road embankments were a combination of deep-seated rotational failure and ongoing long-term creep failure. Likely consequences of the associated failure mechanisms is ongoing pavement failures and potential impacts downslope following deep rotational failure and as such remediation Old Pacific Highway road embankment would be required.

As a part of the redevelopment of the site, works to reduce the stability risks associated with the road alignment would be required. Remediation of the road embankment is likely to include full reconstruction of the road embankment or reinforcement of the embankment via the buttressing of fill against the steep embankments or installation of suitable earth retaining systems.

It should be noted that similar works have been proposed during a previously approved development application under Development Consent No. DA/2450/2007 and as such it is likely that proposed remedial works will satisfy council requirements.

Steep natural upper ridge slopes predominately associated with the various large ridgelines/spurs throughout the site were identified as potentially problematic where removal of the dense vegetation covering the slopes is proposed. Likely risks following the removal of vegetation on the steep slopes may include small rock falls, soil creep or debris flows following periods of wet weather.

It should be noted that the risk, prior to removal of vegetation, has been assessed as low to moderate and as such without remediation it is recommended that development within these areas be avoided. Where development is proposed, regrading of the steep slopes would likely reduce risks to an acceptable level. Regrade could include the buttressing of the steep slopes with fill generated during bulk earthworks or reshaping of the slopes via the use of bench and battering techniques. Following the remediation of the steep slopes, development could be undertaken safely where undertaken in accordance with good hillside practice as described in Appendix G in the AGS Landslide Risk Management paper [13].

7.1.7 Potential Contamination

RCA have undertaken an environmental site assessment and prepared a Remedial Action Plan (RAP) for the Former Landfill Site in September 2008. The study area comprised Lot 2 DP337960 and Lot 1 DP344160. The investigation included assessment of potential contaminants that might be present within spoil piles.

The assessment flagged the issue of the former landfill area, as such a remedial action plan was prepared by RCA and reviewed by a Site Auditor to address the former landfill area. Limited assessment were also undertaken within the former mine activities and clay extraction areas however; with the exception of fly tipping, no identification of gross contamination is present within the remainder of the Site due to the accessibility and greenfield presence across the Site.

As the RCA RAP was prepared in 2008, Cardno were engaged to prepare and amend the existing RAP prepared for the Landfill Area to reflect current legislation and National Environmental Protection Measures (NEPM 1999, amended in 2013) requirements. The preparation and amendments of the Landfill RAP by Cardno, will be under the supervision of a Site Auditor (Charlie Barber) from Australian Environmental Auditors, engaged by the client. It should be appreciated that the concept of the RAP has remained consistent with the earlier version, to a adopt a cap and containment strategy. As the current landfill footprint straddles two lots, the strategy will basically comprised removal of areas of former deposited waste and placement over an existing portion of the landfill such that the waste materials are contained entirely within one lot. On completion of the waste consolidation into one lot, the entire area would be capped with VENM.

The identified landfill area will be addressed within the amended RAP and endorsed by the nominated Site Auditor. Following remediation of the landfill area, a validation report will be provided under the supervision of a Site Auditor and Site Audit Statement would be issued upon completion.

The uncontrolled filling present within the remainder of the Site, would be managed during bulk earthworks operations under the provision of an Unexpected Finds Protocol, to manage any potential contamination issues that may arise during development.

7.1.8 Central Rural Dam

The small rural dam observed in the central valley area is currently of unknown construction and currently observes signs of minor scour. Based on the unknown construction of the dam, it is recommended that reconstruction of the basin be undertaken as part of future works.

8 Limitations

Cardno has performed investigation and consulting services for this project in general accordance with current professional and industry standards. The extent of testing was limited to discrete test locations and variations in ground conditions can occur between test locations that cannot be inferred or predicted.

A geotechnical consultant or qualified engineer shall provide inspections during construction to confirm assumed conditions in this assessment. If subsurface conditions encountered during construction differ from those given in this report, further advice shall be sought without delay.

Cardno, or any other reputable consultant, cannot provide unqualified warranties nor does it assume any liability for the site conditions not observed or accessible during the investigations. Site conditions may also change subsequent to the investigations and assessment due to ongoing use.

This report and associated documentation was undertaken for the specific purpose described in the report and shall not be relied on for other purposes. This report was prepared solely for the use by Wakefield Ashurst Developments & Northern Managers & Construction Pty Ltd and any reliance assumed by other parties on this report shall be at such parties own risk.

9 References

[1] Cardno, *Proposal for Geotechnical Investigation "Mawsons Development" 48982216-001-0027,* 2017.

[2] Cardno, “"Preliminary Slope Stability Assessment", ref 82218007-002.2,” CARNDO, September 2019.

[3] Coffey Geotechnics, “Proposed Mirvac Residential Developments - Wallarah Peninsula Indicative Pavements & Geotechnical Constraints,” December 2012.

[4] Coffey Geotechnics , “Proposed Subdivision - Swansea Valley Precinct, Wallarah Peninsula - Abandoned Mine Assessment,” September 2010.

[5] RCA, “Geotechnical Constraints Asssessment - Norther Precinct (South),” June 2008.

[6] RCA, “Desktop Assessment of Ground Improvement Earthworks Treatment Options for High Level Foundation Support in Mine Spoil Fill,” January 2007.

[7] SKM, “Swansea Open Cut Redevelopment - Preliminary Geotechnical Report,” April 2005.

[8] SKM, “Wallarah Peninsula Geotechnical Review - Lensworth Wallarah Peninsula Pty Ltd,” March 2002.

[9] RCA, “Environmental Site Assessment and Remdial Action Plan,” September 2008.

[10] Gosford-Lake Macquarie Geology Map, “1:100,000 Geological Series Sheet 9131, and part of 9231 (Edition 1),” Geological Survey of NSW, Department of Mineral Resources, 1995.

[11] NSW Office of Environment and Heritage, “eSPADE V2.0,” NSW Office of Environment and Heritage, December 2016. [Online]. Available: http://www.environment.nsw.gov.au/eSpade2WebApp#. [Accessed 23 January 2017].

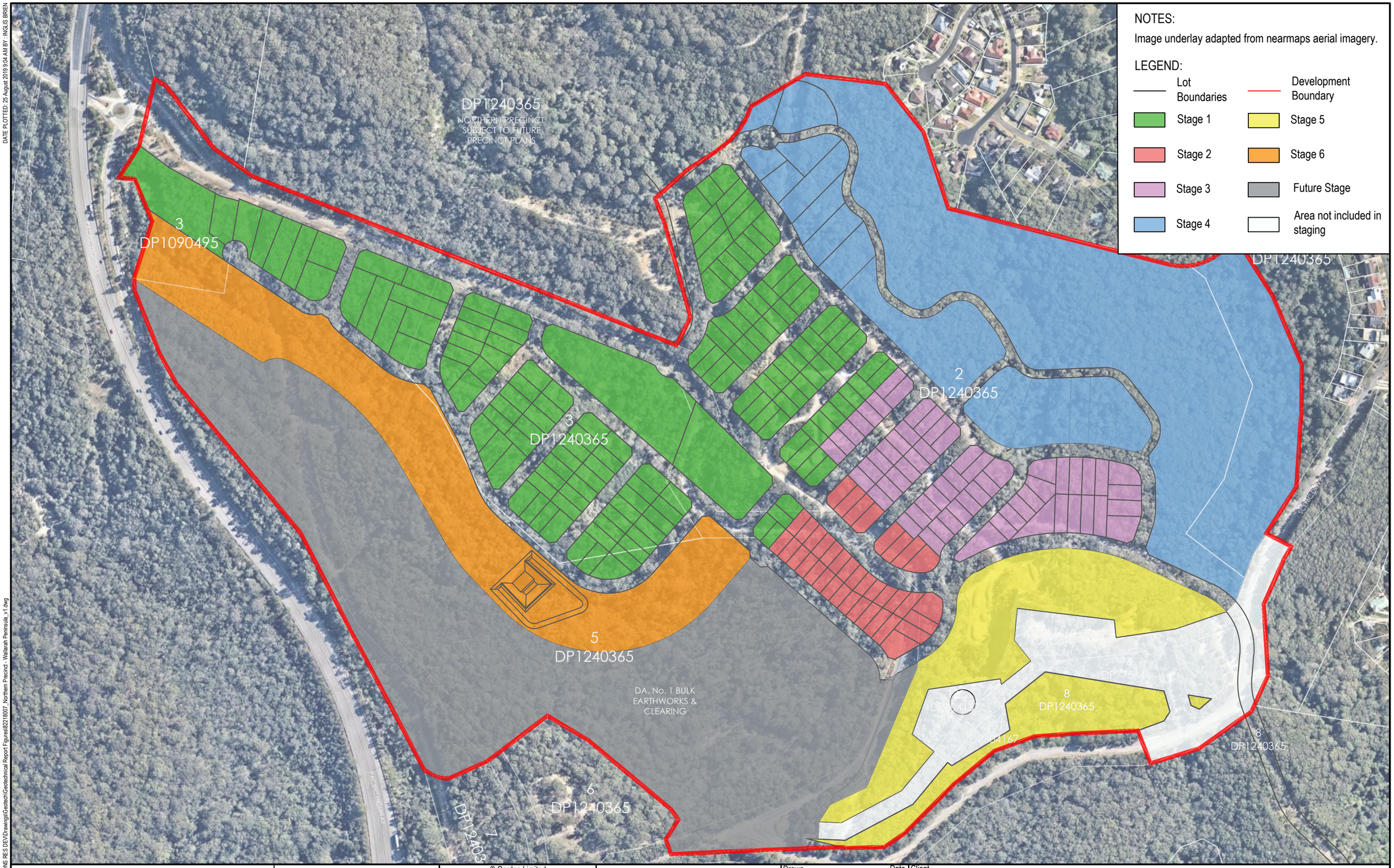
[12] Australian Standard AS3798-2007, “Guidelines on Earthworks for Commercial and Residential Structures,” Standards Australia, 2007.

[13] AGS Landslide Taskforce, “Practice Note Guidelines for Landslide Risk Management 2007c,” *Journal and News of the Austrailian Geomechsanics Society,* vol. 42, no. 1, pp. 63-114, 2007c.

APPENDIX A

FIGURES

DATE PLOTTED: 25 August 2019 9:04 AM BY: INGLIS BRIEN



0 100 160m

SCALE 1:4000 @A3

NORTH

Cardno
Shaping the Future
Cardno (NSW/ACT) Pty Ltd | ABN 95 001 145 035
Unit 1, 10 Denney Street
Broadmeadow, NSW 2292
Tel: 02 4965 4555 Fax: 02 4965 4666
Web: www.cardno.com.au

Drawn	IB	Date 08/02/2018
Checked	DGB	Date 08/02/2018
Designed		Date
Verified		Date
Approved		

Client: Wakefield Ashurst Developments & Northern Managers & Construction Pty Ltd

Project: Northern Sector, Wallarah Peninsula

Title: Site Overview

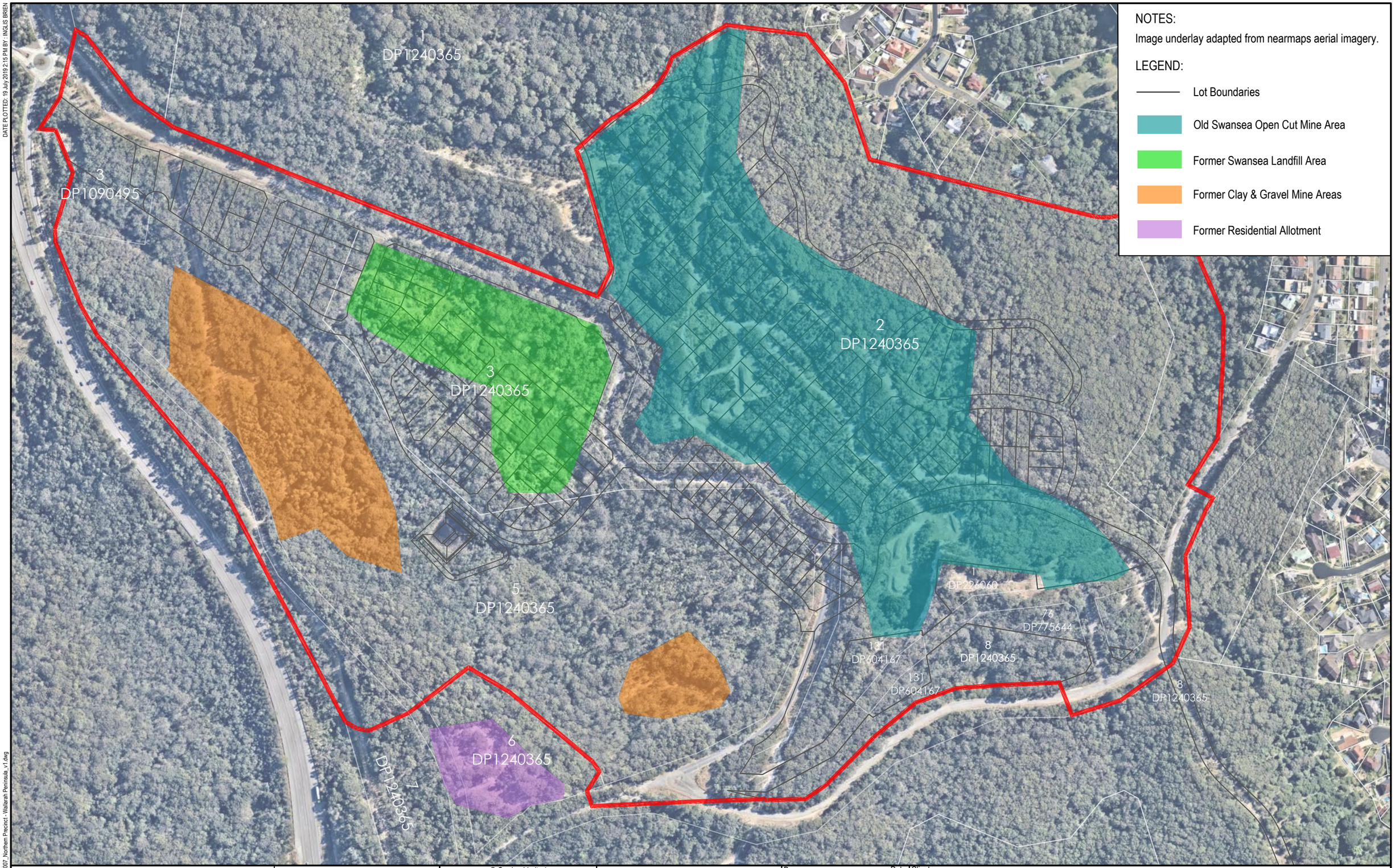
Status: FOR INFORMATION ONLY
NOT TO BE USED FOR CONSTRUCTION PURPOSES

Datum	Cardno Ref.	Scale	Size
MGA 94	82218007	1:4000	A3

Drawing Number: Figure 1

Revision: B

XREFs:
CAD File: N:\Projects\82218007_MAWSONS RES DEV\Drawings\Geotech\Geotechnical Report Figures\82218007_Northern Precinct - Wallarah Peninsula_v1.dwg



DATE PLOTTED: 19 July 2019 2:15 PM BY: INGLIS BRIEN

0 100 160m

SCALE 1:4000 @A3

NORTH

Cardno
Shaping the Future
Cardno (NSW/ACT) Pty Ltd | ABN 95 001 145 035
Unit 1, 10 Denney Street
Broadmeadow, NSW 2292
Tel: 02 4965 4555 Fax: 02 4965 4666
Web: www.cardno.com.au

Drawn	IB	19/07/2019
Checked	DGB	19/07/2019
Designed		
Verified		
Approved		

Client: Wakefield Ashurst Developments & Northern Managers & Construction Pty Ltd

Project: Northern Sector, Wallarah Peninsula

Title: Geotechnical Constraints

Status: FOR INFORMATION ONLY
NOT TO BE USED FOR CONSTRUCTION PURPOSES

Datum	Cardno Ref.	Scale	Size
MGA 94	82218007	1:4000	A3

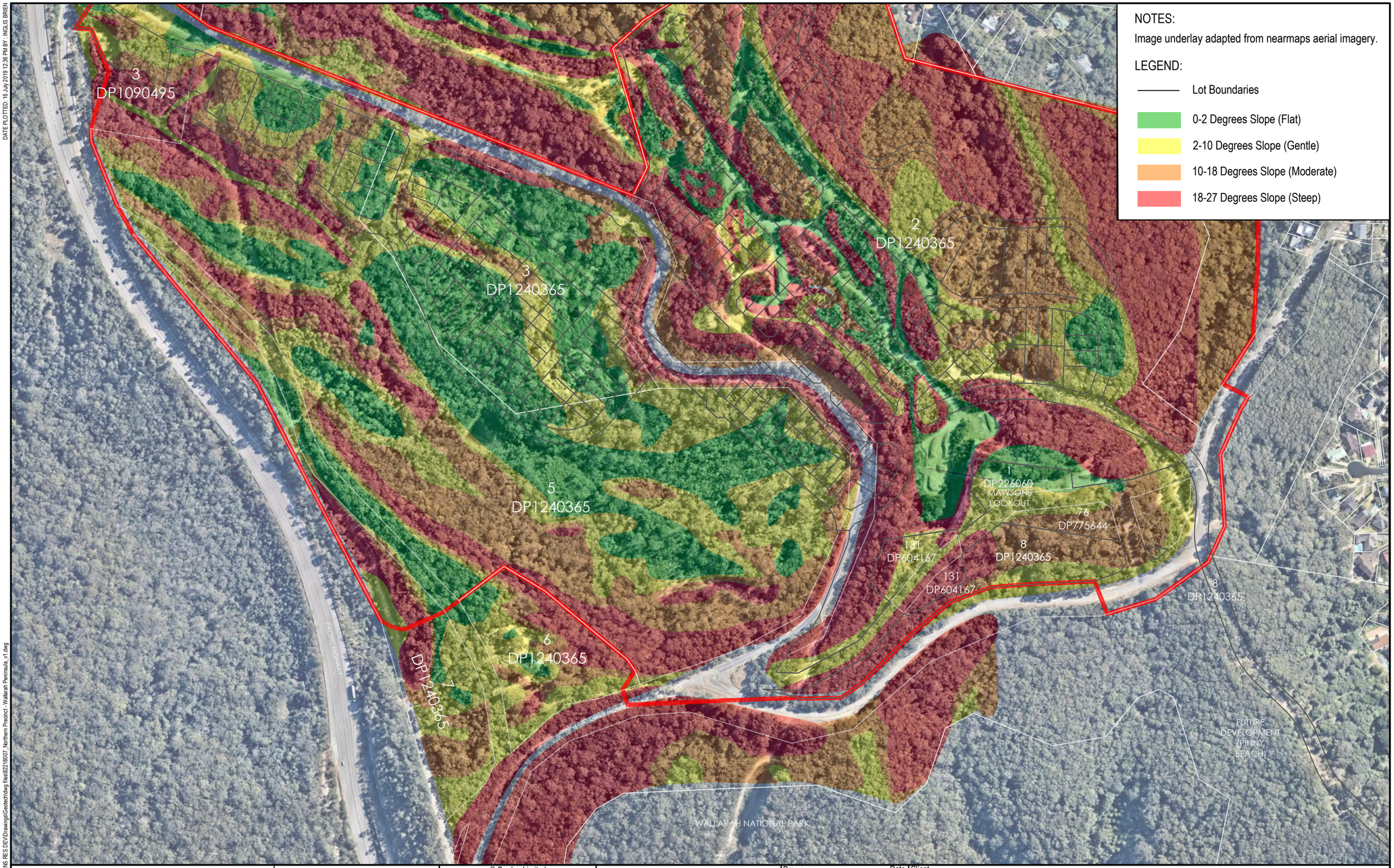
Drawing Number: Figure 2

Revision: D

XREFs:
CAD File: C:\Users\inglis.brien\Desktop\82218007_Northern Precinct - Wallarah Peninsula_v1.dwg

D09530876

DATE PLOTTED: 16 July 2019 12:36 PM BY : INGLIS BRIEN



0 100 160m

SCALE 1:4000 @A3

NORTH

Cardno
Shaping the Future
Cardno (NSW/ACT) Pty Ltd | ABN 95 001 145 035
Unit 1, 10 Denney Street
Broadmeadow, NSW 2292
Tel: 02 4965 4555 Fax: 02 4965 4666
Web: www.cardno.com.au

Drawn	IB	Date 16/07/2019
Checked	DGB	Date 16/07/2019
Designed		Date
Verified		Date
Approved		

Client: Wakefield Ashurst Developments & Northern Managers & Construction Pty Ltd

Project: Northern Sector, Wallarah Peninsula

Title: Site Slopes

Status: FOR INFORMATION ONLY
NOT TO BE USED FOR CONSTRUCTION PURPOSES

Datum	Cardno Ref.	Scale	Size
MGA 94	82218007	1:4000	A3

Drawing Number: Figure 3

Revision: B

XREFs:
CAD File: N:\Projects\82\FY18\007_MAWSONS RES DEV\Drawings\Geotech\dwg files\82218007_Northern Precinct - Wallarah Peninsula_v1.dwg

DATE PLOTTED: 18 September 2019 3:23 PM BY : KOSTANDREAS SYKIOTIS

XREFs:
CAD File: N:\Projects\82\2FY18\007_MAWSONS RES DEV\Drawings\Geotech\Geotechnical Report Figures\82218007_Northern Precinct - Wallarah Peninsula_v1.dwg

0 100 200m
SCALE 1:5000 @A3

NORTH

Cardno
Shaping the Future
Cardno (NSW/ACT) Pty Ltd | ABN 95 001 145 035
Unit 1, 10 Denney Street
Broadmeadow, NSW 2292
Tel: 02 4965 4555 Fax: 02 4965 4666
Web: www.cardno.com.au

Drawn	IB	Date 19/07/2019
Checked	DGB	Date 19/07/2019
Designed		Date
Verified		Date
Approved		

Client: Wakefield Ashurst Developments & Northern Managers & Construction Pty Ltd

Project: Northern Precinct, Wallarah Peninsula

Title: Formerly Disturbed Areas

Status: FOR INFORMATION ONLY
NOT TO BE USED FOR CONSTRUCTION PURPOSES

Datum	Cardno Ref.	Scale	Size
MGA 94	82218007	1:5000	A3

Drawing Number: Figure 4

Revision: A

D09530876

DATE PLOTTED: 19 July 2019 2:26 PM BY: INGLIS BRIEN

NOTES:

Image underlay adapted from nearmaps aerial imagery.

LEGEND:

Lot Boundaries

Previously Disturbed / Cleared Areas for Construction Access & Ancillary Works

0 100 160m

SCALE 1:4000 @A3

NORTH

Cardno
Shaping the Future
Cardno (NSW/ACT) Pty Ltd | ABN 95 001 145 035
Unit 1, 10 Denney Street
Broadmeadow, NSW 2292
Tel: 02 4965 4555 Fax: 02 4965 4666
Web: www.cardno.com.au

Drawn	IB	Date 19/07/2019
Checked	DGB	Date 19/07/2019
Designed		Date
Verified		Date
Approved		

Client: Wakefield Ashurst Developments & Northern Managers & Construction Pty Ltd

Project: Northern Sector, Wallarah Peninsula

Title: Previously Disturbed / Cleared Lands

Status: FOR INFORMATION ONLY
NOT TO BE USED FOR CONSTRUCTION PURPOSES

Datum	Cardno Ref.	Scale	Size
MGA 94	82218007	1:4000	A3

Drawing Number: Figure 5

Revision: A

XREFs:
CAD File: C:\Users\ingls.brien\Desktop\82218007_Northern Precinct - Wallarah Peninsula_v1.dwg

DATE PLOTTED: 19 July 2019 2:57 PM BY: INGLIS BRIEN

NOTES:
Image underlay adapted from nearmaps aerial imagery.

LEGEND:
- Lot Boundaries
- BHXXX Cardno 2017 Borehole Locations
- OCXX SKM - 2005 Test Pit/Bore Locations
- NXX RCA - 2008 Test Pit Locations

0 100 200m
SCALE 1:5000 @A3

NORTH

Cardno (NSW/ACT) Pty Ltd | ABN 95 001 145 035
Unit 1, 10 Denney Street
Broadmeadow, NSW 2292
Tel: 02 4965 4555 Fax: 02 4965 4666
Web: www.cardno.com.au

Drawn	IB	Date 08/02/2018
Checked	DGB	Date 08/02/2018
Designed		Date
Verified		Date
Approved		

Client: Wakefield Ashurst Developments & Northern Managers & Construction Pty Ltd
Project: Northern Sector, Wallarah Peninsula
Title: Test Location Plan
Status: FOR INFORMATION ONLY
NOT TO BE USED FOR CONSTRUCTION PURPOSES

Datum	Cardno Ref.	Scale	Size
MGA 94	82218007	1:4000	A3

Drawing Number: Figure 6
Revision: B

XREFs:
CAD File: C:\Users\inglis.brien\Desktop\82218007_Northern Precinct - Wallarah Peninsula_v1.dwg

APPENDIX

B

ENGINEERING LOGS & EXPLANATORY NOTES

Explanatory Notes

The methods of description and classification of soils and rocks used in this report are based on Australian Standard AS1726-2017 Geotechnical Site Investigations. Material descriptions are deduced from field observation or engineering examination, and may be appended or confirmed by in situ or laboratory testing. The information is dependent on the scope of investigation, the extent of sampling and testing, and the inherent variability of the conditions encountered.

Subsurface investigation may be conducted by one or a combination of the following methods.

Method	
Test Pitting: excavation/trench	
BH	Backhoe bucket
EX	Excavator bucket
R	Ripper
H	Hydraulic Hammer
X	Existing excavation
N	Natural exposure
Manual drilling: hand operated tools	
HA	Hand Auger
Continuous sample drilling	
PT	Push tube
PS	Percussion sampling
SON	Sonic drilling
Hammer drilling	
AH	Air hammer
AT	Air track
Spiral flight auger drilling	
AS	Auger screwing
AD/V	Continuous flight auger: V-bit
AD/T	Continuous spiral flight auger: TC-Bit
HFA	Continuous hollow flight auger
Rotary non-core drilling	
WB	Washbore drilling
RR	Rock roller
Rotary core drilling	
PQ	85mm core (wire line core barrel)
HQ	63.5mm core (wire line core barrel)
NMLC	51.94mm core (conventional core barrel)
NQ	47.6mm core (wire line core barrel)
DT	Diatube (concrete coring)

Sampling is conducted to facilitate further assessment of selected materials encountered.

Sampling method	
Soil sampling	
B	Bulk disturbed sample
D	Disturbed sample
C	Core sample
ES	Environmental soil sample
SPT	Standard Penetration Test sample
U	Thin wall tube ‘undisturbed’ sample
Water sampling	
WS	Environmental water sample

Field testing may be conducted as a means of assessment of the in situ conditions of materials.

Field testing	
SPT	Standard Penetration Test
HP/PP	Hand/Pocket Penetrometer
Dynamic Penetrometers (blows per noted increment)	
DCP	Dynamic Cone Penetrometer
PSP	Perth Sand Penetrometer
MC	Moisture Content
VS	Vane Shear
PBT	Plate Bearing Test
IMP	Borehole Impression Test
PID	Photo Ionization Detector

If encountered, refusal (R), virtual refusal (VR) or hammer bouncing (HB) of penetrometers may be noted.

The quality of the rock can be assessed by the degree of natural defects/fractures and the following.

Rock quality description	
TCR	Total Core Recovery (%) (length of core recovered divided by the length of core run)
RQD	Rock Quality Designation (%) (sum of axial lengths of core greater than 100mm long divided by the length of core run)

Notes on groundwater conditions encountered may include.

Groundwater	
Not Encountered	Excavation is dry in the short term
Not Observed	Water level observation not possible
Seepage	Water seeping into hole
Inflow	Water flowing/flooding into hole

Perched groundwater may result in a misleading indication of the depth to the true water table. Groundwater levels are also likely to fluctuate with variations in climatic and site conditions.

Notes on the stability of excavations may include.

Excavation conditions	
Stable	No obvious/gross short term instability noted
Spalling	Material falling into excavation (minor/major)
Unstable	Collapse of the majority, or one or more face of the excavation

Explanatory Notes: General Soil Description

The methods of description and classification of soils used in this report are based on Australian Standard AS1726-2017 Geotechnical Site Investigations. In practice, a material is described as a soil if it can be remoulded by hand in its field condition or in water. The dominant component is shown in upper case, with secondary components in lower case. In general descriptions cover: soil type, plasticity or particle size/shape, colour, strength or density, moisture and inclusions.

In general, soil types are classified according to the dominant particle on the basis of the following particle sizes.

Soil Classification		Particle Size (mm)
CLAY		< 0.002
SILT		0.002 0.075
SAND	fine	0.075 to 0.21
	medium	0.21 to 0.6
	coarse	0.6 to 2.36
GRAVEL	fine	2.36 to 6.7
	medium	6.7 to 19
	coarse	19 to 63
COBBLES		63 to 200
BOULDERS		> 200

Soil types may be qualified by the presence of minor components on the basis of field examination methods and/or the soil grading.

Terminology	In coarse grained soils		In fine soils
	% fines	% coarse	% coarse
Trace	≤5	≤15	≤15
With	>5, ≤12	>15, ≤30	>15, ≤30

The strength of cohesive soils is classified by engineering assessment or field/lab testing as follows.

Strength	Symbol	Undrained shear strength
Very Soft	VS	≤12kPa
Soft	S	12kPa to ≤25kPa
Firm	F	25kPa to ≤50kPa
Stiff	St	50kPa to ≤100kPa
Very Stiff	VSt	100kPa to ≤200kPa
Hard	H	>200kPa

Cohesionless soils are classified on the basis of relative density as follows.

Relative Density	Symbol	Density Index
Very Loose	VL	<15%
Loose	L	15% to ≤35%
Medium Dense	MD	35% to ≤65%
Dense	D	65% to ≤85%
Very Dense	VD	>85%

The plasticity of cohesive soils is defined by the Liquid Limit (LL) as follows.

Plasticity	Silt LL	Clay LL
Low plasticity	≤ 35%	≤ 35%
Medium plasticity	N/A	> 35% ≤ 50%
High plasticity	> 50%	> 50%

The moisture condition of soil (*w*) is described by appearance and feel and may be described in relation to the Plastic Limit (PL), Liquid Limit (LL) or Optimum Moisture Content (OMC).

Moisture condition and description	
Dry	Cohesive soils: hard, friable, dry of plastic limit. Granular soils: cohesionless and free-running
Moist	Cool feel and darkened colour: Cohesive soils can be moulded. Granular soils tend to cohere
Wet	Cool feel and darkened colour: Cohesive soils usually weakened and free water forms when handling. Granular soils tend to cohere

The structure of the soil may be described as follows.

Zoning	Description
Layer	Continuous across exposure or sample
Lens	Discontinuous layer (lenticular shape)
Pocket	Irregular inclusion of different material

The structure of soil layers may include: defects such as softened zones, fissures, cracks, joints and root-holes; and coarse grained soils may be described as strongly or weakly cemented.

The soil origin may also be noted if possible to deduce.

Soil origin and description	
Fill	Anthropogenic deposits or disturbed material
Topsoil	Zone of soil affected by roots and root fibres
Peat	Significantly organic soils
Colluvial	Transported down slopes by gravity/water
Aeolian	Transported and deposited by wind
Alluvial	Deposited by rivers
Estuarine	Deposited in coastal estuaries
Lacustrine	Deposited in freshwater lakes
Marine	Deposits in marine environments
Residual soil	Soil formed by in situ weathering of rock, with no structure/fabric of parent rock evident
Extremely weathered material	Formed by in situ weathering of geological formations, with the structure/fabric of parent rock intact but with soil strength properties

The origin of the soil generally cannot be deduced solely on the appearance of the material and the inference may be supplemented by further geological evidence or other field observation. Where there is doubt, the terms ‘possibly’ or ‘probably’ may be used

Explanatory Notes: General Rock Description

The methods of description and classification of rocks used in this report are based on Australian Standard AS1726-2017 Geotechnical Site Investigations. In practice, if a material cannot be remoulded by hand in its field condition or in water, it is described as a rock. In general, descriptions cover: rock type, grain size, structure, colour, degree of weathering, strength, minor components or inclusions, and where applicable, the defect types, shape, roughness and coating/infill.

Rock types are generally described according to the predominant grain or crystal size, and in groups for each rock type as follows.

Rock type	Groups
Sedimentary	Deposited, carbonate (porous or non), volcanic ejection
Igneous	Felsic (much quartz, pale), Intermediate, or mafic (little quartz, dark)
Metamorphic	Foliated or non-foliated
Duricrust	Cementing minerology (iron oxides or hydroxides, silica, calcium carbonate, gypsum)

Reference should be made to AS1726 for details of the rock types and methods of classification.

The classification of rock weathering is described based on definitions in AS1726 and summarised as follows.

Term and symbol		Definition
Residual Soil	RS	Soil developed on rock with the mass structure and substance of the parent rock no longer evident
Extremely weathered	XW	Weathered to such an extent that the rock has 'soil-like' properties. Mass structure and substance still evident
Distinctly weathered	DW	The strength is usually changed and may be highly discoloured. Porosity may be increased by leaching, or decreased due to deposition in pores. May be distinguished into MW (Moderately Weathered) and HW (Highly Weathered).
Slightly weathered	SW	Slightly discoloured; little or no change of strength from fresh rock
Fresh Rock	FR	The rock shows no sign of decomposition or staining

The rock material strength can be defined based on the point load index as follows.

Term and symbol		Point Load Index I_s50 (MPa)
Very Low	VL	0.03 to 0.1
Low	L	0.1 to 0.3
Medium	M	0.3 to 1.0
High	H	1.0 to 3
Very High	VH	3 to 10
Extremely High	EH	> 10

It is important to note that the rock material strength as above is distinct from the rock mass strength which can be significantly weaker due to the effect of defects.

A preliminary assessment of rock strength may be made using the field guide detailed in AS1726, and this is conducted in the absence of point load testing.

The defect spacing measured normal to defects of the same set or bedding, is described as follows.

Definition	Defect Spacing (mm)
Thinly laminated	< 6
Laminated	6 to 20
Very thinly bedded	20 to 60
Thinly bedded	60 to 200
Medium bedded	200 to 600
Thickly bedded	600 to 2000
Very thickly bedded	> 2000

Terms for describing rock and defects are as follows.

Defect Terms			
Joint	JT	Sheared zone	SZ
Bedding Parting	BP	Seam	SM
Foliation	FL	Vein	VN
Cleavage	CL	Drill Lift	DL
Crushed Seam	CS	Handling Break	HB
Fracture Zone	FZ	Drilling Break	DB

The shape and roughness of defects in the rock mass are described using the following terms.

Planarity		Roughness	
Planar	PR	Very Rough	VR
Curved	CU	Rough	RF
Undulose	UN	Smooth	S
Irregular	IR	Slickensided	SL
Stepped	ST	Polished	POL
Discontinuous	DIS		

The coating or infill associated with defects in the rock mass are described as follows.

Infill and Coating		
Clean	CN	
Stained	SN	
Carbonaceous	X	
Minerals	MU	Unidentified mineral
	MS	Secondary mineral
	KT	Chlorite
	CA	Calcite
	Fe	Iron Oxide
	Qz	Quartz
Veneer	VNR	Thin or patchy coating
Coating	CT	Infill up to 1mm

Graphic Symbols Index

CLAY	SILT	SAND	GRAVEL
Silty CLAY	Clayey SILT	Clayey SAND	Clayey GRAVEL
Sandy CLAY	Sandy SILT	Silty SAND	Silty GRAVEL
Gravelly CLAY	Gravelly SILT	Gravelly SAND	Sandy GRAVEL
Silty Gravelly CLAY	Clayey Sandy SILT	Clayey Silty SAND	Clayey Silty GRAVEL
Silty Sandy CLAY	Clayey Gravelly SILT	Clayey Gravelly SAND	Clayey Sandy GRAVEL
Sandy Gravelly CLAY	Sandy Gravelly SILT	Silty Gravelly SAND	Silty Sandy GRAVEL

COBBLES & BOULDERS	Sedimentary rock: fine, mostly clay (CLAYSTONE)	Igneous rock: Felsic, fine (RHYOLITE)
PEAT, highly organic soil	Sedimentary rock: fine, mostly silt (SILTSTONE)	Igneous rock: Felsic, coarse (GRANITE)
TOPSOIL	Sedimentary rock: fine, silt and clay (MUDSTONE, SHALE, LAMINITE)	Igneous rock: Mafic, fine to medium (BASALT, DOLERITE)
FILL	Sedimentary rock: medium (SANDSTONE, GREYWACKE)	Igneous rock: Mafic, coarse (GABBRO)
FILL: Asphalt or Bituminous Seal	Sedimentary rock: fine to coarse, angular (BRECCIA)	Metamorphic rock: Foliated, fine to medium (SLATE, PHYLLITE, SHIST)
FILL: Ballast	Sedimentary rock: coarse, rounded (CONGLOMERATE)	Metamorphic rock: Foliated, coarse (GNEISS)
FILL: Concrete	Sedimentary rock: Organic (COAL)	Metamorphic rock: Non-foliated (QUARTZITE, HORNFELS, MARBLE)
FILL: Roadbase	Sedimentary rock: Carbonate (LIMESTONE, DOLOMITE)	
	Sedimentary rock: Volcanic (TUFF, VOLCANIC BRECCIA, AGGLOMERATE)	

BOREHOLE LOG SHEET

Client: Northern Construction
Project: Mawsons Precinct Geotechnical Investigation
Location: North Wallarah

Hole No: BH01

Job No: 82218007 **Sheet:** 1 of 4

Position: E: 372898 N:6335157 **Angle from Horizontal:** -90° **Surface Elevation:**

Rig Type: Scout (Truck Mounted) **Bit:** Impreg N8 **Driller:** Mick Knight

Casing Diameter: NLMC **Contractor:** Total Drilling

Date Started : 24/7/17 **Date Completed:** 24/7/17 **Logged By:** IB **Date Logged:** 24/7/17

Depth (m)	Excavating: Auger 'V' Bit	Excavating: Auger 'TC' Bit	Excavating: Washbore	Excavating: Hand Auger	Excavating: Tooth bucket	Groundwater (m)	Sample or Field Test	Recovered	DCP	RL (m AHD)	Graphic Log	USCS Symbol	Description (SYMBOL, SOIL NAME, plasticity/particle characteristics, colour, minor components, moisture, consistency, structure, ORIGIN)
0						Groundwater Not Encountered	C 0.00 - 12.10 m						Clayey SAND; fine to medium grained, grey-orange, trace gravel, moist
1													
2													Extremely Weathered SANDSTONE; fine grained, orange, very low strength, moist
3													
4													Extremely Weathered PEBBLY SANDSTONE/CONGLOMERATE; fine to medium grained, grey-orange, very low strength, moist
5													Extremely Weathered SILTSTONE; fine grained, grey, very low strength, moist
6													
7													Extremely weathered SANDSTONE; fine grained, orange, moist, very low strength Grey bands
8													
9													

See Standard Sheets for details of abbreviations & basis of descriptions

Cardno
1/10 Denney Street
Broadmeadow NSW 2292
PH: +61 2 4949 4300
FAX: +61 2 4965 4666

BOREHOLE LOG SHEET

Client: Northern Construction
Project: Mawsons Precinct Geotechnical Investigation
Location: North Wallarah

Hole No: BH01

Job No: 82218007 **Sheet:** 2 of 4

Position: E: 372898 N:6335157 **Angle from Horizontal:** -90° **Surface Elevation:**

Rig Type: Scout (Truck Mounted) **Bit:** Impreg N8 **Driller:** Mick Knight

Casing Diameter: NLMC **Contractor:** Total Drilling

Date Started : 24/7/17 **Date Completed:** 24/7/17 **Logged By:** IB **Date Logged:** 24/7/17

Depth (m)	Excavating: Auger 'V' Bit	Excavating: Auger 'TC' Bit	Excavating: Washbore	Excavating: Hand Auger	Excavating: Tooth bucket	Groundwater (m)	Sample or Field Test	Recovered	DCP	RL (m AHD)	Graphic Log	USCS Symbol	Description (SYMBOL, SOIL NAME, plasticity/particle characteristics, colour, minor components, moisture, consistency, structure, ORIGIN)
11							C 0.00 - 12.10 m						Extremely weathered SANDSTONE; fine grained, orange, moist, very low strength
12													
13													CONTINUED AS CORED BOREHOLE
14													
15													
16													
17													
18													
19													

See Standard Sheets for details of abbreviations & basis of descriptions

Cardno
1/10 Denney Street
Broadmeadow NSW 2292
PH: +61 2 4949 4300
FAX: +61 2 4965 4666

CORE LOG SHEET

Client: Northern Construction
Project: Mawsons Precinct Geotechnical Investigation
Location: North Wallarah

Hole No: BH01

Job No: 82218007 **Sheet:** 3 of 4

Position: E: 372898 N:6335157 **Angle from Horizontal:** -90° **Surface Elevation:**

Rig Type: Scout (Truck Mounted) **Bit:** Impreg N8 **Driller:** Mick Knight

Casing Diameter: NLMC **Core Diameter:** **Contractor:** Total Drilling

Date Started : 24/7/17 **Date Completed:** 24/7/17 **Logged By:** IB **Date Logged:** 24/7/17

Depth (m)	Drilling: Hammer Drilling	Drilling: Auger	Drilling: Washbore	Drilling: Casing	Drilling: Coring	Core Recovery (%)	RQD (%)	Samples & Field Tests	Water (m)	RL (m AHD)	Graphic Log	Description	Weathering	Inferred Strength $Is_{(50)}$ MPa	NATURAL FRACTURES: Defect Spacing (mm)	NATURAL FRACTURES: Additional Data
11																
12												CORING COMMENCED AT 12.10m				
13						100	90	C 12.10 - 14.70 m	Water (Groundwater not encountered)			SANDSTONE; fine to medium grained, granular, grey, thinly bedded, pebbly, moist, low strength, weathered	HW			12.42 m: HB, 0°, RF 12.45 m: IS, 0°, Clay
												Gravelly SAND/ XW SANDSTONE; fine to medium grained, orange, moist, extremely low strength/residual soil, extremely weathered	XW DW			
												SANDSTONE; fine to medium grained, granular, grey-orange, pebbly, moist, low strength, distinctively weathered	SW			13.10 m: HB, 50°, RF 13.25 m: HB, 5°, RF 13.33 m: HB, 5°, RF
14												CONGLOMERATE; medium to coarse grained, grey, thinly to thickly bedded (100-500 mm), with Sandstone, strength, slightly weathered, bands of extremeley low strength				13.62 m: HB, 15°, RF 13.96 m: HB, 5°, RF 14.38 m: HB, 5°, RF
15						100	76	C 14.70 - 17.80 m				Extremely weathered rock/Residual soil (crumbles under hand-low pressure)	XW			14.70 m: HB, 0°, RF 14.72 m: DB, 0°, RF 14.80 m: DB, 0°, RF 14.94 m: HB, 0°, RF 15.19 m: HB, 5°, RF
16																15.76 m: HB, 0°, RF 15.86 m: HB, 0°, RF 15.94 m: HB, 0°, RF 16.06 m: HB, 0°, RF 16.12 m: HB, 0°, RF 16.43 m: HB, 0°, RF
17																17.11 m: JT, 0°, RF, CN 17.19 m: HB, 5°, RF 17.53 m: IS, 0°, =10 mm, Clay 17.69 m: IS, 5°, =10 mm, Clay
18						100	90	C 17.80 - 20.88 m				SANDSTONE; fine to medium grained, grey with bands of orange, thinly to thickly bedded, moist, low strength, distinctively weathered, bands of extremeley low strength	SW			17.77 m: DB, 0°, RF 17.80 m: DB, 0°, RF 17.88 m: HB, 0°, RF 18.12 m: IS, 0°, =10 mm, Clay 18.15 m: IS, 0°, =10 mm, Clay 18.59 - 18.83 m: IS, =240 mm, Clay
19																18.93 m: HB, 0°, RF 18.97 m: IS, 0°, =30 mm, Clay 19.18 m: IS, 0°, =30 mm, Clay 19.61 m: DB, 0°, RF

Inferred Strength $Is_{(50)}$ MPa: EL 0.03, VL 0.1, L 0.3, M 1, H 3, VH 10, EH

NATURAL FRACTURES: Defect Spacing (mm): 20, 40, 100, 300, 1000

NATURAL FRACTURES: Additional Data (joints, partings, seams, zones, etc) Description, orientation, infilling or coating, shape, roughness, thickness, other

See Standard Sheets for details of abbreviations & basis of descriptions

Cardno
1/10 Denney Street
Broadmeadow NSW 2292
PH: +61 2 4949 4300
FAX: +61 2 4965 4666

NOTES:

1) Visual strength classification
2) Discontinuities recorded from the horizontal

CORE LOG SHEET

Client: Northern Construction
Project: Mawsons Precinct Geotechnical Investigation
Location: North Wallarah

Hole No: BH01

Job No: 82218007 **Sheet:** 4 of 4

Position: E: 372898 N:6335157 **Angle from Horizontal:** -90° **Surface Elevation:**

Rig Type: Scout (Truck Mounted) **Bit:** Impreg N8 **Driller:** Mick Knight

Casing Diameter: NLMC **Core Diameter:** **Contractor:** Total Drilling

Date Started : 24/7/17 **Date Completed:** 24/7/17 **Logged By:** IB **Date Logged:** 24/7/17

Depth (m)	Drilling: Hammer Drilling	Drilling: Auger	Drilling: Washbore	Drilling: Casing	Drilling: Coring	Core Recovery (%)	RQD (%)	Samples & Field Tests	Water (m)	RL (m AHD)	Graphic Log	Description	Weathering	Inferred Strength $Is_{(50)}$ MPa	NATURAL FRACTURES: Defect Spacing (mm)	NATURAL FRACTURES: Additional Data (joints, partings, seams, zones, etc) Description, orientation, infilling or coating, shape, roughness, thickness, other
21						100	90	C 20.88 - 23.90 m	Water (Groundwater not encountered)			SANDSTONE; fine to medium grained, grey with bands of orange, thinly to thickly bedded, moist, low strength, distinctively weathered, bands of extremeley low strength	DW / SW	EL 0.03 / VL 0.1 / L 0.3 / M 1 / H 3 / VH 10 / EH	20 40 100 300 1000	19.97 m: HB, 0°, RF 20.30 m: HB, 0°, RF 20.88 m: DB, 0°, RF 20.92 m: DB, 0°, RF 21.07 m: DB, 0°, RF 21.23 m: JT, 0°, RF, CN 21.31 m: JT, 0°, RF, CN 21.39 m: JT, 0°, RF, CN 21.51 m: HB, 0°, RF 21.54 m: JT, 0°, RF 21.69 m: IS, 0°, =10 mm, Clay
22						100	80					SILTSTONE; fine grained, grey, moist, pebbly, low strength, moderately to extremely weathered	XW - MW			21.97 m: IS, 0°, =30 mm, Clay 22.41 m: BP, 0°, CN 22.51 m: BP, 0°, CN 22.75 m: IS, 0°, =10 mm, Clay
23												SANDSTONE; fine grained, grey, moist, medium strength, moderately weathered	MW			23.25 m: HB, 0°, RF
24						100	20	C 23.90 - 26.90 m				COAL; crystalline, black, highly cleated, highly fractured sub horizontal and vertical. (Some minor bands of siltstone tuff)	SW - FR			24.08 m: =50 mm, Siltstone tuff inclusion
25																
26																
27						100	20	C 26.90 - 27.74 m				TUFFACEOUS SILTSTONE; fine grained, crystalline, dark grey with black bands, moist, medium strength, distinctly weathered to slightly weathered	DW - SW			
												COAL; crystalline, black, highly cleated, highly fractured sub horizontal and vertical. (Some minor bands of siltstone tuff)	SW - FR			
28						100	20	C 27.74 - 28.39 m				TUFFACEOUS SILTSTONE; fine grained, crystalline, dark grey with black bands, moist, low strength, thin bands of hard material	DW - SW			27.45 m: BP, 0°, S, CN 27.54 m: BP, 0°, S, CN 27.60 m: BP, 0°, S, CN 27.70 m: DB, 0°, S, CN 27.74 m: DB, 0°, S, CN
29												BOREHOLE TERMINATED AT 28.39 m Target depth				

See Standard Sheets for details of abbreviations & basis of descriptions

Cardno
1/10 Denney Street
Broadmeadow NSW 2292
PH: +61 2 4949 4300
FAX: +61 2 4965 4666

NOTES:

1) Visual strength classification
2) Discontinuities recorded from the horizontal

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH001
PROJECT REF : 82218007
SHEET : 1 OF 1

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 14/9/17 DATE COMPLETED : 14/9/17 DATE LOGGED : 14/9/17 LOGGED BY : IB CHECKED BY :

LOCATION : See Drawing for location

DRILLING | MATERIAL

METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			0.0			Gravelly Sandy CLAY; low plasticity, grey-orange			
							0.30m PEBBLY SANDSTONE; granular, fine to coarse grained, light brown			
				1.0						
										1.70 m: Loss of air (void)
				2.0						
							3.00m 3.10m 3.20m SILTSTONE (assumed); no returns			
				3.0			VOID SILTSTONE; granular, fine grained, light grey with sandstone bands			
							3.85m VOID			
				4.0			4.55m SILTSTONE; granular, fine grained, light grey with sandstone bands			
				5.0			5.80m COAL; suspected by the driller, no returns			
				6.0						
				7.0			7.75m CONGLOMERATE;			
				8.0			8.40m Borehole BH001 terminated at 8.40 m Target depth on Conglomerate			Grinding of PCD drill bit
				9.0						
				10.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

File: 82218007 BH001 Page 1 OF 1

GEOTECH.GLB Log CARDNO_BOREHOLE_LOG 82218007_MAWSONS PRECINCT GEOTECH INV_OLD TEMPLATE.GPJ 27/09/2017 09:47 10.0.000

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH002
PROJECT REF : 82218007
SHEET : 1 OF 1

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 14/9/17 DATE COMPLETED : 14/9/17 DATE LOGGED : 14/9/17 LOGGED BY : IB CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL					
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			0.0			Sandy Gravelly CLAY; low plasticity, grey-orange			
							0.30m PEBBLY SANDSTONE; granular, fine to coarse, grey-orange, bands of weathered material (clay)			
				1.0						
				2.0			As above, less gravel (pebbles)			
							2.60m VOID; no returns			2.60 m: Loss of air
				3.0						
				4.0			4.45m SCREE			
							4.80m COAL/SANDSTONE; no returns			
				5.0			5.50m Borehole BH002 terminated at 5.50 m No air returns			
				6.0						
				7.0						
				8.0						
				9.0						
				10.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

File: 82218007 BH002 Page 1 OF 1

GEOTECH.GLB Log CARDNO_BOREHOLE_LOG 82218007_MAWSONS PRECINCT GEOTECH INV_OLD TEMPLATE.GPJ 27/09/2017 09:47 10.0.000

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH003
PROJECT REF : 82218007
SHEET : 1 OF 1

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 14/9/17 DATE COMPLETED : 14/9/17 DATE LOGGED : 14/9/17 LOGGED BY : IB CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL					
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			0.0			Silty Sandy CLAY; low plasticity, brown-orange			
							0.30m PEBBLY SANDSTONE; granular, fine to medium grained, orange-brown			
				1.0			As above, change in colour to light brown			
				2.0						
				3.0						3.0 m: Air loss
				4.0			4.00m 4.20m VOID 4.40m CONGLOMERATE; no returns VOID 4.90m			
				5.0			SANDSTONE; no returns 5.40m			
							Borehole BH003 terminated at 5.40 m No air returns			
				6.0						
				7.0						
				8.0						
				9.0						
				10.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH004
PROJECT REF : 82218007
SHEET : 1 OF 2

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 14/9/17 DATE COMPLETED : 14/9/17 DATE LOGGED : 14/9/17 LOGGED BY : IB CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL					
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			0.0			PEBBLY SANDSTONE; granular, fine to coarse grained, light brown			
				1.0						
				2.0						
				3.0						
							3.80m			
				4.0			SANDSTONE; granular, fine to medium grained, pale grey-white			
				5.0						
							5.85m			
				6.0			VOID			
							6.50m			
							SCREE; no returns			
				7.0						
				8.0						
				9.0						
				10.0						

MOISTURE & GROUNDWATER
- D - Dry
- M - Moist
- W - Wet
- OMC - Optimum MC
- PL - Plastic Limit
- ▶— - Water seepage/inflow
- ▼ - Water level

SAMPLES & FIELD TESTS
- U - Undisturbed Sample
- D - Disturbed Sample
- ES - Environmental sample
- B - Bulk Disturbed Sample
- SPT - Standard Penetration Test
- HP - Hand/Pocket Penetrometer

CONSISTENCY
- VS - Very Soft
- S - Soft
- F - Firm
- St - Stiff
- VSt - Very Stiff
- H - Hard

RELATIVE DENSITY
- VL - Very Loose
- L - Loose
- MD - Medium Dense
- D - Dense
- VD - Very Dense

ROCK STRENGTH
- EL - Extremely low
- VL - Very low
- L - Low
- M - Medium
- H - High
- VH - Very high
- EH - Extremely high

ROCK WEATHERING
- RS - Residual soil
- XW - Extremely weathered
- DW - Distinctly weathered
- SW - Slightly weathered
- FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH004
PROJECT REF : 82218007
SHEET : 2 OF 2

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 14/9/17 DATE COMPLETED : 14/9/17 DATE LOGGED : 14/9/17 LOGGED BY : IB CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL					
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			10.0			SCREE; no returns *(continued)*			
							10.65m			
				11.0			CONGLOMERATE; no return			
							11.40m			
							Borehole BH004 terminated at 11.40 m No air returns			
				12.0						
				13.0						
				14.0						
				15.0						
				16.0						
				17.0						
				18.0						
				19.0						
				20.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH005
PROJECT REF : 82218007
SHEET : 1 OF 1

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 14/9/17 DATE COMPLETED : 14/9/17 DATE LOGGED : 14/9/17 LOGGED BY : IB CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL					
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	GW seepage encountered at 7.7 m			0.0			Sandy Gravelly CLAY; low plasticity, brown-orange			
							0.30m PEBBLY SANDSTONE; granular, fine to coarse grained, light brown			
				1.0						
				2.0			As above, change in colour to orange-grey			
				3.0			As above, less pebbles to sandstone, change in colour to grey			
				4.0			As above, orange-grey			
				5.0			5.10m SILTSTONE TUFF; grey, moist			
							5.60m COAL; poor quality, some minor siltstone beds			Upper Wallarah split
				6.0						
				7.0				XW		
							7.90m SILTSTONE TUFF; grey, moist			
				8.0			8.70m COAL;			
				9.0						
				10.0			10.00m Borehole BH005 terminated at 10.00 m Target depth			

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH006
PROJECT REF : 82218007
SHEET : 1 OF 2

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 14/9/17 DATE COMPLETED : 14/9/17 DATE LOGGED : 14/9/17 LOGGED BY : IB CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL					
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			0.0			Sandy CLAY; low to medium plasticity, grey-orange			
							SANDSTONE; granular, fine-grained, light brown-grey			
				1.0						
							1.50m SILTSTONE; light grey-orange	XW		Extremely weathered/Residual structure
				2.0						
							3.00m SANDSTONE; granular, fine-grained, grey			
				3.0						
				4.0			4.60m COAL; poor quality, moist, black	XW		Upper Wallarah split
							5.00m PEBBLY SANDSTONE/CONGLOMERATE; granular, fine to coarse grained, grey			Thin seam, likely cause of mining ceasation
				5.0			5.50m SILTSTONE; grey (residual structure), moist			
								XW		
				6.0			6.50m SANDSTONE; granular, fine grained, grey			
				7.0			7.50m COAL; poor quality, moist, black			Middle Wallarah split
AH								XW		
				8.0			8.60m SILTSTONE TUFF; grey-black			
				9.0			9.50m SILTSTONE; light-grey, white, moist			
				10.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH006
PROJECT REF : 82218007
SHEET : 2 OF 2

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 14/9/17 DATE COMPLETED : 14/9/17 DATE LOGGED : 14/9/17 LOGGED BY : IB CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL					
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			10.0			SILTSTONE; light-grey, white, moist *(continued)*			
				11.0						
				12.0			12.20m COAL; good quality, dry, black			Bottom Wallarah split
				13.0						
				14.0			14.10m SILTSTONE TUFF; dark grey-brown			
				15.0						
				16.0						
				17.0			17.90m			
				18.0			Borehole BH006 terminated at 17.90 m Target depth on medium strength Sandstone			
				19.0						
				20.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH007
PROJECT REF : 82218007
SHEET : 1 OF 2

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 14/9/17 DATE COMPLETED : 14/9/17 DATE LOGGED : 14/9/17 LOGGED BY : IB CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL					
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			0.0			PEBBLY SANDSTONE/CONGLOMERATE; granular, fine-grained, grey-brown			
				1.0						
							1.80m			
				2.0			CONGLOMERATE; granular, fine to coarse, blue-grey			MUNMORAH CONGLOMERATE
				3.0						
				4.0						
				5.0						
				6.0						
				7.0						
				8.0						
				9.0						
				10.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH007
PROJECT REF : 82218007
SHEET : 2 OF 2

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 14/9/17 DATE COMPLETED : 14/9/17 DATE LOGGED : 14/9/17 LOGGED BY : IB CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL					
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			10.0			CONGLOMERATE; granular, fine to coarse, blue-grey *(continued)*			
				11.0						
				12.0						
				13.0			13.50m			
							Borehole BH007 terminated at 13.50 m Target depth			
				14.0						
				15.0						
				16.0						
				17.0						
				18.0						
				19.0						
				20.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH008
PROJECT REF : 82218007
SHEET : 1 OF 1

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 15/9/17 DATE COMPLETED : 15/9/17 DATE LOGGED : 15/9/17 LOGGED BY : IB CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL					
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			0.0			Sandy CLAY; low to medium plasticity, orange-grey			
							0.30m SANDSTONE (PEBBLY); granular, fine to coarse, brown-orange			
				1.0						
				2.0						
				3.0			As above, less pebbles, change in colour to grey-orange			
				4.0						
				5.0			As above, change in colour to grey			
				6.0			6.60m VOID			
				7.0			7.50m SCREE; no returns			
				8.0						
				9.0			9.25m CONGLOMERATE (assumed); no returns			
				10.0			9.65m Borehole BH008 terminated at 9.65 m No air returns			

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH009
PROJECT REF : 82218007
SHEET : 1 OF 2

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 15/9/17 DATE COMPLETED : 15/9/17 DATE LOGGED : 15/9/17 LOGGED BY : GA CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL					
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			0.0			PEBBLY SANDSTONE; granular, fine to coarse grained, brown-grey			
				1.0						
				2.0						
				3.0			As above, less pebbles, change in colour to grey-orange			
				4.0						
				5.0						
				6.0						
				7.0			As above, more pebbles			
				8.0						
				9.0			As above, less pebbles			
				10.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH009
PROJECT REF : 82218007
SHEET : 2 OF 2

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 15/9/17 DATE COMPLETED : 15/9/17 DATE LOGGED : 15/9/17 LOGGED BY : GA CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL				
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			10.0			PEBBLY SANDSTONE; granular, fine to coarse grained, brown-grey *(continued)*			
				11.0						
				12.0			12.00m VOID 12.30m			
							SCREE; no returns 12.85m			
				13.0			SANDSTONE/COAL (assumed); no returns 13.70m			Drilling was soft, so possibly sandstone or coal. However, cannot be confirmed as no returns
							CONGLOMERATE; no returns 14.00m			
				14.0			Borehole BH009 terminated at 14.00 m No air returns			
				15.0						
				16.0						
				17.0						
				18.0						
				19.0						
				20.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH010
PROJECT REF : 82218007
SHEET : 1 OF 3

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 15/9/17 DATE COMPLETED : 15/9/17 DATE LOGGED : 15/9/17 LOGGED BY : GA CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL					
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			0.0			SANDSTONE (Pebbly); granular, fine to coarse grained, light brown-grey			
				1.0						
				2.0			As above, change in colour to orange-grey			
				3.0			As above, no pebbles			
				4.0			As above, more pebbly			
				5.0						
				6.0						
				7.0						
				8.0						
				9.0			9.00m SANDSTONE; granular, fine grained, grey			
				10.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH010
PROJECT REF : 82218007
SHEET : 2 OF 3

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 15/9/17 DATE COMPLETED : 15/9/17 DATE LOGGED : 15/9/17 LOGGED BY : GA CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL				
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			10.0			SANDSTONE; granular, fine grained, grey *(continued)*			Drilling got easier (Softer area)
				11.0						
				12.0						
				13.0						
							13.40m COAL; poor quality, black	XW		
				14.0						
				15.0						
				16.0			16.40m SILTSTONE TUFF; grey			
				17.0						
				18.0			18.30m COAL; poor quality, black	XW		
				19.0			18.80m SILTSTONE TUFF; brown			
				20.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH010
PROJECT REF : 82218007
SHEET : 3 OF 3

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 15/9/17 DATE COMPLETED : 15/9/17 DATE LOGGED : 15/9/17 LOGGED BY : GA CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL					
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			20.0			SILTSTONE TUFF; brown *(continued)*			
				21.0						
				22.0						
				23.0			23.40m			
							Borehole BH010 terminated at 23.40 m Target depth			
				24.0						
				25.0						
				26.0						
				27.0						
				28.0						
				29.0						
				30.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH011
PROJECT REF : 82218007
SHEET : 1 OF 3

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 15/9/17 DATE COMPLETED : 15/9/17 DATE LOGGED : 15/9/17 LOGGED BY : GA CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL				
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			0.0			SPRAYED SEAL, PAVEMENT and SUBGRADE (Clay)			
							0.50m SANDSTONE (pebbly); fine to medium grained, grey-orange			
				1.0						
				2.0						
				3.0						
				4.0						
				5.0						
				6.0						
				7.0						
				8.0						
				9.0			9.00m SILTSTONE; grey			
				10.0						

MOISTURE & GROUNDWATER
- D - Dry
- M - Moist
- W - Wet
- OMC - Optimum MC
- PL - Plastic Limit
- ▶— - Water seepage/inflow
- ▼ - Water level

SAMPLES & FIELD TESTS
- U - Undisturbed Sample
- D - Disturbed Sample
- ES - Environmental sample
- B - Bulk Disturbed Sample
- SPT - Standard Penetration Test
- HP - Hand/Pocket Penetrometer

CONSISTENCY
- VS - Very Soft
- S - Soft
- F - Firm
- St - Stiff
- VSt - Very Stiff
- H - Hard

RELATIVE DENSITY
- VL - Very Loose
- L - Loose
- MD - Medium Dense
- D - Dense
- VD - Very Dense

ROCK STRENGTH
- EL - Extremely low
- VL - Very low
- L - Low
- M - Medium
- H - High
- VH - Very high
- EH - Extremely high

ROCK WEATHERING
- RS - Residual soil
- XW - Extremely weathered
- DW - Distinctly weathered
- SW - Slightly weathered
- FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH011
PROJECT REF : 82218007
SHEET : 2 OF 3

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 15/9/17 DATE COMPLETED : 15/9/17 DATE LOGGED : 15/9/17 LOGGED BY : GA CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL				
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			10.0			SILTSTONE; grey *(continued)*			
				11.0			11.00m COAL; poor quality			
				12.0				XW		
				13.0			13.75m SILTSTONE TUFF; grey			
				14.0						
				15.0			15.50m COAL; poor quality			
				16.0			16.10m SILTSTONE TUFF; grey	XW		
				17.0						
				18.0						
				19.0						
				20.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH011
PROJECT REF : 82218007
SHEET : 3 OF 3

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 15/9/17 DATE COMPLETED : 15/9/17 DATE LOGGED : 15/9/17 LOGGED BY : GA CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL					
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			20.0			SILTSTONE TUFF; grey *(continued)*			
				21.0			21.00m COAL; poor quality	XW		
				22.0			22.40m SILTSTONE TUFF; grey			
				23.0			23.40m Borehole BH011 terminated at 23.40 m Target depth			
				24.0						
				25.0						
				26.0						
				27.0						
				28.0						
				29.0						
				30.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH012
PROJECT REF : 82218007
SHEET : 1 OF 2

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 15/9/17 DATE COMPLETED : 15/9/17 DATE LOGGED : 15/9/17 LOGGED BY : IB CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL					
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			0.0			SPRAYED SEAL and PAVEMENT			
							0.50m PEBBLY SANDSTONE; fine to coarse grained, light orange-grey			
				1.0						
				2.0						
				3.0						
				4.0						
				5.0						
				6.0						
				7.0			7.00m SILTSTONE; fine grained, grey			
				8.0						
				9.0						
				10.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH012
PROJECT REF : 82218007
SHEET : 2 OF 2

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 15/9/17 DATE COMPLETED : 15/9/17 DATE LOGGED : 15/9/17 LOGGED BY : IB CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL					
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			10.0			SILTSTONE; fine grained, grey *(continued)* As above, change in colour to brown			
				11.0			11.10m COAL; poor quality, moist	XW		
				12.0						
				13.0						
				14.0			14.25m SILTSTONE TUFF; fine grained, grey 14.50m Borehole BH012 terminated at 14.50 m Target depth			
				15.0						
				16.0						
				17.0						
				18.0						
				19.0						
				20.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH013
PROJECT REF : 82218007
SHEET : 1 OF 2

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 15/9/17 DATE COMPLETED : 15/9/17 DATE LOGGED : 15/9/17 LOGGED BY : IB CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL					
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			0.0			SPRAYED SEAL and PAVEMENT			
							0.50m SANDSTONE; granular, fine to medium grained, brown			
				1.0						
				2.0			As above, change in colour to orange-grey			
				3.0						
				4.0						
				5.0						
				6.0						
				7.0			7.30m SILTSTONE; fine grained, light grey			
				8.0			8.60m			
				9.0			COAL; black, moist	XW		
				10.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH013
PROJECT REF : 82218007
SHEET : 2 OF 2

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 15/9/17 DATE COMPLETED : 15/9/17 DATE LOGGED : 15/9/17 LOGGED BY : IB CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL				
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			10.0			COAL; black, moist *(continued)*	XW		
				11.0			11.65m SILTSTONE; fine grained, moist	XW		
				12.0			12.00m Borehole BH013 terminated at 12.00 m Target depth			
				13.0						
				14.0						
				15.0						
				16.0						
				17.0						
				18.0						
				19.0						
				20.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH014
PROJECT REF : 82218007
SHEET : 1 OF 2

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 25/9/17 DATE COMPLETED : 25/9/17 DATE LOGGED : 25/9/17 LOGGED BY : IB CHECKED BY :

LOCATION : See Drawing for location

DRILLING | MATERIAL

METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			0.0			Gravelly CLAY; low plasticity, orange-grey	D		
							0.30m SANDSTONE; fine grained, light orange			
				1.0						
				2.0						
				3.0						
				4.0						
				5.0			5.00m PEBBLY SANDSTONE/CONGLOMERATE; fine to coarse grained, light brown			
				6.0						
				7.0			7.00m PEBBLY SANDSTONE; fine to coarse grained, orange			
				8.0						
				9.0						
				10.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH014
PROJECT REF : 82218007
SHEET : 2 OF 2

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 25/9/17 DATE COMPLETED : 25/9/17 DATE LOGGED : 25/9/17 LOGGED BY : IB CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL					
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			10.0			PEBBLY SANDSTONE; fine to coarse grained, orange *(continued)*			
				11.0						
				12.0			As above, change in colour to grey, seams of fine grained sandstone			
				13.0						
				14.0						
				15.0						
				16.0						
				17.0						
				18.0			18.00m 18.20m AIR VOID			
							Borehole BH014 terminated at 18.20 m No air returns			
				19.0						
				20.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH015
PROJECT REF : 82218007
SHEET : 1 OF 1

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 25/9/17 DATE COMPLETED : 25/9/17 DATE LOGGED : 25/9/17 LOGGED BY : IB CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL				
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			0.0			Sandy Gravelly CLAy; low plasticity, orange			
							0.30m CONGLOMERATE; fine to coarse grained, orange-brown			
				1.0						
				2.0						
				3.0			3.00m AIR VOID			
							3.30m Borehole BH015 terminated at 3.30 m No air returns			
				4.0						
				5.0						
				6.0						
				7.0						
				8.0						
				9.0						
				10.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

File: 82218007 BH015 Page 1 OF 1

GEOTECH.GLB Log CARDNO_BOREHOLE_LOG 82218007_MAWSONS PRECINCT GEOTECH INV_OLD TEMPLATE.GPJ 27/09/2017 09:47 10.0.000

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH016
PROJECT REF : 82218007
SHEET : 1 OF 2

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 25/9/17 DATE COMPLETED : 25/9/17 DATE LOGGED : 25/9/17 LOGGED BY : IB CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL					
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			0.0			Gravelly CLAY; low plasticity, grey-orange			
							0.30m SANDSTONE; fine grained, orange, moist, weathered seam			
				1.0						
				2.0						
				3.0			3.00m 3.10m AIR VOID SANDSTONE; fine grained, grey-orange, some pebbly seams			
				4.0						
				5.0						
				6.0						
				7.0			7.00m 7.10m AIR VOID PEBBLY SANDSTONE; fine to coarse grained, grey, with orange bands			
				8.0						
				9.0						
				10.0						

MOISTURE & GROUNDWATER
- D - Dry
- M - Moist
- W - Wet
- OMC - Optimum MC
- PL - Plastic Limit
- ▶— - Water seepage/inflow
- ▼ - Water level

SAMPLES & FIELD TESTS
- U - Undisturbed Sample
- D - Disturbed Sample
- ES - Environmental sample
- B - Bulk Disturbed Sample
- SPT - Standard Penetration Test
- HP - Hand/Pocket Penetrometer

CONSISTENCY
- VS - Very Soft
- S - Soft
- F - Firm
- St - Stiff
- VSt - Very Stiff
- H - Hard

RELATIVE DENSITY
- VL - Very Loose
- L - Loose
- MD - Medium Dense
- D - Dense
- VD - Very Dense

ROCK STRENGTH
- EL - Extremely low
- VL - Very low
- L - Low
- M - Medium
- H - High
- VH - Very high
- EH - Extremely high

ROCK WEATHERING
- RS - Residual soil
- XW - Extremely weathered
- DW - Distinctly weathered
- SW - Slightly weathered
- FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH016
PROJECT REF : 82218007
SHEET : 2 OF 2

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 25/9/17 DATE COMPLETED : 25/9/17 DATE LOGGED : 25/9/17 LOGGED BY : IB CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL					
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			10.0			PEBBLY SANDSTONE; fine to coarse grained, grey, with orange bands *(continued)*			
				11.0			11.40m AIR VOID			
							11.70m Borehole BH016 terminated at 11.70 m No air returns			
				12.0						
				13.0						
				14.0						
				15.0						
				16.0						
				17.0						
				18.0						
				19.0						
				20.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH017
PROJECT REF : 82218007
SHEET : 1 OF 2

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 25/9/17 DATE COMPLETED : 25/9/17 DATE LOGGED : 25/9/17 LOGGED BY : IB CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL				
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH				0.0			Sandy CLAY; low plasticity, orange			
							0.30m SANDSTONE; fine grained, light orange grey			
				1.0						
				2.0						
				3.0						
				4.0						
				5.0			As above, change in colour to brown			
							5.70m COAL; poor quality, black, moist			Top Wallarah
				6.0				XW		
				7.0			7.40m SILTSTONE TUFF; very fine grained, grey, moist			
				8.0						
				9.0			9.50m COAL; poor quality, black, moist	XW		Middle Wallarah
				10.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH017
PROJECT REF : 82218007
SHEET : 2 OF 2

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 25/9/17 DATE COMPLETED : 25/9/17 DATE LOGGED : 25/9/17 LOGGED BY : IB CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL					
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	GW seepage encountered at 10.00 m			10.0			10.20m COAL; poor quality, black, moist *(continued)*	XW		
							SILTSTONE; very fine grained, light grey and white			
				11.0						
				12.0						
				13.0						
				14.0			14.50m			
							COAL; fresh, black, hard			Bottom Wallarah
				15.0						
				16.0			16.90m			
				17.0			SILTSTONE TUFF; dark grey			
							17.40m			
							Borehole BH017 terminated at 17.40 m			
							Target depth			
				18.0						
				19.0						
				20.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH018
PROJECT REF : 82218007
SHEET : 1 OF 2

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 25/9/17 DATE COMPLETED : 25/9/17 DATE LOGGED : 25/9/17 LOGGED BY : IB CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL					
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			0.0			Gravelly CLAY; low plasticity, orange-brown			
							0.30m SANDSTONE; fine grained, light yellow-grey			
				1.0						
				2.0						
				3.0						
				4.0						
				5.0			5.20m As above, change in colour to brown			
							COAL; black, moist	XW		Upper Wallarah
				6.0						
				7.0			7.10m SILTSTONE TUFF; very fine grained, dark grey			
				8.0			8.90m			
				9.0			COAL; black-brown	XW		Middle Wallarah
							9.40m SILTSTONE TUFF; very fine grained, light grey, moist			
				10.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH018
PROJECT REF : 82218007
SHEET : 2 OF 2

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 25/9/17 DATE COMPLETED : 25/9/17 DATE LOGGED : 25/9/17 LOGGED BY : IB CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL					
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			10.0			SILTSTONE TUFF; very fine grained, light grey, moist *(continued)*			
				11.0						
				12.0						
				13.0						
				14.0						
							14.20m COAL; fresh, black			Bottom Wallarah
				15.0						
							15.80m SILTSTONE TUFF; very fine grained, light grey-brown			
				16.0						
				17.0			17.40m Borehole BH018 terminated at 17.40 m Target depth			
				18.0						
				19.0						
				20.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH019
PROJECT REF : 82218007
SHEET : 1 OF 2

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 26/9/17 DATE COMPLETED : 26/9/17 DATE LOGGED : 26/9/17 LOGGED BY : IB CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL				
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			0.0			0.20m Gravelly CLAY; low plasticity, light-grey-brown			
							SANDSTONE; fine grained, light grey with orange bands			
				1.0						
				2.0						
				3.0						
				4.0			4.00m PEBBLY SANDSTONE; fine to coarse grained, light-grey-orange			
				5.0			5.50m			
							5.70m AIR VOID No returns			
				6.0						
				7.0						
				8.0						
				9.0						
				10.0			10.00m			

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH019
PROJECT REF : 82218007
SHEET : 2 OF 2

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 26/9/17 DATE COMPLETED : 26/9/17 DATE LOGGED : 26/9/17 LOGGED BY : IB CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL					
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			10.0			COAL (assumed); no returns			
				11.0			11.40m			
							Borehole BH019 terminated at 11.40 m No air returns			
				12.0						
				13.0						
				14.0						
				15.0						
				16.0						
				17.0						
				18.0						
				19.0						
				20.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH020
PROJECT REF : 82218007
SHEET : 1 OF 2

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 26/9/17 DATE COMPLETED : 26/9/17 DATE LOGGED : 26/9/17 LOGGED BY : IB CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL				
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			0.0			0.10m Gravelly CLAY; low plasticity, orange-brown SANDSTONE; fine grained, light orange-grey			
				1.0						
				2.0			As above, becoming fine grained with pebbly seams, change in colour to orange			
				3.0						
				4.0						
				5.0						
				6.0						
				7.0			As above, less pebbles, change in colour to grey with orange bands			
				8.0						
				9.0						
				10.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH020
PROJECT REF : 82218007
SHEET : 2 OF 2

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 26/9/17 DATE COMPLETED : 26/9/17 DATE LOGGED : 26/9/17 LOGGED BY : IB CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL					
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			10.0			SANDSTONE; fine grained, light orange-grey *(continued)*			
							10.45m AIR VOID			
							10.75m PEBBLY SANDSTONE/CONGLOMERATE (assumed)			
				11.0			11.20m AIR VOID			Assumed roadway in Upper Wallarah
				12.0			12.30m SCREE; from collapsed workings			
							12.80m No returns			
				13.0						
				14.0			14.50m			
							Borehole BH020 terminated at 14.50 m No air returns			
				15.0						
				16.0						
				17.0						
				18.0						
				19.0						
				20.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH021
PROJECT REF : 82218007
SHEET : 1 OF 2

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 26/9/17 DATE COMPLETED : 26/9/17 DATE LOGGED : 26/9/17 LOGGED BY : IB CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL					
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			0.0			Sandy CLAY; low plasticity, orange			
							0.30m SANDSTONE; fine grained, orange			
				1.0						
				2.0			As above, change in colour to light grey with orange bands			
				3.0						
				4.0						
				5.0						
				6.0			6.00m SILTSTONE; very fine grained, grey			
				7.0			7.00m COAL; poor quality, black, moist	XW		Upper Wallarah
				8.0						
				9.0						
				10.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH021
PROJECT REF : 82218007
SHEET : 2 OF 2

RIG TYPE : Track Scout METHOD : CONTRACTOR : Total Drilling DRILLER : RW

DATE STARTED : 26/9/17 DATE COMPLETED : 26/9/17 DATE LOGGED : 26/9/17 LOGGED BY : IB CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL					
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH	Not Encountered			10.0			10.20m COAL; poor quality, black, moist *(continued)*	XW		
							TUFFACEOUS SILTSTONE; very fine grained, brown 10.80m			
				11.0			COAL; black, moist 11.30m	XW		Middle Wallarah
							TUFFACEOUS SILTSTONE; very fine grained brown			
				12.0			As above, change in colour to grey-white			
				13.0			13.80m			
				14.0			COAL; good quality, black 14.50m			Bottom Wallarah
							Borehole BH021 terminated at 14.50 m Target depth			
				15.0						
				16.0						
				17.0						
				18.0						
				19.0						
				20.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH022
PROJECT REF : 82218007
SHEET : 1 OF 2

RIG TYPE : | METHOD : | CONTRACTOR : | DRILLER :

DATE STARTED : | DATE COMPLETED : | DATE LOGGED : | LOGGED BY : | CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL					
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH				0.0			FILL: Silty Sandy CLAY; medium to high plasticity, grey, trace organics (mine spoil)			
				1.0						
				2.0						
				3.0						
				4.0						
				5.0						
				6.0						
				7.0						
							7.20m SILTSTONE TUFF; very fine grained, light grey, dry			
				8.0			8.30m COAL; black, dry			Middle Wallarah
				9.0			9.10m SILTSTONE TUFF; very fine grained, grey, weathered, moist, with less weathered bands			
				10.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

BOREHOLE LOG

CLIENT : Wakefield Ashurst and Northern Construction and Managers
PROJECT : Mine Subsidence Investigation
LOCATION : Mawsons

HOLE NO : BH022
PROJECT REF : 82218007
SHEET : 2 OF 2

RIG TYPE : | METHOD : | CONTRACTOR : | DRILLER :

DATE STARTED : | DATE COMPLETED : | DATE LOGGED : | LOGGED BY : | CHECKED BY :

LOCATION : See Drawing for location

DRILLING					MATERIAL					
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
AH				10.0			SILTSTONE TUFF; very fine grained, grey, weathered, moist, with less weathered bands *(continued)*			
				11.0						
				12.0						
							12.80m			
				13.0			COAL; black, dry seams of tuffaceous siltstone approximately 300 mm			Bottom Wallarah
				14.0						
							14.80m			
				15.0			SILTSTONE TUFF; very fine grained, grey, moist			
							15.40m			
							Borehole BH022 terminated at 15.40 m			
				16.0						
				17.0						
				18.0						
				19.0						
				20.0						

MOISTURE & GROUNDWATER
D - Dry
M - Moist
W - Wet
OMC - Optimum MC
PL - Plastic Limit
▶— - Water seepage/inflow
▼ - Water level

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
ES - Environmental sample
B - Bulk Disturbed Sample
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

ROCK STRENGTH
EL - Extremely low
VL - Very low
L - Low
M - Medium
H - High
VH - Very high
EH - Extremely high

ROCK WEATHERING
RS - Residual soil
XW - Extremely weathered
DW - Distinctly weathered
SW - Slightly weathered
FR - Fresh rock

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO (NSW/ACT) PTY LTD

APPENDIX C

LABORATORY RESULTS

POINT LOAD STRENGTH TEST RESULTS

CLIENT: Wakefield Ashurst & Northern Managers & Con **DATE: 26/07/2017**

PROJECT: Northern Precinct, Wallarah Peninsula GI **PROJECT No: 82218007**

LOCATION: Caves Beach

Bore	Depth (m)	Sample length (mm)	Sample diameter (mm)	Minimum cross-sectional area of plane (mm)	Separation at failure (mm)	Orientation A = axial D = diametrical I = irregular AS = Anisotropic rock	Load at failure (kN)	Point load strength, I_s	Point load index, $I_{s(50)}$	Rock type & structure	Moisture content & storage history	Failure mechanism M = massive B = bedded J = jointed	Strength
BH01	12.15	80.0	52.0	2124	49.5	D	0.31	0.1	0.1	HW Sandstone	Stored in core box	M	Low
BH01	12.13	49.0	52.0	2548	45.0	A	0.46	0.1	0.1	HW Sandstone	Stored in core box	M	Low
BH01	12.84	102.0	52.0	2124	48.0	D	0.49	0.2	0.2	HW Sandstone	Stored in core box	M	Low
BH01	12.82	39.0	52.0	2028	35.5	A	0.41	0.2	0.2	HW Sandstone	Stored in core box	M	Low
BH01	13.16	98.0	52.0	2124	48.0	D	0.74	0.3	0.3	HW Sandstone	Stored in core box	M	Medium
BH01	13.14	47.0	52.0	2444	43.0	A	0.36	0.1	0.1	HW Sandstone	Stored in core box	M	Low
BH01	13.44	123.0	52.0	2124	49.5	D	0.15	0.06	0.06	HW Sandstone	Stored in core box	M	Very Low
BH01	13.46	49.5	52.0	2574	44.0	A	0.51	0.2	0.2	HW Sandstone	Stored in core box	M	Low
BH01	13.78	123.0	52.0	2124	48.0	D	1.41	0.6	0.6	Interbedded Sandstone / Siltstone	Stored in core box	M	Medium
BH01	13.81	46.5	52.0	2418	41.5	A	2.02	0.7	0.7	Interbedded Sandstone / Siltstone	Stored in core box	M	Medium
BH01	14.10	143.0	52.0	2124	48.0	D	1.27	0.6	0.5	Pebbly Sandstone	Stored in core box	M	Medium
BH01	14.08	41.0	52.0	2132	37.0	A	2.03	0.7	0.8	Pebbly Sandstone	Stored in core box	M	Medium
BH01	14.45	112.0	52.0	2124	48.5	D	0.69	0.3	0.3	Pebbly Sandstone	Stored in core box	M	Low
BH01	14.47	48.5	52.0	2522	43.0	A	0.67	0.2	0.2	Pebbly Sandstone	Stored in core box	M	Low
BH01	14.77	80.0	52.0	2124	49.0	D	0.49	0.2	0.2	Pebbly Sandstone	Stored in core box	M	Low
BH01	14.79	48.0	52.0	2496	43.0	A	2.05	0.6	0.7	Pebbly Sandstone	Stored in core box	M	Medium
BH01	15.26	134.0	52.0	2124	47.0	D	1.50	0.7	0.7	Pebbly Sandstone	Stored in core box	M	Medium
BH01	15.24	45.5	52.0	2366	42.0	A	1.49	0.5	0.5	Pebbly Sandstone	Stored in core box	M	Medium
BH01	15.92	82.0	52.0	2124	49.0	D	0.24	0.10	0.10	Pebbly Sandstone	Stored in core box	M	Very Low
BH01	15.90	47.0	52.0	2444	42.0	A	0.49	0.2	0.2	Pebbly Sandstone	Stored in core box	M	Low

Test Methods: AS4133.4.1-1993 Cl 3.2 - Diametrical test
AS4133.4.1-1993 Cl 3.3 - Axial test
AS4133.4.1-1993 Cl 3.2 - Block and irregular lump test
AS4133.4.1-1993 Cl 3.5 - Anisometrical rock test

Cardno Pty Ltd	**Calculated by: JG**	**Date: 26/07/2017**
Office: Broadmeadow	**Checked by: IB**	**Date: 21/12/2017**

POINT LOAD STRENGTH TEST RESULTS

Cardno Shaping the Future

CLIENT: Wakefield Ashurst & Northern Managers & Con **DATE:** 26/07/2017

PROJECT: Northern Precinct, Wallarah Peninsula GI **PROJECT No:** 82218007

LOCATION: Caves Beach

Bore	Depth (m)	Sample length (mm)	Sample diameter (mm)	Minimum cross-sectional area of plane (mm)	Separation at failure (mm)	Orientation (A = axial, D = diametrical, I = irregular, AS = Anisotropic rock)	Load at failure (kN)	Point load strength, I_s	Point load index, $I_{s(50)}$	Rock type & structure	Moisture content & storage history	Failure mechanism (M = massive, B = bedded, J = jointed)	Strength
BH01	16.26	85.0	52.0	2124	49.0	D	0.18	0.07	0.07	Pebbly Sandstone	Stored in core box	M	Very Low
BH01	16.28	46.0	52.0	2392	42.5	A	0.56	0.2	0.2	Pebbly Sandstone	Stored in core box	M	Low
BH01	16.80	126.0	52.0	2124	48.0	D	0.38	0.2	0.2	Grey Sandstone	Stored in core box	M	Low
BH01	16.78	50.0	52.0	2600	47.0	A	0.39	0.1	0.1	Grey Sandstone	Stored in core box	M	Low
BH01	17.23	119.0	52.0	2124	48.0	D	0.70	0.3	0.3	Grey Sandstone	Stored in core box	M	Low
BH01	17.21	43.0	52.0	2236	39.0	A	0.38	0.1	0.1	Grey Sandstone	Stored in core box	M	Low
BH01	17.62	78.0	52.0	2124	48.0	D	0.37	0.2	0.2	Grey Sandstone	Stored in core box	M	Low
BH01	17.64	44.0	52.0	2288	39.0	A	0.30	0.1	0.1	Grey Sandstone	Stored in core box	M	Low
BH01	18.46	80.0	52.0	2124	49.0	D	0.22	0.09	0.09	Grey Sandstone	Stored in core box	M	Very Low
BH01	19.09	65.0	52.0	2124	48.0	D	0.29	0.1	0.1	Grey Sandstone	Stored in core box	M	Low
BH01	19.07	39.0	52.0	2028	35.5	A	0.56	0.2	0.2	Grey Sandstone	Stored in core box	M	Low
BH01	19.54	110.0	52.0	2124	48.0	D	0.61	0.3	0.3	Grey Sandstone	Stored in core box	M	Low
BH01	19.52	46.0	52.0	2392	43.0	A	0.67	0.2	0.2	Grey Sandstone	Stored in core box	M	Low
BH01	19.84	68.0	52.0	2124	49.5	D	0.12	0.05	0.05	Grey Sandstone	Stored in core box	M	Very Low
BH01	19.79	36.0	52.0	1872	33.5	A	0.20	0.08	0.08	Grey Sandstone	Stored in core box	M	Very Low
BH01	20.05	110.0	52.0	2124	48.0	D	0.46	0.2	0.2	Grey Sandstone	Stored in core box	M	Low
BH01	20.03	47.0	52.0	2444	43.5	A	0.57	0.2	0.2	Grey Sandstone	Stored in core box	M	Low
BH01	20.16	95.0	52.0	2124	48.0	D	0.41	0.2	0.2	Grey Sandstone	Stored in core box	M	Low
BH01	20.19	45.0	52.0	2340	40.0	A	0.73	0.2	0.3	Grey Sandstone	Stored in core box	M	Low
BH01	20.71	120.0	52.0	2124	48.0	D	0.41	0.2	0.2	Grey Sandstone	Stored in core box	M	Low

Test Methods: AS4133.4.1-1993 Cl 3.2 - Diametrical test; AS4133.4.1-1993 Cl 3.2 - Block and irregular lump test; AS4133.4.1-1993 Cl 3.3 - Axial test; AS4133.4.1-1993 Cl 3.5 - Anisometrical rock test

Cardno Pty Ltd	**Calculated by: JG**	**Date: 26/07/2017**
Office: Broadmeadow	**Checked by: IB**	**Date: 21/12/2017**

POINT LOAD STRENGTH TEST RESULTS

Cardno
Shaping the Future

CLIENT: Wakefield Ashurst & Northern Managers & Con **DATE:** 26/07/2017

PROJECT: Northern Precinct, Wallarah Peninsula GI **PROJECT No:** 82218007

LOCATION: Caves Beach

Bore	Depth (m)	Sample length (mm)	Sample diameter (mm)	Minimum cross-sectional area of plane (mm)	Separation at failure (mm)	Orientation (A = axial, D = diametrical, I = irregular, AS = Anisotropic rock)	Load at failure (kN)	Point load strength, I_s	Point load index, $I_{s(50)}$	Rock type & structure	Moisture content & storage history	Failure mechanism (M = massive, B = bedded, J = jointed)	Strength
BH01	20.73	46.0	52.0	2392	43.0	A	0.66	0.2	0.2	Grey Sandstone	Stored in core box	M	Low
BH01	21.12	95.0	52.0	2124	48.0	D	0.22	0.10	0.09	Grey Sandstone	Stored in core box	M	Very Low
BH01	21.14	48.0	52.0	2496	44.0	A	0.60	0.2	0.2	Grey Sandstone	Stored in core box	M	Low
BH01	21.80	95.0	52.0	2124	46.0	D	0.08	0.04	0.04	Grey Sandstone	Stored in core box	M	Very Low
BH01	21.77	47.5	52.0	2470	42.0	A	0.10	0.03	0.03	Grey Sandstone	Stored in core box	M	Very Low
BH01	22.05	96.0	52.0	2124	49.5	D	0.10	0.04	0.04	Grey Sandstone	Stored in core box	M	Very Low
BH01	22.03	47.5	52.0	2470	44.0	A	0.12	0.04	0.04	Grey Sandstone	Stored in core box	M	Very Low
BH01	22.92	73.0	52.0	2124	48.0	D	0.50	0.2	0.2	Grey Sandstone	Stored in core box	M	Low
BH01	22.94	39.5	52.0	2054	35.5	A	0.87	0.3	0.3	Grey Sandstone	Stored in core box	M	Medium
BH01	23.24	110.0	52.0	2124	47.0	D	0.83	0.4	0.4	Grey Sandstone	Stored in core box	M	Medium
BH01	23.26	42.0	52.0	2184	38.0	A	1.13	0.4	0.4	Grey Sandstone	Stored in core box	M	Medium
BH01	23.62	90.0	52.0	2124	47.0	D	0.74	0.3	0.3	Grey Sandstone	Stored in core box	M	Medium
BH01	23.60	35.0	52.0	1820	32.0	A	0.88	0.4	0.4	Grey Sandstone	Stored in core box	M	Medium
BH01	26.68	107.0	52.0	2124	47.0	D	1.12	0.5	0.5	Grey Sandstone	Stored in core box	M	Medium
BH01	26.74	37.0	52.0	1924	33.0	A	1.28	0.5	0.5	Grey Sandstone	Stored in core box	M	Medium
BH01	26.85	85.0	52.0	2124	48.0	D	1.14	0.5	0.5	Grey Sandstone	Stored in core box	M	Medium
BH01	26.87	39.5	52.0	2054	34.5	A	1.17	0.4	0.5	Grey Sandstone	Stored in core box	M	Medium
BH01	27.49	95.0	52.0	2124	50.5	D	5.63	2.2	2.2	Grey Sandstone	Stored in core box	M	High
BH01	27.60	31.5	52.0	1638	25.0	A	3.40	1.6	1.6	Grey Sandstone	Stored in core box	M	High
BH01	27.90	100.0	52.0	2124	44.0	D	0.31	0.2	0.2	Grey Sandstone	Stored in core box	M	Low

Test Methods: AS4133.4.1-1993 Cl 3.2 - Diametrical test; AS4133.4.1-1993 Cl 3.2 - Block and irregular lump test; AS4133.4.1-1993 Cl 3.3 - Axial test; AS4133.4.1-1993 Cl 3.5 - Anisometrical rock test

Cardno Pty Ltd	**Calculated by: JG**	**Date: 26/07/2017**
Office: Broadmeadow	**Checked by: IB**	**Date: 21/12/2017**

POINT LOAD STRENGTH TEST RESULTS

CLIENT: Wakefield Ashurst & Northern Managers & Con **DATE: 26/07/2017**

PROJECT: Northern Precinct, Wallarah Peninsula GI **PROJECT No: 82218007**

LOCATION: Caves Beach

Bore	Depth (m)	Sample length (mm)	Sample diameter (mm)	Minimum cross-sectional area of plane (mm)	Separation at failure (mm)	Orientation (A = axial, D = diametrical, I = irregular, AS = Anisotropic rock)	Load at failure (kN)	Point load strength, I_s	Point load index, $I_{s(50)}$	Rock type & structure	Moisture content & storage history	Failure mechanism (M = massive, B = bedded, J = jointed)	Strength
BH01	27.93	45.0	52.0	2340	40.0	A	0.16	0.05	0.05	Grey Sandstone	Stored in core box	M	Very Low
BH01	28.31	70.0	52.0	2124	50.0	D	0.08	0.03	0.03	Grey Sandstone	Stored in core box	M	Very Low
BH01	28.37	45.0	52.0	2340	49.0	A	0.22	0.07	0.08	Grey Sandstone	Stored in core box	M	Very Low

Test Methods: AS4133.4.1-1993 Cl 3.2 - Diametrical test; AS4133.4.1-1993 Cl 3.2 - Block and irregular lump test; AS4133.4.1-1993 Cl 3.3 - Axial test; AS4133.4.1-1993 Cl 3.5 - Anisometrical rock test

D09530876

RCA AUSTRALIA
GEOTECHNICAL • ENVIRONMENTAL

92 Hill St
CARRINGTON NSW 2294
Ph: (02) 4902 9200
Fax: (02) 4902 9299

CALIFORNIA BEARING RATIO TEST REPORT

Client :	Stockland Wallarah Peninsula P/L	Job Number :	5837
Project :	Northern Precinct		
Location :	Wallarah Peninsula, A2		

Sample number :	M1749
Sample description :	Clayey gravelly SAND - FILL
Sample depth (m) :	0.32-0.6
Date sampled :	29.11.06

TEST PROCEDURES

Test Method :	AS1289.6.1.1
Date tested :	19.12.06
Condition tested :	4 Day Soaked
Laboratory density ratio :	100 % std
Laboratory moisture ratio :	101 %
No of blows used :	53 /layer
Drop of rammer :	300 mm
Mass of rammer :	2.7 kg
Surcharge :	9 kg
% retained on 19mm/Was it excluded?	3.3%/YES

TEST RESULTS

Maximum dry density :		1.94 t/m^3
Optimum moisture content :		12.4 %
Dry density before soaking :		1.94 t/m^3
Dry density after soaking :		1.94 t/m^3
Moisture content		
- at compaction :		12.6 %
- after soaking :		13.1 %
- after penet'n	- top 30mm :	13.0 %
	- remaining specimen :	12.5 %
Swell after soaking :		0 %

PENETRATION	C.B.R VALUE (%)	
	TOP	BOTTOM
2.5mm	10	-
5.0mm	13	-

Remarks:

NATA TECHNICAL COMPETENCE

NATA Accredited Laboratory Number: 9811

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with ISO/IEC 17025

RCA Australia
REPORT No: 5837/008
AUTHORISED SIGNATORY: Adrian Buck
POSITION: Laboratory Manager

DATE: 12/2/2007

LWS-CBR-005/1

D09530876

RCA AUSTRALIA
GEOTECHNICAL • ENVIRONMENTAL

92 Hill St
CARRINGTON NSW 2294
Ph: (02) 4902 9200
Fax: (02) 4902 9299

CALIFORNIA BEARING RATIO TEST REPORT

Client :	Stockland Wallarah Peninsula P/L	Job Number :	5837
Project :	Northern Precinct		
Location :	Wallarah Peninsula, N4		

Sample number :	M1753
Sample description :	Gravelly CLAY
Sample depth (m) :	0.3-0.6
Date sampled :	29.11.06

TEST PROCEDURES

Test Method :	AS1289.6.1.1
Date tested :	19.12.06
Condition tested :	4 Day Soaked
Laboratory density ratio :	99 % std
Laboratory moisture ratio :	99 %
No of blows used :	53 /layer
Drop of rammer :	300 mm
Mass of rammer :	2.7 kg
Surcharge :	9 kg
% retained on 19mm/Was it excluded?	2.0%/YES

TEST RESULTS

Maximum dry density :		1.61 t/m^3
Optimum moisture content :		22.4 %
Dry density before soaking :		1.59 t/m^3
Dry density after soaking :		1.58 t/m^3
Moisture content		
- at compaction :		22.1 %
- after soaking :		24.0 %
- after penet'n	- top 30mm :	24.7 %
	- remaining specimen :	22.8 %
Swell after soaking :		1 %

PENETRATION	C.B.R VALUE (%)	
	TOP	BOTTOM
2.5mm	6	-
5.0mm	6	-

Remarks:

NATA TECHNICAL COMPETENCE

NATA Accredited Laboratory Number: 9811

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with ISO/IEC 17025

RCA Australia
REPORT No: 5837/010
AUTHORISED SIGNATORY: Adrian Buck
POSITION: Laboratory Manager

DATE: 12/2/2007

LWS-CBR-005/1

D09530876

RCA AUSTRALIA
GEOTECHNICAL • ENVIRONMENTAL

92 Hill St
CARRINGTON NSW 2294
Ph: (02) 4902 9200
Fax: (02) 4902 9299

CALIFORNIA BEARING RATIO TEST REPORT

Client :	Stockland Wallarah Peninsula P/L	Job Number :	5837
Project :	Northern Precinct		
Location :	Wallarah Peninsula, N8		

Sample number :	M1752
Sample description :	Weathered CONGLOMERATE
Sample depth (m) :	0.1-0.2
Date sampled :	29.11.06

TEST PROCEDURES

Test Method :	AS1289.6.1.1
Date tested :	19.12.06
Condition tested :	4 Day Soaked
Laboratory density ratio :	100 % std
Laboratory moisture ratio :	100 %
No of blows used :	53 /layer
Drop of rammer :	300 mm
Mass of rammer :	2.7 kg
Surcharge :	9 kg
% retained on 19mm/Was it excluded?	17.9%/NO

TEST RESULTS

Maximum dry density :		1.78 t/m^3
Optimum moisture content :		15.6 %
Dry density before soaking :		1.78 t/m^3
Dry density after soaking :		1.78 t/m^3
Moisture content		
- at compaction :		15.5 %
- after soaking :		17.6 %
- after penet'n	- top 30mm :	17.7 %
	- remaining specimen :	15.8 %
Swell after soaking :		0 %

PENETRATION	C.B.R VALUE (%)	
	TOP	BOTTOM
2.5mm	25	-
5.0mm	25	-

Remarks:

NATA TECHNICAL COMPETENCE

NATA Accredited Laboratory Number: 9811

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with ISO/IEC 17025

RCA Australia
REPORT No: 5837/009
AUTHORISED SIGNATORY: Adrian Buck
POSITION: Laboratory Manager

DATE: 12/2/2007

LWS-CBR-005/1

D09530876

RCA AUSTRALIA
GEOTECHNICAL • ENVIRONMENTAL

92 Hill St
CARRINGTON NSW 2294
Ph: (02) 4902 9200
Fax: (02) 4902 9299

CALIFORNIA BEARING RATIO TEST REPORT

Client :	Stockland Wallarah Peninsula P/L	Job Number :	5837
Project :	Northern Precinct		
Location :	Wallarah Peninsula, N11		

Sample number :	M1754
Sample description :	Silty CLAY
Sample depth (m) :	0.6-0.8
Date sampled :	29.11.06

TEST PROCEDURES

Test Method :	AS1289.6.1.1
Date tested :	19.12.06
Condition tested :	4 Day Soaked
Laboratory density ratio :	97 % std
Laboratory moisture ratio :	104 %
No of blows used :	53 /layer
Drop of rammer :	300 mm
Mass of rammer :	2.7 kg
Surcharge :	9 kg
% retained on 19mm/Was it excluded?	0%/YES

TEST RESULTS

Maximum dry density :		1.48 t/m^3
Optimum moisture content :		25.9 %
Dry density before soaking :		1.44 t/m^3
Dry density after soaking :		1.38 t/m^3
Moisture content		
- at compaction :		26.9 %
- after soaking :		33.1 %
- after penet'n	- top 30mm :	34.3 %
	- remaining specimen :	28.8 %
Swell after soaking :		4 %

PENETRATION	C.B.R VALUE (%)	
	TOP	BOTTOM
2.5mm	4	-
5.0mm	4	-

Remarks:

NATA TECHNICAL COMPETENCE

NATA Accredited Laboratory Number: 9811

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with ISO/IEC 17025

RCA Australia
REPORT No: 5837/011
AUTHORISED SIGNATORY: Adrian Buck
POSITION: Laboratory Manager

DATE: 12/2/2007

LWS-CBR-005/1

D09530876

RCA AUSTRALIA
GEOTECHNICAL • ENVIRONMENTAL

92 Hill St
CARRINGTON NSW 2294
Ph: (02) 4902 9200
Fax: (02) 4902 9299

CALIFORNIA BEARING RATIO TEST REPORT

Client :	Stockland Wallarah Peninsula P/L	Job Number :	5837
Project :	Northern Precinct		
Location :	Wallarah Peninsula, N13		

Sample number :	M1755
Sample description :	CLAY, high plasticity
Sample depth (m) :	0.8-1.0
Date sampled :	29.11.06

TEST PROCEDURES

Test Method :	AS1289.6.1.1
Date tested :	19.12.06
Condition tested :	4 Day Soaked
Laboratory density ratio :	100 % std
Laboratory moisture ratio :	99 %
No of blows used :	53 /layer
Drop of rammer :	300 mm
Mass of rammer :	2.7 kg
Surcharge :	9 kg
% retained on 19mm/Was it excluded?	0%/YES

TEST RESULTS

Maximum dry density :		1.66 t/m^3
Optimum moisture content :		20.9 %
Dry density before soaking :		1.66 t/m^3
Dry density after soaking :		1.62 t/m^3
Moisture content		
- at compaction :		20.6 %
- after soaking :		23.3 %
- after penet'n	- top 30mm :	24.8 %
	- remaining specimen :	22.0 %
Swell after soaking :		2 %

PENETRATION	C.B.R VALUE (%)	
	TOP	BOTTOM
2.5mm	3.5	-
5.0mm	3.5	-

Remarks:

NATA TECHNICAL COMPETENCE
NATA Accredited Laboratory Number: 9811

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with ISO/IEC 17025

RCA Australia
REPORT No: 5837/012
AUTHORISED SIGNATORY: Adrian Buck
POSITION: Laboratory Manager

DATE: 12/2/2007

LWS-CBR-005/1

D09530876

RCA AUSTRALIA
GEOTECHNICAL • ENVIRONMENTAL

92 Hill St
CARRINGTON NSW 2294
Ph: (02) 4902 9200
Fax: (02) 4902 9299

MOISTURE CONTENT, PLASTICITY INDEX AND LINEAR SHRINKAGE DETERMINATIONS

CLIENT: Stockland Wallarah Peninsula Pty Ltd **DATE:** 29.11.06

PROJECT: Northern Precinct **PROJECT No:** 5837

LOCATION: Wallarah Peninsula **CLIENT REF:** -

SAMPLE NO.	IDENTIFICATION	DESCRIPTION	CODE	W %	W_L %	W_P %	I_P %	LS %
M1749	A2 @ 0.32-0.6m	Clayey gravelly SAND - FILL	2/4	-	21	16	5	-
M1754	N11 @ 0.6-0.6m	Silty CLAY	2/4	-	75	26	49	-
M1755	N13 @ 0.8-1.0m	CLAY, high plasticity	2/4	-	65	18	47	-

Explanations of Symbols

W - Moisture content
W_L - Liquid limit
W_P - Plastic limit
I_P - Plasticity index
LS - Linear shrinkage
N/O - Not Obtainable
NP- Non Plastic

Codes

1. Air dried
2. Low temperature oven (<50 degrees C)
3. Natural state
4. Oven dried (105-110 degrees C)

Test Methods Used

AS1289.3.1.2, 3.2.1, 3.3.1

REMARKS: -

NATA TECHNICAL COMPETENCE

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with ISO/IEC 17025.

RCA Australia
REPORT No: 5837/007
AUTHORISED SIGNATORY: Adrian Buck
POSITION: Laboratory Manager

DATE: 12.02.07

NATA Accredited Laboratory Number: 9811

D09530876

RCA AUSTRALIA
GEOTECHNICAL • ENVIRONMENTAL

92 Hill St
CARRINGTON NSW 2294
Ph: (02) 4902 9200
Fax: (02) 4902 9299

EMERSON CLASS NUMBER DETERMINATION OF A SOIL

CLIENT:	Stockland Wallarah Peninsula Pty Ltd	**DATE:**	06.12.06
PROJECT:	Northern Precinct	**PROJECT No:**	5837
LOCATION:	Wallarah Peninsula	**CLIENT REF:**	-

SAMPLE No:	M1753
DEPTH:	0.3-0.6m
MATERIAL DESCRIPTION:	Gravelly CLAY
SOURCE OF MATERIAL:	N4
DATE OF SAMPLING:	29.11.06
TEST METHOD:	**AS1289 3.8.1**

TYPE OF WATER USED FOR TEST: Demineralised

TEMP OF WATER USED FOR TEST (°C): 23

EMERSON CLASS No: 4

REMARKS: -

NATA TECHNICAL COMPETENCE

NATA Accredited Laboratory Number: 9811

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with ISO/IEC 17025.

RCA Australia
REPORT No: 5837/004
AUTHORISED SIGNATORY: Adrian Buck
POSITION: Laboratory Manager

DATE: 12.02.07

D09530876

RCA AUSTRALIA
GEOTECHNICAL • ENVIRONMENTAL

92 Hill St
CARRINGTON NSW 2294
Ph: (02) 4902 9200
Fax: (02) 4902 9299

EMERSON CLASS NUMBER DETERMINATION OF A SOIL

CLIENT:	Stockland Wallarah Peninsula Pty Ltd	**DATE:**	06.12.06
PROJECT:	Northern Precinct	**PROJECT No:**	5837
LOCATION:	Wallarah Peninsula	**CLIENT REF:**	-

SAMPLE No:	M1751
DEPTH:	0.7m
MATERIAL DESCRIPTION:	Clay FILL
SOURCE OF MATERIAL:	N5
DATE OF SAMPLING:	29.11.06
TEST METHOD:	**AS1289 3.8.1**

TYPE OF WATER USED FOR TEST:	Demineralised
TEMP OF WATER USED FOR TEST (°C):	23

EMERSON CLASS No: 4

REMARKS: -

NATA TECHNICAL COMPETENCE

NATA Accredited Laboratory Number: 9811

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with ISO/IEC 17025.

RCA Australia
REPORT No: 5837/003
AUTHORISED SIGNATORY: Adrian Buck
POSITION: Laboratory Manager

DATE: 12.02.07

D09530876

RCA AUSTRALIA
GEOTECHNICAL • ENVIRONMENTAL

92 Hill St
CARRINGTON NSW 2294
Ph: (02) 4902 9200
Fax: (02) 4902 9299

EMERSON CLASS NUMBER DETERMINATION OF A SOIL

CLIENT:	Stockland Wallarah Peninsula Pty Ltd	**DATE:**	06.12.06
PROJECT:	Northern Precinct	**PROJECT No:**	5837
LOCATION:	Wallarah Peninsula	**CLIENT REF:**	-

SAMPLE No:	M1754
DEPTH:	0.6-0.8m
MATERIAL DESCRIPTION:	Silty CLAY
SOURCE OF MATERIAL:	N11
DATE OF SAMPLING:	29.11.06
TEST METHOD:	**AS1289 3.8.1**

TYPE OF WATER USED FOR TEST:	Demineralised
TEMP OF WATER USED FOR TEST (°C):	23

EMERSON CLASS No: 4

REMARKS: -

NATA TECHNICAL COMPETENCE

NATA Accredited Laboratory Number: 9811

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with ISO/IEC 17025.

RCA Australia
REPORT No: 5837/005
AUTHORISED SIGNATORY: Adrian Buck
POSITION: Laboratory Manager

DATE: 12.02.07

D09530876

RCA AUSTRALIA
GEOTECHNICAL • ENVIRONMENTAL

92 Hill St
CARRINGTON NSW 2294
Ph: (02) 4902 9200
Fax: (02) 4902 9299

EMERSON CLASS NUMBER DETERMINATION OF A SOIL

CLIENT:	Stockland Wallarah Peninsula Pty Ltd	**DATE:**	06.12.06
PROJECT:	Northern Precinct	**PROJECT No:**	5837
LOCATION:	Wallarah Peninsula	**CLIENT REF:**	-

SAMPLE No:	M1755
DEPTH:	0.8-1.0m
MATERIAL DESCRIPTION:	CLAY, high plasticity
SOURCE OF MATERIAL:	N13
DATE OF SAMPLING:	29.11.06
TEST METHOD:	**AS1289 3.8.1**

TYPE OF WATER USED FOR TEST:	Demineralised
TEMP OF WATER USED FOR TEST (°C):	23

EMERSON CLASS No: 4

REMARKS: -

NATA TECHNICAL COMPETENCE

NATA Accredited Laboratory Number: 9811

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with ISO/IEC 17025.

RCA Australia
REPORT No: 5837/006
AUTHORISED SIGNATORY: Adrian Buck
POSITION: Laboratory Manager

DATE: 12.02.07

D09530876

RCA AUSTRALIA
GEOTECHNICAL • ENVIRONMENTAL

92 Hill St
CARRINGTON NSW 2294
Ph: (02) 4902 9200
Fax: (02) 4902 9299

EMERSON CLASS NUMBER DETERMINATION OF A SOIL

CLIENT:	Stockland Wallarah Peninsula Pty Ltd	**DATE:**	06.12.06
PROJECT:	Northern Precinct	**PROJECT No:**	5837
LOCATION:	Wallarah Peninsula	**CLIENT REF:**	-

SAMPLE No:	M1750
DEPTH:	0.5m
MATERIAL DESCRIPTION:	Silty CLAY
SOURCE OF MATERIAL:	N15
DATE OF SAMPLING:	29.11.06
TEST METHOD:	**AS1289 3.8.1**

TYPE OF WATER USED FOR TEST:	Demineralised
TEMP OF WATER USED FOR TEST (°C):	23

EMERSON CLASS No: 4

REMARKS: -

NATA TECHNICAL COMPETENCE

NATA Accredited Laboratory Number: 9811

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with ISO/IEC 17025.

RCA Australia
REPORT No: 5837/002
AUTHORISED SIGNATORY: Adrian Buck
POSITION: Laboratory Manager

DATE: 12.02.07

D09530876

AUSTRALIAN SOIL TESTING PTY LTD. A.B.N. 79 003 493 623

19 Bermill Street, Rockdale, NSW, 2216 P.O. Box 2014, Rockdale D.C. NSW 2216

Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

SOIL CLASSIFICATION TEST DATA

CLIENT: **Sinclair Knight Merz**
PO Box 164 St Leonards NSW 1590

PROJECT: **Swansea Open Cut.**

LAB. NO.	SAMPLE SOURCE	SAMPLE DESCRIPTION	MOISTURE CONTENT (%) 1	DRY DENSITY (t/m^3)	LIQUID LIMIT 2	PLASTIC INDEX 3	LINEAR SHRINKAGE (%) 4
28470	OC19	CLAYEY GRAVELLY SAND: grey, fine to coarse sand, fine to medium gravel, low plasticity.	-	-	26	9	-
28471	OC20	GRAVELLY CLAYEY SAND: grey, fine to coarse sand, low plasticity, fine to medium gravel.	-	-	30	12	-
28472	OC23	SANDY CLAYEY GRAVELLY: grey, fine to medium gravel, low plasticity, fine to coarse sand.	-	-	31	13	-
28473	OC24	GRAVELLY CLAYEY SAND: grey, fine to coarse sand, low plasticity, fine to medium gravel.	-	-	31	14	-
28474	OC25	GRAVELLY CLAYEY SAND: grey, fine to coarse sand, low plasticity, fine to medium gravel.	-	-	27	11	-

NOTES TO TESTING

1 Test method: AS 1289 2.1.1-1992
2 Test Method: AS 1289 3.1.2
Preparation: dry sieved
Sample History: air dried
3 Test Method: AS 1289 3.2.1, 3.3.1
Preparation and sample history as 2.

Sampled by: Client

Job Number: 116-026

Date Tested: 11.03.03

Form C01 excel issue 4 Jan 1997 CWS

Signed: SVickers Name: Scott Vickers

Title: STO Date: 19.03.03

D09530876

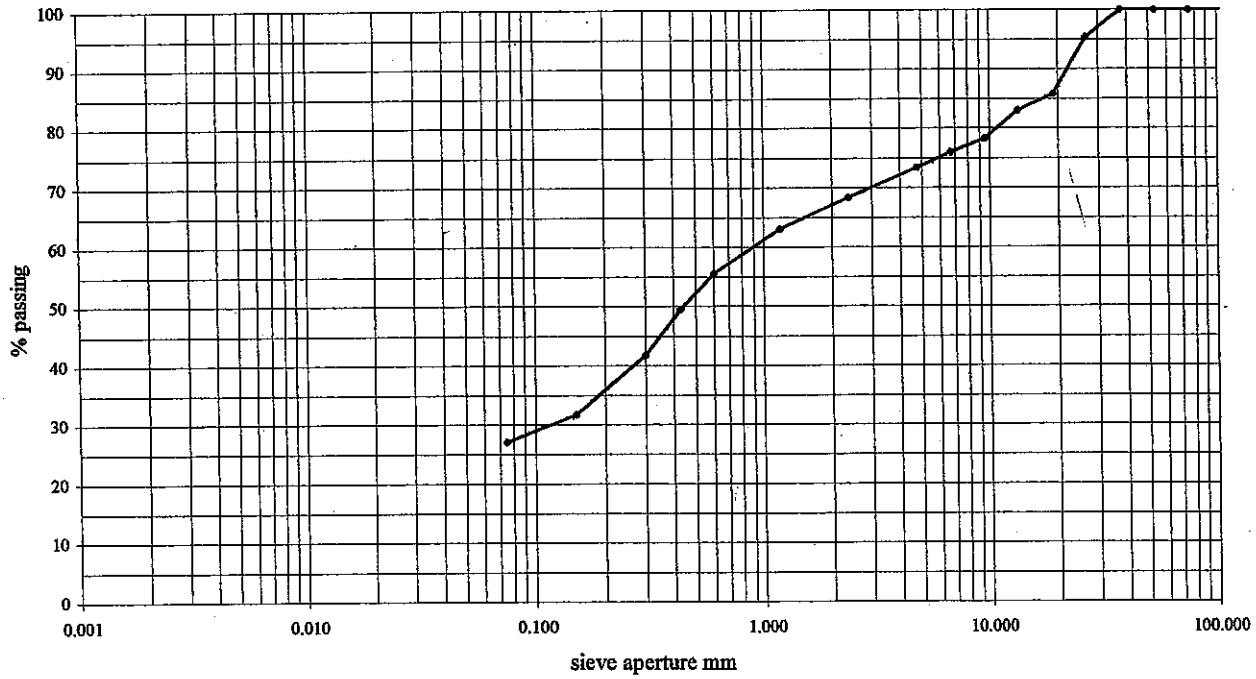
AUSTRALIAN SOIL TESTING PTY LTD. A.B.N. 79 003 493 623

19 Bermill Street, Rockdale, NSW, 2216 P.O. Box 2014, Rockdale D.C. NSW 2216

Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

PARTICLE SIZE DISTRIBUTION TEST REPORT

Client:	**Sinclair Knight Merz**		
Address:	**PO Box 164 St Leonards NSW 1590**		
Project:	**Swansea Open Cut.**		
Test Method:	**AS1289.3.6.1**		
Job Number:	**116-026**	Lab No:	**28470**
Sample:	**OC19**	Date Tested:	**11.03.03**
Sampled by:	**Client**	Tested by:	**SV/TE**



Clay	Silt	Sand	Gravel

Sample Description: **CLAYEY GRAVELLY SAND: grey, fine to coarse sand, fine to medium gravel, low plasticity.**

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0		1.18	63
75.0		0.600	56
53.0		0.425	49
37.5	100	0.300	42
26.5	95	0.150	32
19.0	86	0.075	27
13.2	83	0.050	
9.5	78	0.020	
6.7	76	0.010	
4.75	73	0.005	
2.36	68	0.002	

Hydrometer Type: N/A
Dispersant Type: N/A
Pretreatment: Nil
Loss on pretreatment: Nil

Remarks:

FILE: EXCEL\report\1289361

issue 3/01

Signed: ..... Name: Scott Vickers

Title: STO Date: 19.03.03

D09530876

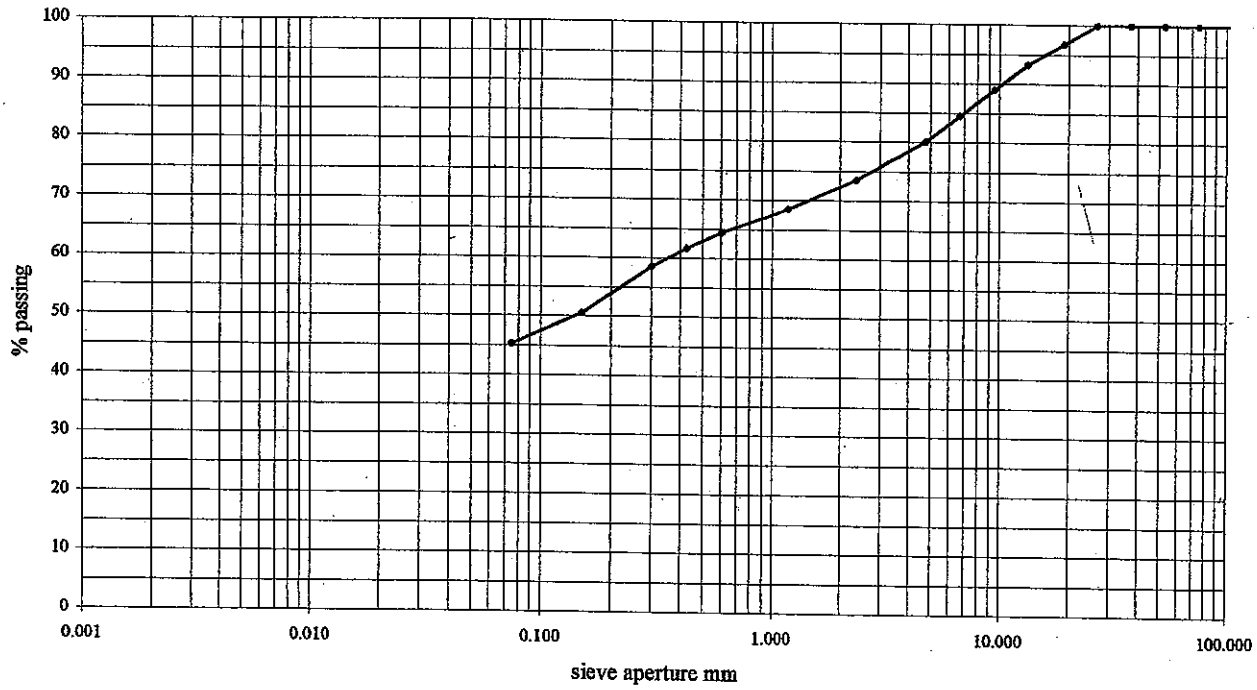
AUSTRALIAN SOIL TESTING PTY LTD. A.B.N. 79 003 493 623

19 Bermill Street, Rockdale, NSW, 2216 P.O. Box 2014, Rockdale D.C. NSW 2216

Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

PARTICLE SIZE DISTRIBUTION TEST REPORT

Client:	**Sinclair Knight Merz**		
Address:	**PO Box 164 St Leonards NSW 1590**		
Project:	**Swansea Open Cut.**		
Test Method:	**AS1289.3.6.1**		
Job Number:	**116-026**	Lab No:	**28471**
Sample:	**OC20**	Date Tested:	**11.03.03**
Sampled by:	**Client**	Tested by:	**SV/TE**



Clay	Silt	Sand	Gravel

Sample Description: **GRAVELLY CLAYEY SAND: grey, fine to coarse sand, low plasticity, fine to medium gravel.**

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0		1.18	68
75.0		0.600	64
53.0		0.425	62
37.5		0.300	58
26.5	100	0.150	50
19.0	97	0.075	45
13.2	93	0.050	
9.5	89	0.020	
6.7	85	0.010	
4.75	80	0.005	
2.36	74	0.002	

Hydrometer Type: N/A
Dispersant Type: N/A
Pretreatment: Nil
Loss on pretreatment: Nil

Remarks:

FILE: EXCEL\report\1289361

issue 3/01

Signed: SHickes Name: Scott Hickes

Title: SPO Date: 19.03.03

D09530876

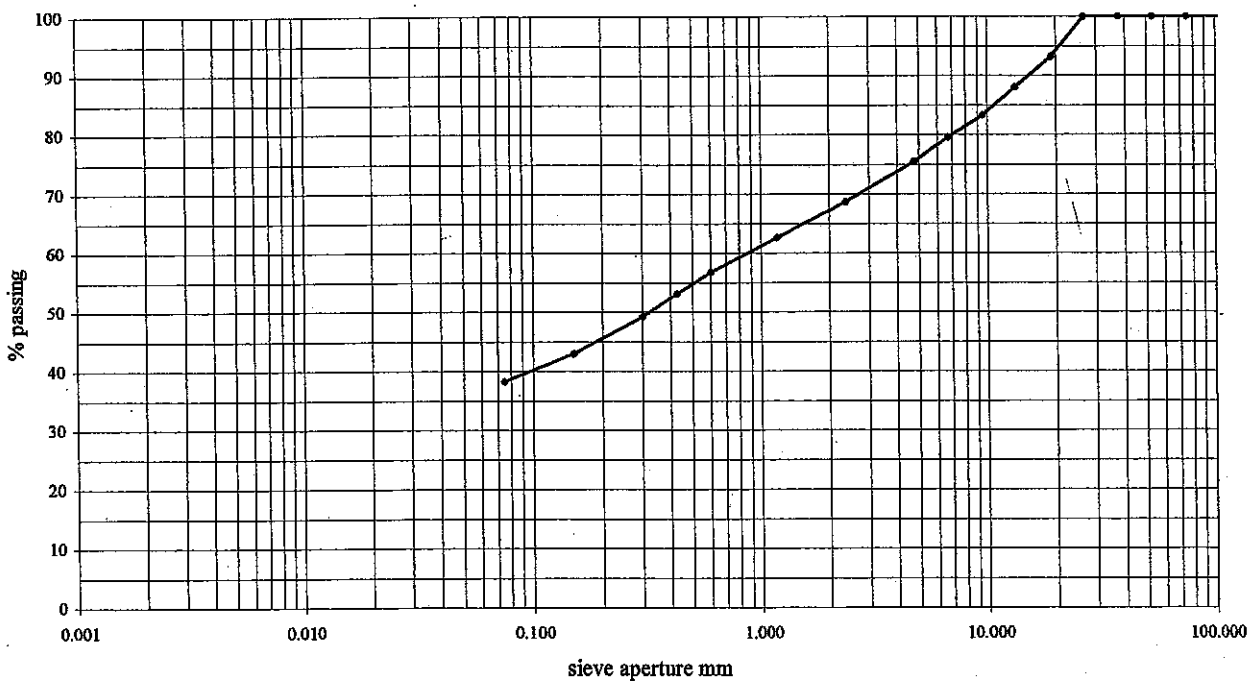
AUSTRALIAN SOIL TESTING PTY LTD. A.B.N. 79 003 493 623

19 Bermill Street, Rockdale, NSW, 2216 P.O. Box 2014, Rockdale D.C. NSW 2216

Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

PARTICLE SIZE DISTRIBUTION TEST REPORT

Client:	**Sinclair Knight Merz**		
Address:	**PO Box 164 St Leonards NSW 1590**		
Project:	**Swansea Open Cut.**		
Test Method:	**AS1289.3.6.1**		
Job Number:	**116-026**	Lab No:	**28472**
Sample:	**OC23**	Date Tested:	**11.03.03**
Sampled by:	**Client**	Tested by:	**SV/TE**



Clay	Silt	Sand	Gravel

Sample Description: **SANDY CLAYEY GRAVELLY: grey, fine to medium gravel, low plasticity, fine to coarse sand.**

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0		1.18	63
75.0		0.600	57
53.0		0.425	53
37.5		0.300	49
26.5	100	0.150	43
19.0	93	0.075	38
13.2	88	0.050	
9.5	83	0.020	
6.7	80	0.010	
4.75	75	0.005	
2.36	69	0.002	

Hydrometer Type: N/A
Dispersant Type: N/A
Pretreatment: Nil
Loss on pretreatment: Nil

Remarks:

FILE: EXCEL\report\1289361

issue 3/01

Signed: SVickers Name: Scott Vickers

Title: STO Date: 19.03.03

D09530876

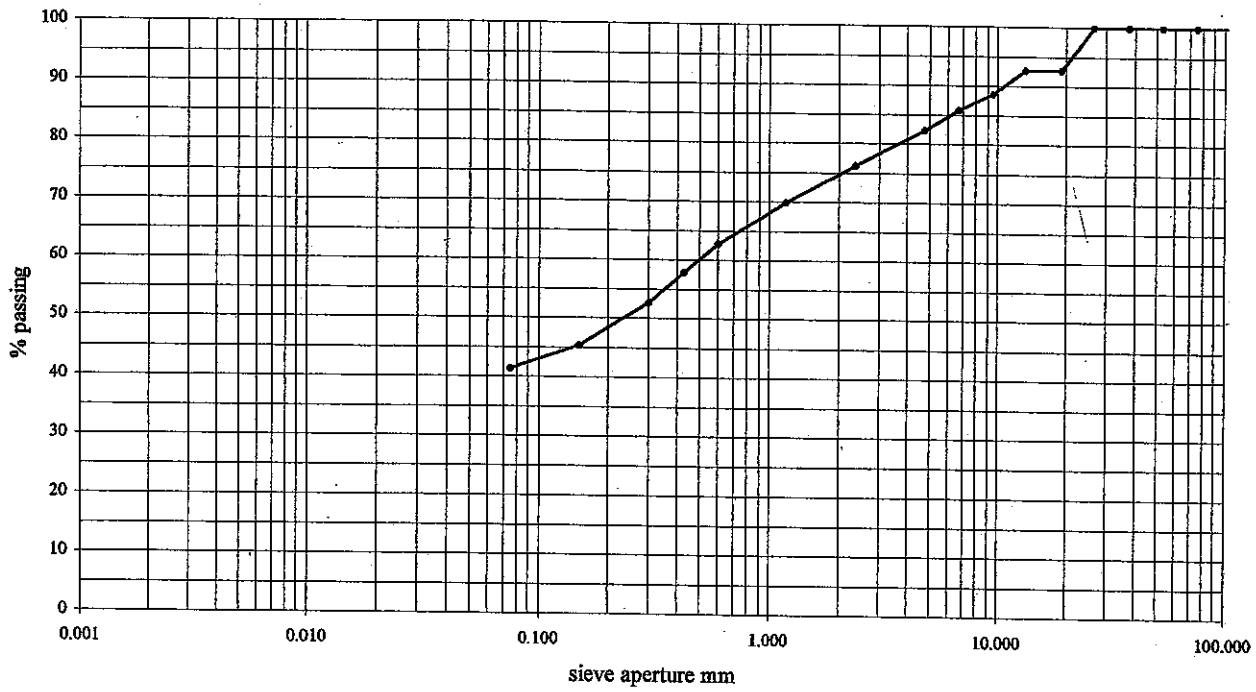
AUSTRALIAN SOIL TESTING PTY LTD. A.B.N. 79 003 493 623

19 Bermill Street, Rockdale, NSW, 2216 P.O. Box 2014, Rockdale D.C. NSW 2216

Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

PARTICLE SIZE DISTRIBUTION TEST REPORT

Client:	**Sinclair Knight Merz**		
Address:	**PO Box 164 St Leonards NSW 1590**		
Project:	**Swansea Open Cut.**		
Test Method:	**AS1289.3.6.1**		
Job Number:	**116-026**	Lab No:	**28473**
Sample:	**OC24**	Date Tested:	**11.03.03**
Sampled by:	**Client**	Tested by:	**SV/TE**



Clay	Silt	Sand	Gravel

Sample Description: **GRAVELLY CLAYEY SAND: grey, fine to coarse sand, low plasticity, fine to medium gravel.**

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0		1.18	70
75.0		0.600	63
53.0		0.425	58
37.5		0.300	53
26.5	100	0.150	45
19.0	93	0.075	41
13.2	93	0.050	
9.5	89	0.020	
6.7	86	0.010	
4.75	82	0.005	
2.36	76	0.002	

Hydrometer Type: N/A
Dispersant Type: N/A
Pretreatment: Nil
Loss on pretreatment: Nil

Remarks:

FILE: EXCEL\report\1289361

Signed: S.Hickers. Name: Scott Hickers

Title: SSO Date: 19.03.03

D09530876

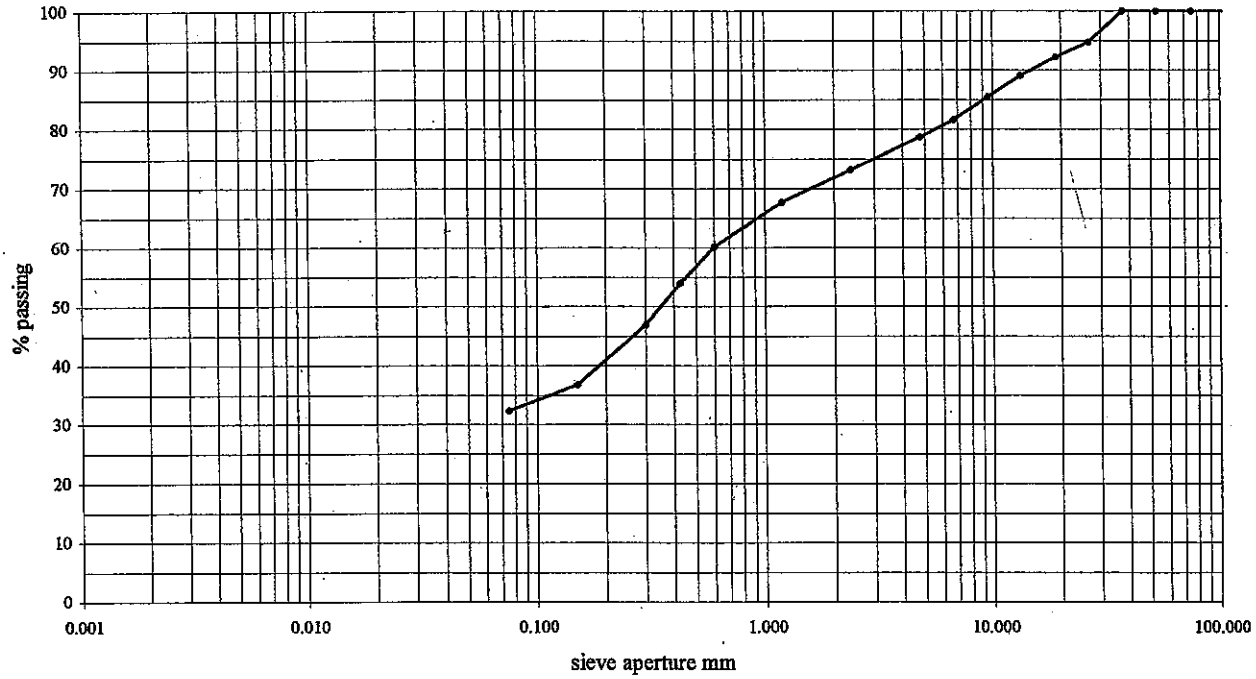
AUSTRALIAN SOIL TESTING PTY LTD. A.B.N. 79 003 493 623

19 Bermill Street, Rockdale, NSW, 2216 P.O. Box 2014, Rockdale D.C. NSW 2216

Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

PARTICLE SIZE DISTRIBUTION TEST REPORT

Client:	**Sinclair Knight Merz**		
Address:	**PO Box 164 St Leonards NSW 1590**		
Project:	**Swansea Open Cut.**		
Test Method:	**AS1289.3.6.1**		
Job Number:	**116-026**	Lab No:	**28474**
Sample:	**OC25**	Date Tested:	**11.03.03**
Sampled by:	**Client**	Tested by:	**SV/TE**



Clay	Silt	Sand	Gravel

Sample Description: **GRAVELLY CLAYEY SAND: grey, fine to coarse sand, low plasticity, fine to medium gravel.**

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0		1.18	68
75.0		0.600	60
53.0		0.425	54
37.5	100	0.300	47
26.5	95	0.150	37
19.0	92	0.075	32
13.2	89	0.050	
9.5	85	0.020	
6.7	82	0.010	
4.75	79	0.005	
2.36	73	0.002	

Hydrometer Type: N/A
Dispersant Type: N/A
Pretreatment: Nil
Loss on pretreatment: Nil

Remarks:

FILE: EXCEL\report\1289361

issue 3/01

Signed: SVickers Name: Scott Vickers

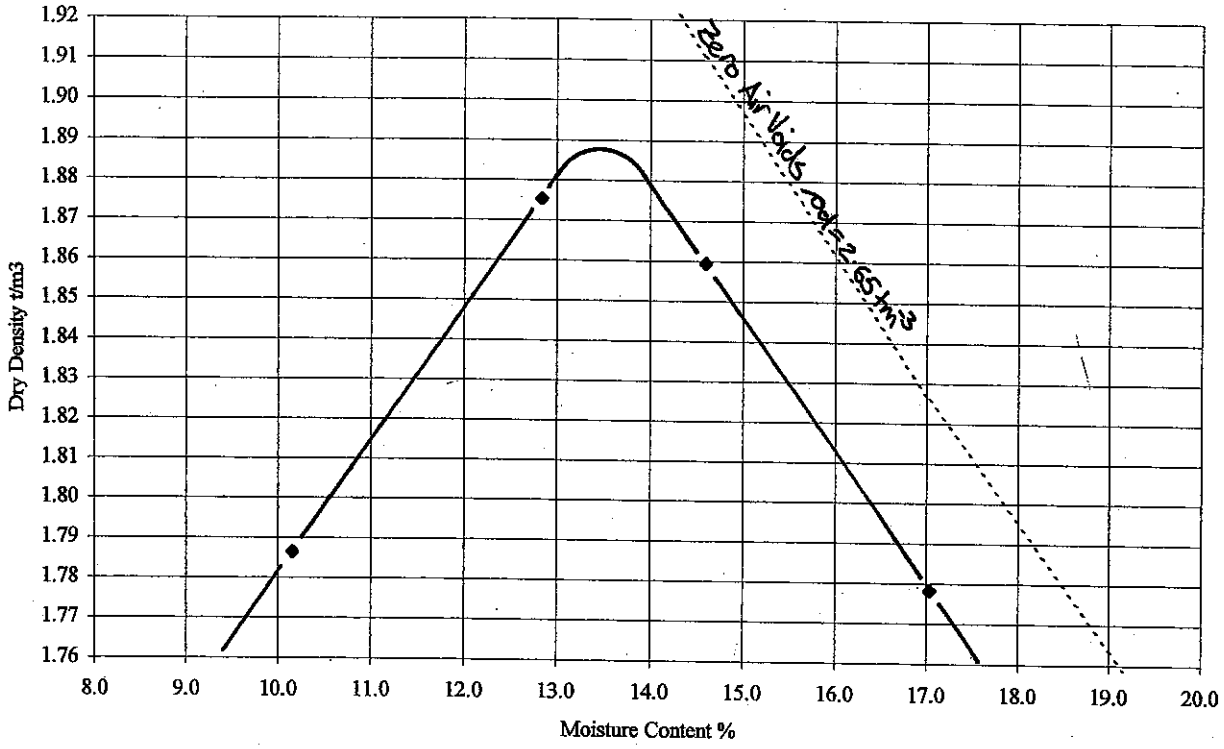
Title: STO Date: 19.03.03

D09530876

AUSTRALIAN SOIL TESTING PTY LTD. A.B.N. 79 003 493 623
19 Bermill Street, Rockdale, NSW, 2216 P.O. Box 2014, Rockdale D.C. NSW 2216
Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

Client: **Sinclair Knight Merz**
Address: PO Box 164 St Leonards NSW 1590
Project: **Swansea Open Cut.**

DRY DENSITY / MOISTURE RELATION TEST REPORT



Laboratory Number:	28470	
Sample Source:	OC19	
Sample Description:	CLAYEY GRAVELLY SAND: grey, fine to coarse sand, fine to medium gravel, low plasticity.	
Maximum Dry Density:	**1.89**	t/m^3
Optimum Moisture Content:	**13.5**	%
Oversize Material	19.0	mm
% Oversize		%
Date Tested	11.03.03	
Sampled by:	Client	
Compactive Effort	Standard	
Test Method	**AS1289.5.1.1 -1993**	
No of layers	3	
Blows per layer	25	
Mass of rammer	2.7	kg
Drop of rammer	300	mm

Comments

Form E04 excel Issue 2 Jan 1997 CWS

Signed: SWickers Name: Scott Wickers
Title: STO Date: 19.03.03

D09530876

AUSTRALIAN SOIL TESTING PTY LTD. A.B.N. 79 003 493 623

19 Bermill Street, Rockdale, NSW, 2216 P.O. Box 2014, Rockdale D.C. NSW 2216

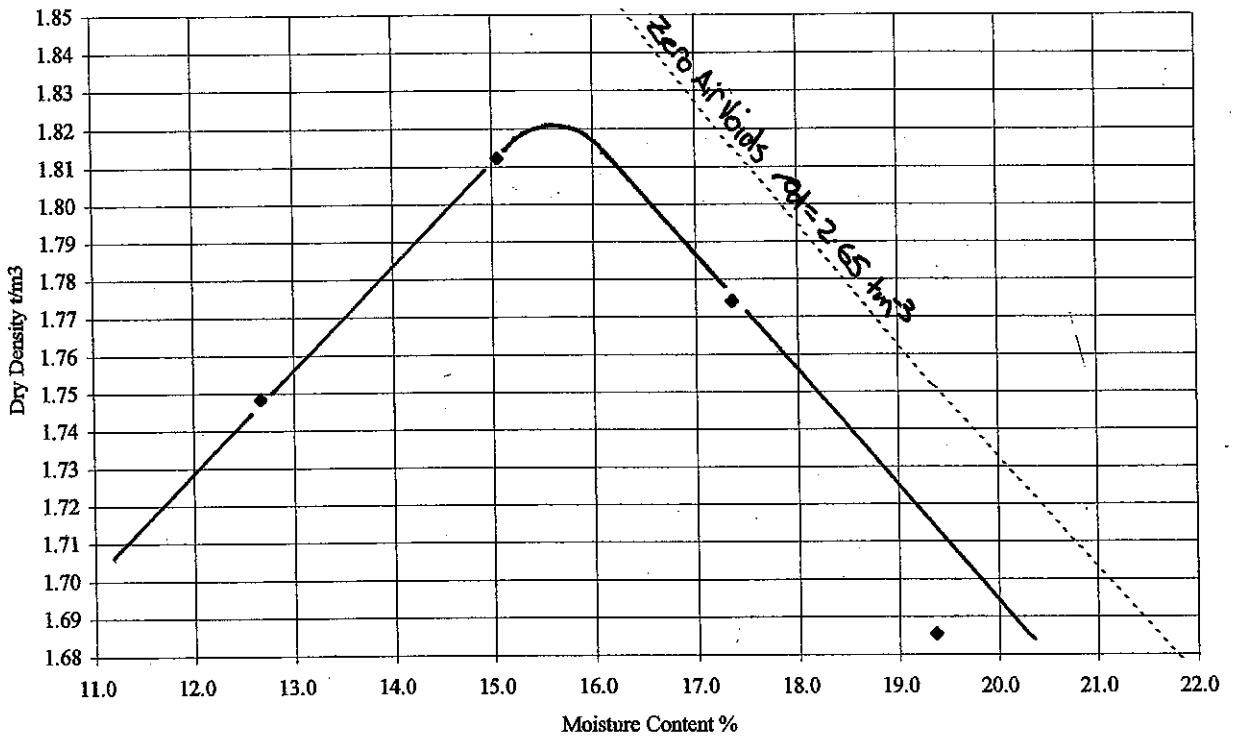
Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

Client: **Sinclair Knight Merz**

Address: PO Box 164 St Leonards NSW 1590

Project: **Swansea Open Cut.**

DRY DENSITY / MOISTURE RELATION TEST REPORT



Laboratory Number:	28471	
Sample Source:	OC20	
Sample Description:	GRAVELLY CLAYEY SAND: grey, fine to coarse sand, low plasticity, fine to medium gravel.	
Maximum Dry Density:	**1.82**	t/m^3
Optimum Moisture Content:	**15.5**	%
Oversize Material	19.0	mm
% Oversize		%
Date Tested	11.03.03	
Sampled by:	Client	
Compactive Effort	Standard	
Test Method	**AS1289.5.1.1 -1993**	
No of layers	3	
Blows per layer	25	
Mass of rammer	2.7	kg
Drop of rammer	300	mm

Comments

Form E04 excel Issue 2 Jan 1997 CWS

Signed: ..... Name: Scott Vickers

Title: STO Date: 19.03.03

D09530876

AUSTRALIAN SOIL TESTING PTY LTD. A.B.N. 79 003 493 623

19 Bermill Street, Rockdale, NSW, 2216 P.O. Box 2014, Rockdale D.C. NSW 2216

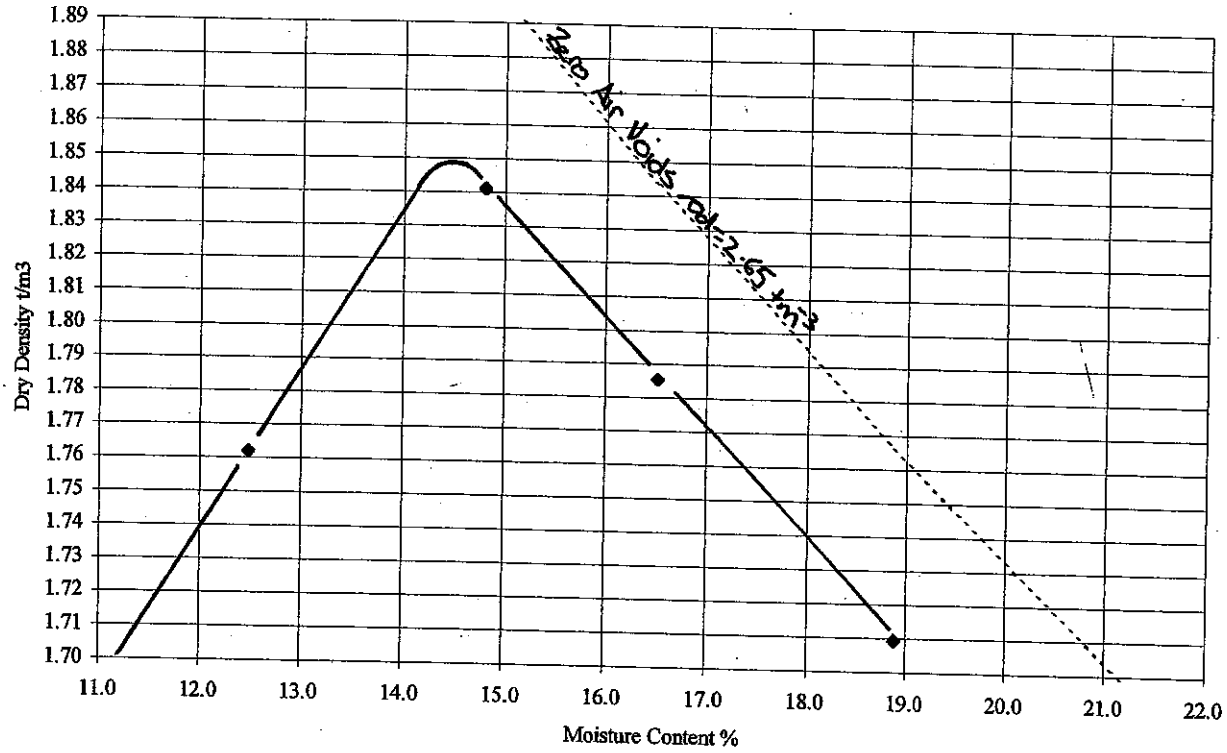
Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

Client: **Sinclair Knight Merz**

Address: PO Box 164 St Leonards NSW 1590

Project: **Swansea Open Cut.**

DRY DENSITY / MOISTURE RELATION TEST REPORT



Laboratory Number:	28472	
Sample Source:	OC23	
Sample Description:	SANDY CLAYEY GRAVELLY: grey, fine to medium gravel, low plasticity, fine to coarse sand.	
Maximum Dry Density:	**1.85**	t/m^3
Optimum Moisture Content:	**14.5**	%
Oversize Material	19.0	mm
% Oversize		%
Date Tested	11.03.03	
Sampled by:	Client	
Compactive Effort	Standard	
Test Method	**AS1289.5.1.1 -1993**	
No of layers	3	
Blows per layer	25	
Mass of rammer	2.7	kg
Drop of rammer	300	mm

Comments

Signed: S Vickers.

Title: STO

Form E04 excel Issue 2 Jan 1997 CWS

Name: Scott Vickers

Date: 19.03.03

D09530876

AUSTRALIAN SOIL TESTING PTY LTD. A.B.N. 79 003 493 623

19 Bermill Street, Rockdale, NSW, 2216 P.O. Box 2014, Rockdale D.C. NSW 2216

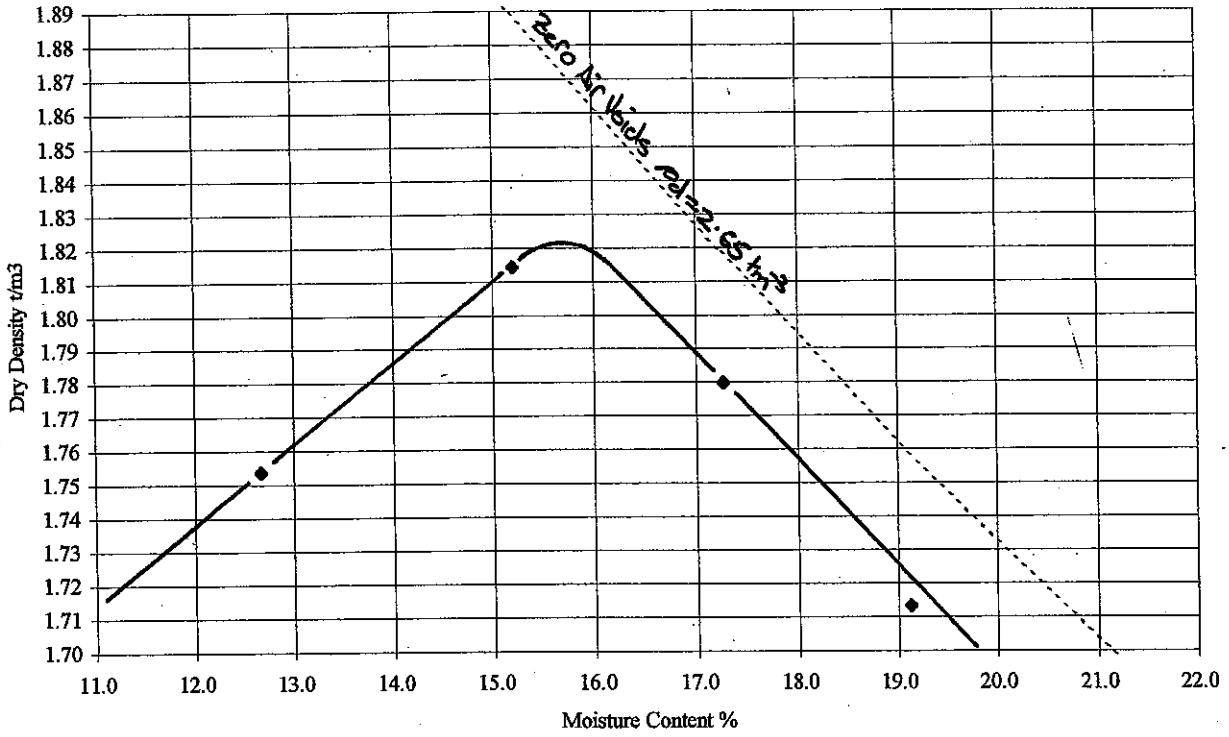
Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

Client: **Sinclair Knight Merz**

Address: PO Box 164 St Leonards NSW 1590

Project: **Swansea Open Cut.**

DRY DENSITY / MOISTURE RELATION TEST REPORT



Laboratory Number:	28473	
Sample Source:	OC24	
Sample Description:	GRAVELLY CLAYEY SAND: grey, fine to coarse sand, low plasticity, fine to medium gravel.	
Maximum Dry Density:	**1.82**	t/m^3
Optimum Moisture Content:	**15.5**	%
Oversize Material	19.0	mm
% Oversize	2.0	%
Date Tested	11.03.03	
Sampled by:	Client	
Compactive Effort	Standard	
Test Method	**AS1289.5.1.1 -1993**	
No of layers	3	
Blows per layer	25	
Mass of rammer	2.7	kg
Drop of rammer	300	mm

Comments

Form E04 excel Issue 2 Jan 1997 CWS

Signed: SNichols Name: Scott Nichols

Title: STO Date: 19.03.03

D09530876

AUSTRALIAN SOIL TESTING PTY LTD. A.B.N. 79 003 493 623

19 Bermill Street, Rockdale, NSW, 2216 P.O. Box 2014, Rockdale D.C. NSW 2216

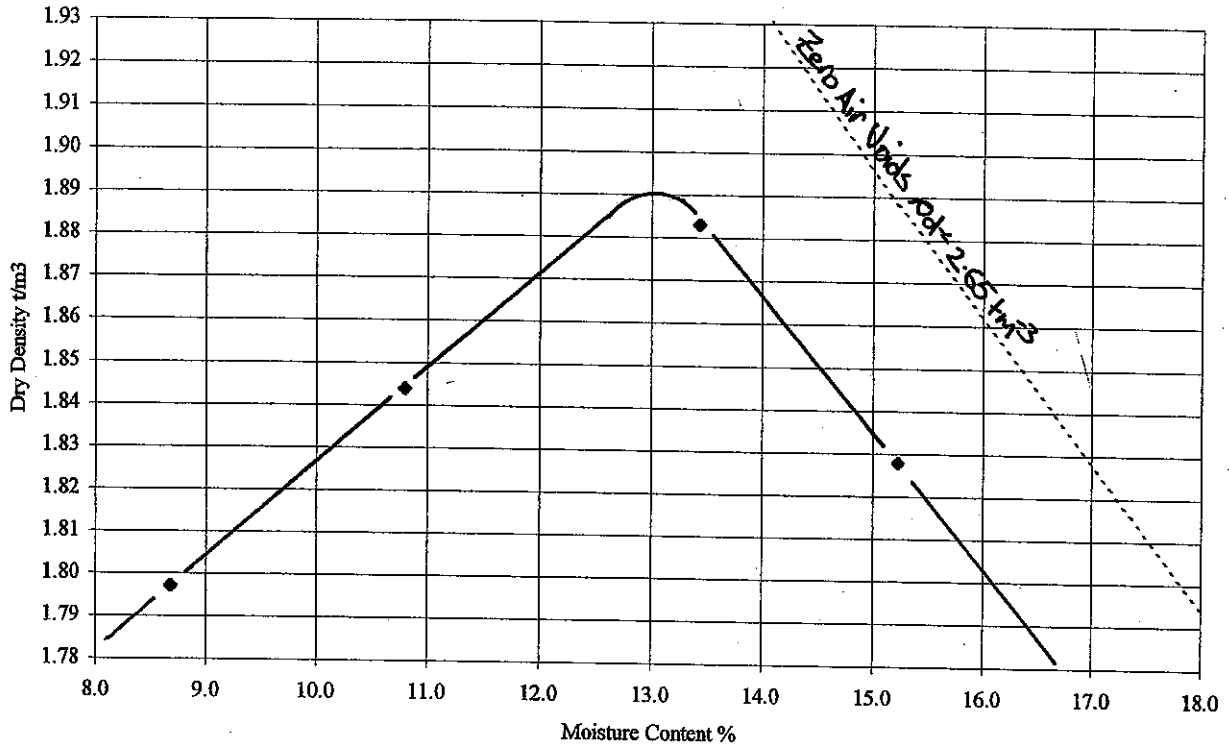
Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

Client: **Sinclair Knight Merz**

Address: PO Box 164 St Leonards NSW 1590

Project: **Swansea Open Cut.**

DRY DENSITY / MOISTURE RELATION TEST REPORT



Laboratory Number:	28474	
Sample Source:	OC25	
Sample Description:	GRAVELLY CLAYEY SAND: grey, fine to coarse sand, low plasticity, fine to medium gravel.	
Maximum Dry Density:	**1.89**	t/m^3
Optimum Moisture Content:	**13.0**	%
Oversize Material	19.0	mm
% Oversize		%
Date Tested	11.03.03	
Sampled by:	Client	
Compactive Effort	Standard	
Test Method	**AS1289.5.1.1 -1993**	
No of layers	3	
Blows per layer	25	
Mass of rammer	2.7	kg
Drop of rammer	300	mm

Comments

Signed: SWickes.

Title: STO

Name: Scott Vickers

Date: 19.03.03

D09530876

AUSTRALIAN SOIL TESTING PTY LTD. A.B.N. 79 003 493 623

19 Bermill Street, Rockdale, NSW, 2216 P.O. Box 2014, Rockdale D.C. NSW 2216

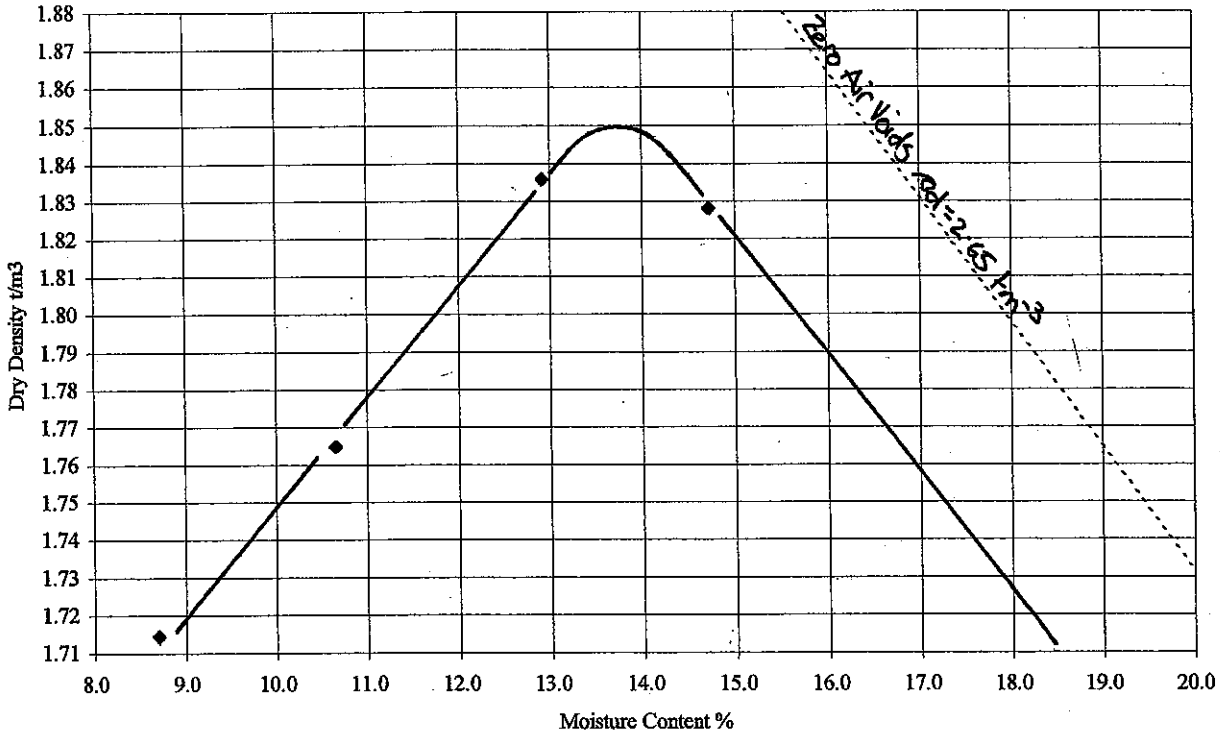
Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

Client: **Sinclair Knight Merz**

Address: PO Box 164 St Leonards NSW 1590

Project: **Swansea Open Cut.**

DRY DENSITY / MOISTURE RELATION TEST REPORT



Laboratory Number:	28475	
Sample Source:	OC26	
Sample Description:	CLAYEY GRAVELLY SAND: grey, fine to coarse sand, fine to medium gravel, low plasticity.	
Maximum Dry Density:	**1.85**	t/m^3
Optimum Moisture Content:	**13.5**	%
Oversize Material	19.0	mm
% Oversize	11.6	%
Date Tested	11.03.03	
Sampled by:	Client	
Compactive Effort	Standard	
Test Method	**AS1289.5.1.1 -1993**	
No of layers	3	
Blows per layer	25	
Mass of rammer	2.7	kg
Drop of rammer	300	mm

Comments

Form E04 excel Issue 2 Jan 1997 CWS

Signed: SVickers Name: Scott Vickers

Title: STO Date: 19.03.03

D09530876

AUSTRALIAN SOIL TESTING PTY LTD. A.B.N. 79 003 493 623

19 Bermill Street, Rockdale, NSW, 2216 P.O. Box 2014, Rockdale D.C. NSW 2216

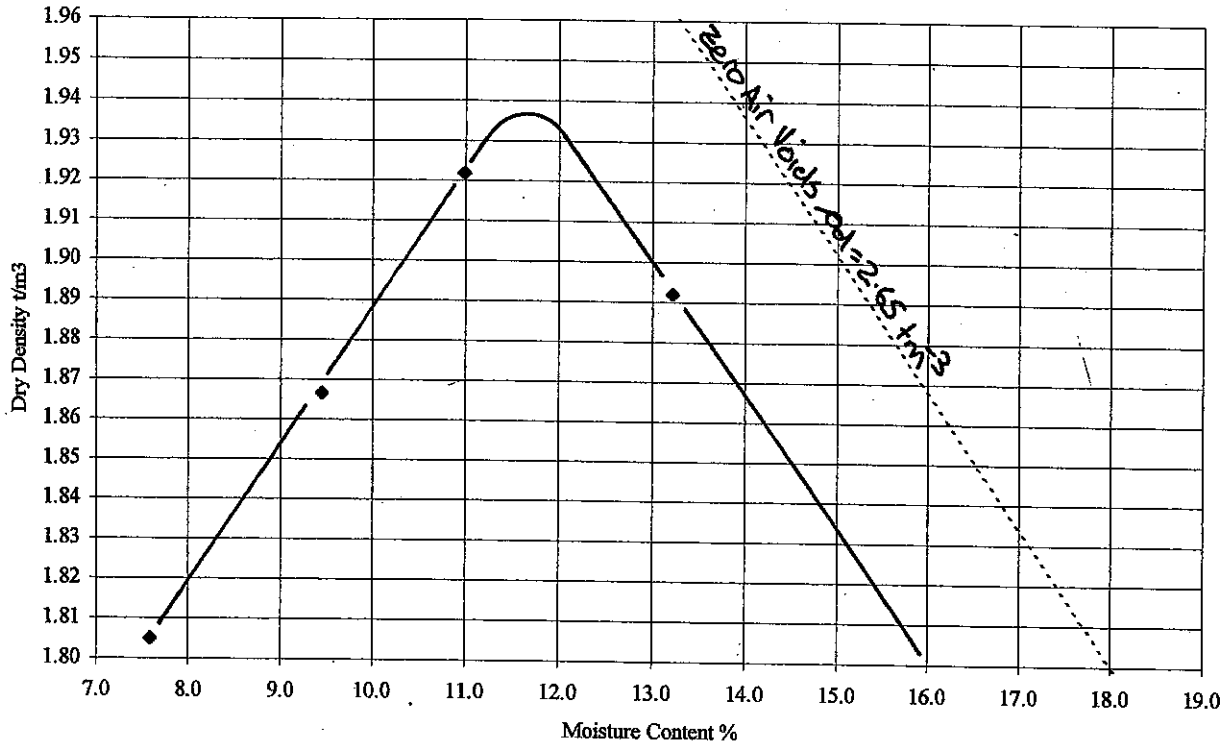
Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

Client: **Sinclair Knight Merz**

Address: PO Box 164 St Leonards NSW 1590

Project: **Swansea Open Cut.**

DRY DENSITY / MOISTURE RELATION TEST REPORT



Laboratory Number:	28476	
Sample Source:	OC28	
Sample Description:	CLAYEY GRAVELLY SAND: grey, fine to coarse sand, fine to medium gravel, low plasticity.	
Maximum Dry Density:	**1.94**	t/m^3
Optimum Moisture Content:	**11.5**	%
Oversize Material	19.0	mm
% Oversize	12.2	%
Date Tested	11.03.03	
Sampled by:	Client	
Compactive Effort	Standard	
Test Method	**AS1289.5.1.1 -1993**	
No of layers	3	
Blows per layer	25	
Mass of rammer	2.7	kg
Drop of rammer	300	mm

Comments

Signed: Vickers

Title: STO

Name: Scott Vickers

Date: 19.03.03

D09530876

AUSTRALIAN SOIL TESTING PTY LTD. A.B.N. 79 003 493 623

19 Bermill Street, Rockdale, NSW, 2216 P.O. Box 2014, Rockdale D.C. NSW 2216

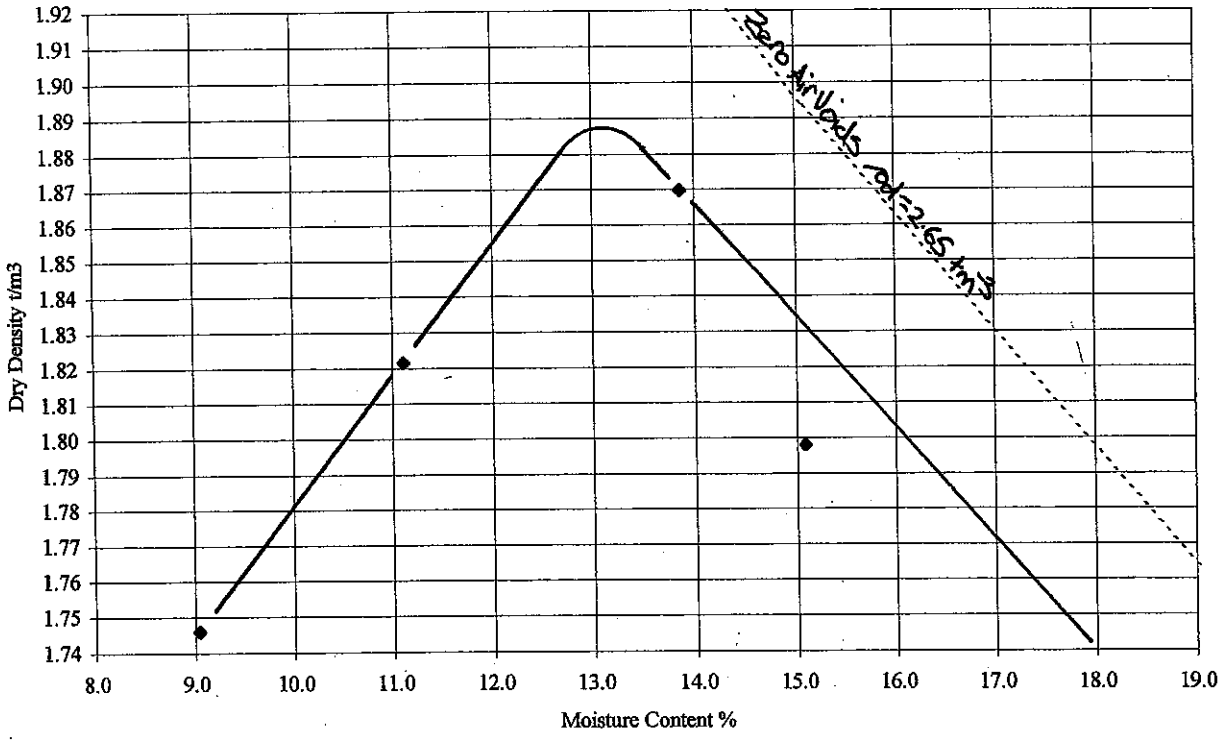
Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

Client: **Sinclair Knight Merz**

Address: PO Box 164 St Leonards NSW 1590

Project: **Swansea Open Cut.**

DRY DENSITY / MOISTURE RELATION TEST REPORT



Laboratory Number:	28488	
Sample Source:	OC33	
Sample Description:	CLAYEY GRAVELLY SAND: grey, fine to coarse sand, fine to medium gravel, low plasticity.	
Maximum Dry Density:	**1.89**	t/m^3
Optimum Moisture Content:	**13.0**	%
Oversize Material	19.0	mm
% Oversize	2.0	%
Date Tested	11.03.03	
Sampled by:	Client	
Compactive Effort	Standard	
Test Method	**AS1289.5.1.1 -1993**	
No of layers	3	
Blows per layer	25	
Mass of rammer	2.7	kg
Drop of rammer	300	mm

Comments

Form E04 excel Issue 2 Jan 1997 CWS

Signed: ..... Name: Scott Vickers

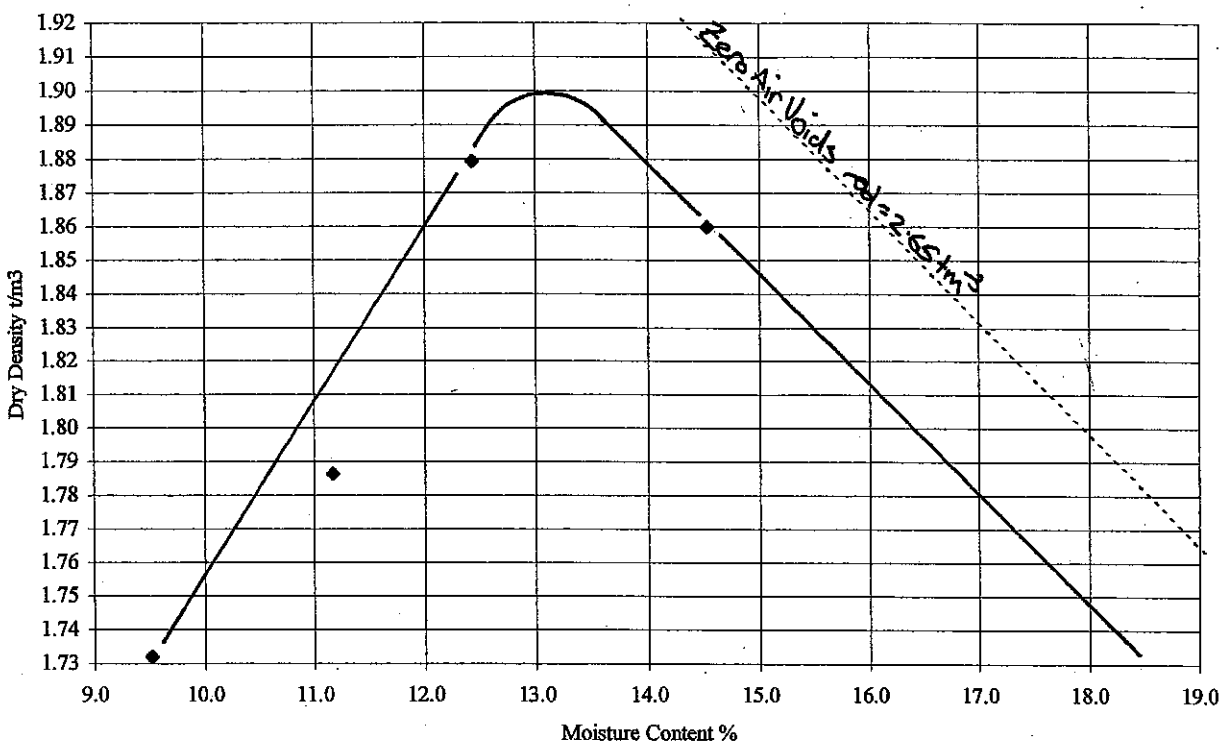
Title: STO Date: 19.03.03

D09530876

AUSTRALIAN SOIL TESTING PTY LTD. A.B.N. 79 003 493 623
19 Bermill Street, Rockdale, NSW, 2216 P.O. Box 2014, Rockdale D.C. NSW 2216
Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

Client: **Sinclair Knight Merz**
Address: PO Box 164 St Leonards NSW 1590
Project: **Swansea Open Cut.**

DRY DENSITY / MOISTURE RELATION TEST REPORT



Laboratory Number:	28489	
Sample Source:	OC35	
Sample Description:	CLAYEY GRAVELLY SAND: grey, fine to coarse sand, fine to medium gravel, low plasticity.	
Maximum Dry Density:	**1.90**	t/m^3
Optimum Moisture Content:	**13.0**	%
Oversize Material	19.0	mm
% Oversize	2.0	%
Date Tested	11.03.03	
Sampled by:	Client	
Compactive Effort	Standard	
Test Method	**AS1289.5.1.1 -1993**	
No of layers	3	
Blows per layer	25	
Mass of rammer	2.7	kg
Drop of rammer	300	mm

Comments

Form E04 excel Issue 2 Jan 1997 CWS

Signed: S.Vickers. Name: Scott Vickers
Title: STO Date: 19.03.03

D09530876

AUSTRALIAN SOIL TESTING PTY LTD. A.B.N. 79 003 493 623

19 Bermill Street, Rockdale, NSW, 2216 P.O. Box 2014, Rockdale D.C. NSW 2216

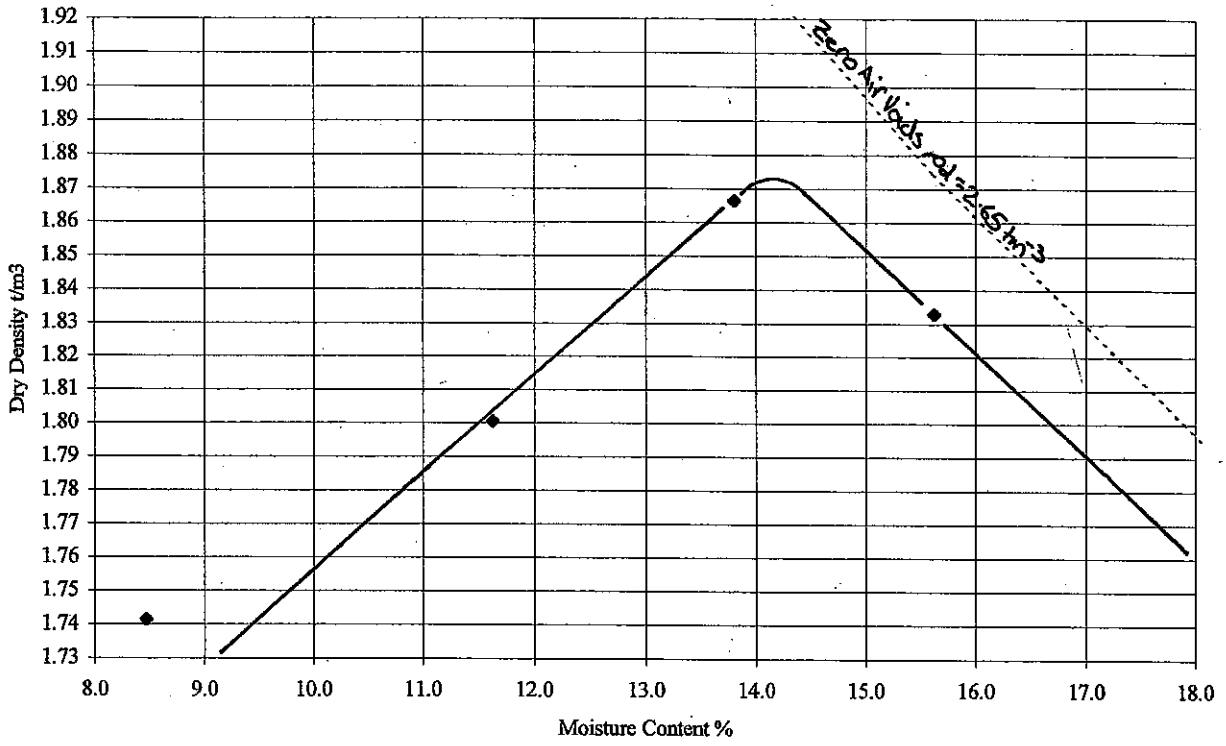
Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

Client: **Sinclair Knight Merz**

Address: PO Box 164 St Leonards NSW 1590

Project: **Swansea Open Cut.**

DRY DENSITY / MOISTURE RELATION TEST REPORT



Laboratory Number:	28490	
Sample Source:	OC38	
Sample Description:	CLAYEY GRAVELLY SAND: grey, fine to coarse sand, fine to medium gravel, low plasticity.	
Maximum Dry Density:	**1.87**	t/m^3
Optimum Moisture Content:	**14.0**	%
Oversize Material	19.0	mm
% Oversize	1.5	%
Date Tested	11.03.03	
Sampled by:	Client	
Compactive Effort	Standard	
Test Method	**AS1289.5.1.1 -1993**	
No of layers	3	
Blows per layer	25	
Mass of rammer	2.7	kg
Drop of rammer	300	mm

Comments

Form E04 excel Issue 2 Jan 1997 CWS

Signed: S Vickers. Name: Scott Vickers

Title: STO Date: 19.03.03

D09530876

AUSTRALIAN SOIL TESTING PTY LTD. A.B.N. 79 003 493 623
19 Bermill Street, Rockdale, NSW, 2216 P.O. Box 2014, Rockdale D.C. NSW 2216
Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

CALIFORNIA BEARING RATIO TEST REPORT

CLIENT: **Sinclair Knight Merz**
PO Box 164 St Leonards NSW 1590

PROJECT: **Swansea Open Cut.**

SAMPLE SOURCE	OC19	
SAMPLE DESCRIPTION	CLAYEY GRAVELLY SAND: grey, fine to coarse sand, fine to medium gravel, low plasticity.	
LABORATORY NUMBER	28470	
	SOAKED	
CBR VALUE @ 2.5mm	8	
@ 5.0mm	10	
SAMPLE DATA		
Compaction Specification	100% of MDD at 100% of OMC	
Maximum Dry Density (MDD)	1.89	t/m^3
Optimum Moisture Content (OMC)	13.5	%
Surcharge	4.5	kg
No of days soaked	4	
SAMPLE PREPARATION		
TEST DATA		
Dry Density - before soaking	1.88	t/m^3
- after soaking	1.87	t/m^3
Density Ratio - before soaking	99.4	%
- after soaking	99.2	%
Moisture Content - before soaking	13.2	%
(before test) - after soaking	14.3	%
Moisture Content - top 30mm	14.8	%
(after test) - whole sample	13.8	%
Swell after soaking	0.2	%
COMPACTIVE EFFORT	Standard	
Number of layers	3	
Blows per layer	53	
Mass of rammer	2.7	kg
Drop of rammer	300	mm

COMMENTS
% mass retained on 19 mm sieve: 0

Sampled By: Client
Date Tested: 17.03.03

Tested in accordance with AS1289.6.1.1-1998 Determination of the California Bearing Ratio of a soil - Standard Laboratory Method for a remoulded specimen.
Form E03 excel issue 2 August 1998 CWS

Signed: SWickers Name: Scott Vickers
Title: STO Date: 19.03.03

D09530876

AUSTRALIAN SOIL TESTING PTY LTD. A.B.N. 79 003 493 623
19 Bermill Street, Rockdale, NSW, 2216 P.O. Box 2014, Rockdale D.C. NSW 2216
Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

CALIFORNIA BEARING RATIO TEST REPORT

CLIENT: **Sinclair Knight Merz**
PO Box 164 St Leonards NSW 1590

PROJECT: **Swansea Open Cut.**

SAMPLE SOURCE	OC20	
SAMPLE DESCRIPTION	GRAVELLY CLAYEY SAND: grey, fine to coarse sand, low plasticity, fine to medium gravel.	
LABORATORY NUMBER	28471	
	SOAKED	
CBR VALUE @ 2.5mm	10	
@ 5.0mm	11	
SAMPLE DATA		
Compaction Specification	100% of MDD at 100% of OMC	
Maximum Dry Density (MDD)	1.82	t/m^3
Optimum Moisture Content (OMC)	15.5	%
Surcharge	4.5	kg
No of days soaked	4	
SAMPLE PREPARATION		
TEST DATA		
Dry Density - before soaking	1.82	t/m^3
- after soaking	1.81	t/m^3
Density Ratio - before soaking	99.8	%
- after soaking	99.4	%
Moisture Content - before soaking	15.3	%
(before test) - after soaking	16.8	%
Moisture Content - top 30mm	17.2	%
(after test) - whole sample	15.9	%
Swell after soaking	0.4	%
COMPACTIVE EFFORT	Standard	
Number of layers	3	
Blows per layer	53	
Mass of rammer	2.7	kg
Drop of rammer	300	mm

COMMENTS
% mass retained on 19 mm sieve: 0

Sampled By: Client
Date Tested: 17.03.03

Tested in accordance with AS1289.6.1.1-1998 Determination of the California Bearing Ratio of a soil - Standard Laboratory Method for a remoulded specimen.
Form E03 excel issue 2 August 1998 CWS

Signed: SVickers. Name: Scott Vickers
Title: STO Date: 19.03.03

D09530876

AUSTRALIAN SOIL TESTING PTY LTD. A.B.N. 79 003 493 623
19 Bermill Street, Rockdale, NSW, 2216 P.O. Box 2014, Rockdale D.C. NSW 2216
Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

CALIFORNIA BEARING RATIO TEST REPORT

CLIENT: **Sinclair Knight Merz**
PO Box 164 St Leonards NSW 1590

PROJECT: **Swansea Open Cut.**

SAMPLE SOURCE	OC23	
SAMPLE DESCRIPTION	SANDY CLAYEY GRAVELLY: grey, fine to medium gravel, low plasticity, fine to coarse sand.	
LABORATORY NUMBER	28472	
	SOAKED	
CBR VALUE @ 2.5mm	9	
@ 5.0mm	10	
SAMPLE DATA		
Compaction Specification	100% of MDD at 100% of OMC	
Maximum Dry Density (MDD)	1.85	t/m^3
Optimum Moisture Content (OMC)	14.5	%
Surcharge	4.5	kg
No of days soaked	4	
SAMPLE PREPARATION		
TEST DATA		
Dry Density - before soaking	1.85	t/m^3
- after soaking	1.85	t/m^3
Density Ratio - before soaking	100.1	%
- after soaking	100.1	%
Moisture Content - before soaking	14.4	%
(before test) - after soaking	16.4	%
Moisture Content - top 30mm	17.5	%
(after test) - whole sample	15.9	%
Swell after soaking	0.0	%
COMPACTIVE EFFORT	Standard	
Number of layers	3	
Blows per layer	53	
Mass of rammer	2.7	kg
Drop of rammer	300	mm

COMMENTS
% mass retained on 19 mm sieve: 0

Sampled By: Client
Date Tested: 17.03.03

Tested in accordance with AS1289.6.1.1-1998 Determination of the California Bearing Ratio of a soil - Standard Laboratory Method for a remoulded specimen.
Form E03 excel issue 2 August 1998 CWS

Signed: S Vickers
Title: STO
Name: Scott Vickers
Date: 19.03.03

D09530876

AUSTRALIAN SOIL TESTING PTY LTD. A.B.N. 79 003 493 623

19 Bermill Street, Rockdale, NSW, 2216 P.O. Box 2014, Rockdale D.C. NSW 2216

Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

CALIFORNIA BEARING RATIO TEST REPORT

CLIENT: **Sinclair Knight Merz**
PO Box 164 St Leonards NSW 1590

PROJECT: **Swansea Open Cut.**

SAMPLE SOURCE	OC24	
SAMPLE DESCRIPTION	GRAVELLY CLAYEY SAND: grey, fine to coarse sand, low plasticity, fine to medium gravel.	
LABORATORY NUMBER	28473	
	SOAKED	
CBR VALUE @ 2.5mm	9	
@ 5.0mm	9	
SAMPLE DATA		
Compaction Specification	100% of MDD at 100% of OMC	
Maximum Dry Density (MDD)	1.82	t/m^3
Optimum Moisture Content (OMC)	15.5	%
Surcharge	4.5	kg
No of days soaked	4	
SAMPLE PREPARATION		
TEST DATA		
Dry Density - before soaking	1.84	t/m^3
- after soaking	1.82	t/m^3
Density Ratio - before soaking	101.0	%
- after soaking	100.2	%
Moisture Content - before soaking	15.4	%
(before test) - after soaking	17.3	%
Moisture Content - top 30mm	18.1	%
(after test) - whole sample	21.1	%
Swell after soaking	0.7	%
COMPACTIVE EFFORT	Standard	
Number of layers	3	
Blows per layer	53	
Mass of rammer	2.7	kg
Drop of rammer	300	mm

COMMENTS

% mass retained on 19 mm sieve: 2.0

Sampled By: Client
Date Tested: 17.03.03

Tested in accordance with AS1289.6.1.1-1998 Determination of the California Bearing Ratio of a soil - Standard Laboratory Method for a remoulded specimen.

Form E03 excel issue 2 August 1998 CWS

Signed: S Vickers. Name: Scott Vickers.

Title: STO Date: 19.03.03

D09530876

AUSTRALIAN SOIL TESTING PTY LTD. A.B.N. 79 003 493 623
19 Bermill Street, Rockdale, NSW, 2216 P.O. Box 2014, Rockdale D.C. NSW 2216
Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

CALIFORNIA BEARING RATIO TEST REPORT

CLIENT: **Sinclair Knight Merz**
PO Box 164 St Leonards NSW 1590

PROJECT: **Swansea Open Cut.**

SAMPLE SOURCE	OC25	
SAMPLE DESCRIPTION	GRAVELLY CLAYEY SAND: grey, fine to coarse sand, low plasticity, fine to medium gravel.	
LABORATORY NUMBER	28474	
	SOAKED	
CBR VALUE @ 2.5mm	11	
@ 5.0mm	13	
SAMPLE DATA		
Compaction Specification	100% of MDD at 100% of OMC	
Maximum Dry Density (MDD)	1.89	t/m^3
Optimum Moisture Content (OMC)	13.0	%
Surcharge	4.5	kg
No of days soaked	4	
SAMPLE PREPARATION		
TEST DATA		
Dry Density - before soaking	1.90	t/m^3
- after soaking	1.89	t/m^3
Density Ratio - before soaking	100.4	%
- after soaking	100.1	%
Moisture Content - before soaking	13.4	%
(before test) - after soaking	14.7	%
Moisture Content - top 30mm	15.0	%
(after test) - whole sample	13.9	%
Swell after soaking	0.3	%
COMPACTIVE EFFORT	Standard	
Number of layers	3	
Blows per layer	53	
Mass of rammer	2.7	kg
Drop of rammer	300	mm

COMMENTS
% mass retained on 19 mm sieve: 2.0

Sampled By: Client
Date Tested: 17.03.03

Tested in accordance with AS1289.6.1.1-1998 Determination of the California Bearing Ratio of a soil - Standard Laboratory Method for a remoulded specimen.
Form E03 excel issue 2 August 1998 CWS

Signed: S Vickers. Name: Scott Vickers
Title: STO Date: 19.03.03

APPENDIX

D

FORMERLY DISTURBED LAND & HISTORICAL AEIRALS

D09530876

D09530876

D09530876

D09530876

D09530876

D09530876

D09530876


2017
nearmap

Preliminary Site Investigation

Old Pacific Highway & Scenic Drive, Pinny Beach

82220067-004.1

Prepared for

Wakfield Ashurst Developments Pty Ltd and Northern Managers & Construction Pty Ltd

20 May 2020

Cardno

Contact Information

Cardno (NSW/ACT) Pty Ltd
ABN 95 001 145 035

Unit 1
10 Denney Street
Broadmeadow NSW 2292
Australia

Phone +61 2 4965 4555
Fax +61 2 4965 4666

Document Information

Prepared for	Wakefield Ashurst Developments Pty Ltd and Northern Mangers & Construction Pty Ltd
Project Name	Old Pacific Highway & Scenic Drive, Pinny Beach
File Reference	82220004
Job Reference	82220067-004.1
Date	20 May 2020
Version Number	1

Author(s):

Dimce Stojanovski
Senior Scientist

Effective Date 20/05/2020

Approved By:

Bob Campbell

Senior Environmental Scientist

Date Approved 20/05/2020

Document History

Version	Effective Date	Description of Revision	Prepared by	Reviewed by
0	14/05/2020	Initial Issue	DS	BC
1	20/05/2020	Amendments	DS	BC

Table of Contents

Appendices

Tables

1 Introduction

1.1 Background

Cardno (NSW/ACT) Pty Ltd (Cardno) were engaged by Wakefield Ltd (the Client), to prepare a Preliminary Site Investigation (PSI) report for a section of Old Pacific Highway (approx. 2 km) and Scenic Drive (0.5km), Pinny Beach. It is understood that the relevant section of Old Pacific Highway will form part of the overall proposed Mawson residential development. The Site and associated area of assessment was limited to the road reserve / corridor and are shown on **Figure 1**, attached in **Appendix A.**

Based on plans provided by the Client (see **Appendix A**), the proposed development will comprise:

- Western portion of Old Pacific Highway will form part of internal subdivision pavements; and
- Central and eastern portion of Old Pacific Highway will form part of the commercial allotment and residential allotments.

The PSI comprised a site inspection / transect walkover, desktop study of available historical data including a review of historical aerial photographs and NSW EPA database.

The assessment was undertaken with reference to NSW EPA “Guidelines for Consultants Reporting on Contaminated Sites” [1] and National Environment Protection Measure (NEPM) for the Assessment of Site Contamination, 1999 [2].

1.2 Purpose and Objectives

The purpose of this PSI is to provide the Client with preliminary advice on the contamination status of the site and subsequent implications for the intended use. The PSI reviews current and historical activities undertaken at the site and provides a preliminary environmental assessment of the potential for soil and/or groundwater contamination to be present on the site.

The objectives of the PSI are to:

- To the extent practicable, identify the potential for past or present activities on; and surrounding the site, to have impacted soil or groundwater at the site.
- Identify potential areas and contaminants of concern at the site.
- Identify potential receptors of concern and assess the potential for the protected beneficial uses of the land to be impacted due to contamination.
- To make a preliminary assessment of whether contamination is likely to affect the future use or development of the site.
- Assess the requirement, if any, for further environmental investigation to assess or make the site suitable for the proposed use.

1.3 Scope

In order to meet the objectives of the PSI, Cardno carried out the following tasks in order to satisfy the purpose and objectives of this assessment.

Defined the Site, Features & Surrounds:

- Obtained the property title description from a Land-data Property Report.
- Defined the site boundaries based on title information, available data and established a site base plan.
- Identified the site features.
- Defined the topography, surface water drainage of the site and its proximity to the nearest surface water body.

- Identified the location of nearby sensitive environments and receptors such as residential, child-care and primary schools, wetlands, streams or rivers.
- Identified the zoning of the site under the local Planning Scheme.

Hydrogeology & Groundwater Resource Use

- Ascertained the actual utilisation of groundwater at and near the site through a search of the NSW Groundwater Database at NSW Office of Water website.

Review of Public Records on Site History

Publicly available documents relevant to the site (to the extent readily available) included:

- Historical and current maps of the area.
- Selected historical aerial photos available from the Department of Lands.
- Undertook a review of the NSW EPA Contaminated Lands Register to identify nearby contaminated sites reported to the NSW EPA under section 60 of the CLM (1997)

Site Inspection & Surrounds

- Confirmed the site features and identified any visible evidence of fuel storage tanks (above or belowground) and other infrastructure with potential to act as a source of soil and/or groundwater.
- Confirmed the soil type and looked for evidence of site cutting and filling.
- Assessed the surrounding area (to a radius of approximately 200 m) for potential sources of contamination of soil or groundwater at the site.
- Transect walkover.

Reporting

- Prepared this Preliminary Site Investigation (PSI) report to document the assessment activities and results to including findings and recommendations relevant to the objectives of the assessment.
- Developed a Conceptual Site Model (CSM) for the site, identifying complete and potential pathways between known and potential sources and receptors. This CSM is incorporated in this investigation report.

2 Site Inspection and Surrounding Environment

2.1 Site Identification

The subject Site details are presented in **Table 2.1** below. For Site location, refer to **Figure 1** in **Appendix A.**

Table 2-1 Site Details

Site Address	Old Pacific Highway and Scenic Drive, Pinny Beach
Site Area	Old Pacific Highway (approx. 2.0 km) Scenic Drive (approx. 0.5 km)
Local Government Area	Lake Macquarie City Council
Relative Zoning	R1 (Old Pacific Highway)

2.2 Site Use and Features

A Site inspection was undertaken by a Geotechnical Engineer from Cardno on 11th May 2020 in order to identify and map salient features of the site and the surrounding area. Site features and observations are detailed in **Table 2-2** below.

Table 2-2 Site features and Observations

Item	Observations
Site use	▪ Road Reserve (Old Pacific Highway – Redundant)
Weather condition	▪ Sunny
Site slope and drainage features	▪ Site slopes fall to the south, south-east ▪ The road alignment generally traverses north-south ▪ Drainage is expected to comprise of surficial runoff, following the existing contours of Site and road drainage network.
Nearby water bodies	▪ An unnamed creeks / drainage network traversing east-west, south of Site.
Site surface coverings	▪ The alignment comprised of bitumen wearing course. ▪ Road reserve comprised of overgrown / dense grass cover and mature trees.
Surface soils	▪ Surface soils within the road reserve appear to be predominately natural sandy topsoil materials. ▪ Site won fill during cut / fill earthworks of Old Pacific Highway ▪ Exposed weathered bedrock within cut sections.
Site cut and fill	▪ Cut and fill operations are noted which formed the alignment of Old Pacific Highway & Scenic Drive
Buildings	▪ Nil
Potential asbestos in building materials	▪ Refer to transect walkover
Manufacturing, industrial or chemical processes and infrastructure	▪ Not observed
Fuel storage tanks (USTs/ASTs)	▪ Not observed
Dangerous goods	▪ Not observed

Item	Observations
Presence of stockpiles, fly tipping or anthropogenic materials	▪ Refer to transect walkover
Liquid waste disposal features	▪ Refer to transect walkover
Evidence of previous site contamination investigations	▪ Not observed
Evidence of land contamination (staining or odours)	▪ Refer to transect walkover
Evidence of groundwater contamination	▪ Not observed.
Groundwater use	▪ Not observed.
Vegetation	▪ Dense grass cover and mature tree within the road reserve
Site fencing	▪ Fenced and gated at both entries of Old Pacific Highway

2.3 Transect Walkover

During the Site inspection, Cardno also undertook a transect assessment to note areas of “fly tipping” and potential areas of concern. The findings of the transect walkover is present in **Table 2-3** . Photographs and figures from the transect walkover are present in **Appendix B** It must be appreciated that the assessment was limited to the road corridor and Site observations were limited due to the presence of overgrown vegetation.

Table 2-3 Transect Assessment – Old Pacific Highway

Chainage	Observations
CH 0 – CH 400	▪ Concrete barricades ▪ Building refuse – ceramics, bricks, concrete, steel, timber, ▪ Concrete pipe and PVC ▪ Green waste ▪ Fallen trees and branches ▪ Domestic waste – chair, plastics, white goods, electrical appliances etc ▪ Potential Asbestos Containing fragments (ACM), CH 20, Photo Area A2 & CH 165, Photo Area B3 ▪ Fill stockpiles (soil and rock) ▪ Fill mounds ▪ Tyres and car bumper
CH 400 – CH 1000	▪ Building refuse – bricks, iron sheeting, concrete, steel, glass & plastics. ▪ Potential ACM (CH 525, Photo Area F1) ▪ Car plastics / parts ▪ Soil and concrete stockpile ▪ Domestic refuse – white goods, cushions, plastics, chair & bed ▪ Tyres ▪ Evidence of burnt car remains and melted plastics (CH 820) ▪ Remanent guard rail around bend (CH 800-950) ▪ Potential ACM, plastics, minor white goods (CH950-1000, Photo Area J1)

Chainage	Observations
CH 1000 – CH 1500	▪ Domestic waste – pillows, plastics ▪ Access track (CH 1020) ▪ Minor green waste ▪ Access tracks (CH 1180 & CH 1340) ▪ Minor rubber and tyres ▪ Evidence of previous barriers removed / destroyed and in piles (CH 1400 – 1500) ▪ Evidence of burnt plastics & rubber (CH 1400 – 1500)
CH 1500 – CH 2000	▪ Stockpiles – green waste ▪ Steel sheeting, car bumpers, rubber and glass ▪ Building refuse – bricks, concrete and ceramics ▪ Evidence of burnt car remains – burnt plastics, motor part in verge (CH 1650) ▪ Access track (approx. CH 1910) ▪ Building refuse – timber, plastics, carpet, white goods, ceramics and potential ACM (approx CH 2000, Photo Area S1)
Section of Scenic Drive (CH 0 – 500)	▪ Minor fly tipping – plastics, concrete and domestic refuse. ▪ Remnants of burnt car remains. ▪ Remnants of former concrete foot path.

2.4 Surrounding Environment and Land uses

The site is located within an area of remnant bushland and former open-cut and underground coal mines. Land uses around the site are detailed in the **Table 2-4** below.

Table 2-4 Surrounding Land Use

Direction	Land Use or Activity
North	▪ Northern Portion of Swansea opencut coal mine site ▪ Bushland ▪ Further north, residential development
West	▪ Pacific Highway ▪ Bushland ▪ Further west, residential development
East	▪ Eastern portion of Swansea open cut coalmine site ▪ Bushland ▪ Further east, residential development
South	▪ Former landfill area ▪ Former clay pits ▪ bushland

3 Published Data

3.1 Regional Geology

Reference to the Gosford-Lake Macquarie 1:100,000 geological map [3] indicates that the site is situated within two distinct geological formations:

- The Moon Island Beach Subgroup of the Newcastle Coal Measures, comprising Late Permian age deposits of conglomerate, tuff, siltstone, claystone and black coal and soils derived from the weathering of these rock types.
- The Munmorah Conglomerate of the Narrabeen group, comprising Early Triassic aged deposits of conglomerate, pebbly sandstone and shale and soils derived from the weathering of these rock types.

3.2 Acid Sulfate Soils

Review of the Department of Land and Water Conservation Acid Sulfate Soil Risk Map – Swansea Edition 2 [4] indicates that the Site is situated within area of no known occurrence.

3.3 Hydrogeology

A search of the NSW Groundwater Database from Department of Primary Industries – Office of Water NSW. Found groundwater bores were located within a 2km radius of the site. The searches are detailed in the table below.

Table 3-1 Registered Groundwater Bore Search

Bore ID	Distance from the Site	Intended Purpose	Latitude[1]	Longitude	Depth of bore (mbgs[2])	Standing Water level (mbgs)	Water Bearing Zones (mbgs)
GW065867	800m west	Ground Water Exploration	33° 6' 45.3" S	151° 37' 12.1" E	19.10	-	-
GW065866	800m north	Ground Water Exploration	33° 6' 22.3" S	151° 37' 48.1" E	27.50	6.00	11.00-13.00 20.00-27.00
GW065865	650m west	Ground Water Exploration	33° 7' 4.3" S	151° 37' 23.1" E	34.00	14.40	29.00-32.00
GW065864	1km west	Ground Water Exploration	33° 6' 57.3" S	151° 36' 58.1" E	15.0	-	-
GW065863	850m west	Ground Water Exploration	33° 6' 43.3" S	151° 37' 0.1" E	9.80	9.20	8.00-9.40
GW065861	1km west	Ground Water Exploration	33° 6' 43.3" S	151° 37' 0.1" E	18.20	-	-
GW065860	900m west	Ground Water Exploration	33° 6' 43.3" S	151° 37' 0.1" E	10.10	6.50	8.40-9.90

[1] Longitude and latitude for unknown bores inferred from Google Earth.
[2] mbgs – metres below ground surface

3.4 EPA Records Search

3.4.1 Contaminated Land Record of Notices

The Contaminated Land Record of Notices is maintained by the Office of Environment and Heritage (OEH) in accordance with Part 5 of the Contaminated Land Management (CLM) Act 1997 and contains regulatory notices issued by the Environment Protection Authority (EPA) in relation to contaminated sites. A search of NSW EPA Record of Notices revealed no notices listed within 1 km of the site. Searches are contained in **Appendix C**.

3.4.2 PoEO Public Register

The PoEO Public Register under Section 308 of the Protection of the Environment Operations (PoEO) Act 1997 contains Environment Protection Licences (EPLs), applications and notices issued by the EPA.

The Public Register was searched on 13 May 2020 to identify any issues of relevance to the Site (within approx. 1km). This is summarised in the table below and search results attached in **Appendix C**

Table 3-2 Former Licenced Activities under the PoEO Act 1997, now revoked or surrendered

EPL	Organisation	Status	Location	Date Issued	Activity	Distance
13424	Lake Macquarie City Council	Surrendered	Swansea Quarry 465 Pacific Hwy Swansea NSW	17 Nov 2011	Waste storage	Approx. 750m north of subject Site

3.4.3 List of NSW Contaminated Sites Notified to the EPA

In response to 2008 amendments to the CLM Act clarifying the Section 60 duty to report contaminated sites, the EPA has received approximately 1,000 notifications from owners or occupiers of sites where they believe the sites are contaminated. Sites appearing on this list indicate that the notifiers consider that the sites are contaminated and warrant reporting to EPA; however, the contamination may or may not be significant enough to warrant regulation by the EPA. The EPA needs to review and, if necessary, obtain more information before it can decide as to whether a site warrants regulation.

A search of the List of NSW Contaminated Sites Notified to the EPA on 13 May 2020 revealed no sites listed on the list of notified sites within 1 km of the Site. Search results are attached as **Appendix C**.

4 Site History

4.1 General

The Site history comprised the review of available published data and aerial review. The Site history review is detailed herein.

4.1.1 Previous Assessment

No previous Site contamination assessments were made evident or provided to Cardno during the preparation of this PSI. As such, it is assumed that previous contamination assessment of the land is limited or non-existent.

4.1.2 Historical Title Deeds Search

As the Site is situated within the road corridor / reserve, no historical title deed searches were undertaken as part of the Site history assessment.

4.1.3 Section 10.7 Planning Information

As the site is situated within the road reserve, no Section 10.7 Certificate searches were undertaken as part of the site history assessment.

4.1.4 Review of the Historical Aerial Photos

Cardno has conducted a review of historical aerial photographs or available aerial imagery, current site inspection, previous investigations and knowledge of the area.

A summary of the interpreted site features is detailed in Table 4-1 below and aerial photographs are provided in **Appendix A.**

Table 4-1 Aerial Imagery Review

Date	Reference	Observations
1954	Black and White NSW 3341-357	**Onsite:** ▪ Old Pacific Highway is visible and constructed ▪ Scenic Drive alignment is present. Appears to be unsealed **Offsite:** ▪ The Swansea open cut coal mine is located to the north of the study area and east of the Old Pacific Hwy. It is characterised by extensive clearing and excavation and extending for approximately 1.5km. ▪ An area of has been cleared to the south-west / west of the Old Pacific Hwy for a clay pits ▪ An area of approximately 1.5ha has been cleared to the west of the site for a clay pit. ▪ Several tracks are visbible within the surroundings of the alignment ▪ The former Swansea Quarry site is located approximately 1km to the north of the site. ▪ The remainder of the surrounding land comprises of moderately dense tree cover.
1965	Black and White NSW 1403-5147	**Onsite:** ▪ Generally consistent with 1954 photograph ▪ Scenic Drive – constructed **Offsite:** ▪ Generally consistent with the 1954 photograph detailed above with the exception of: – The clay pits to the south and west of the site have expanded in area – Piles of material within fromer clay pit areas are visible south of Old Pacfic Highway, indicating that it had begun to be use as a landfill

Date	Reference	Observations
		– Increased residential development to the north-east, including construction of new roads.
1971	Colour NSW 2403-49	**Onsite:** ▪ Generally consistent with the 1965 photograph **Offsite:** ▪ The Swansea open cut coal mine has expanded approximately 300m southward. ▪ Significant clearing south of Old Pacific Highway (landfill area) ▪ The area south-east of the site, immediately to the west of the Old Pacific Hwy, has been cleared of trees. ▪ Trees have been cleared to the south of the site in the vicinity of a newly constructed house. ▪ A dam has been constructed approximately to the south of the site. ▪ Several clay pits have been established to the west of the site. ▪ Residential development has increased to the north east of the site
1980	Colour NSW 2879-141	**Onsite:** ▪ Generally consistent with the 1971 photograph **Offsite:** ▪ Increased residential development to the north east.
1983	Black and White NSW 3341-357	**Onsite:** ▪ Generally consistent with the 1980 photograph **Offsite:** ▪ Generally consistent with the 1980 photograph
1994	Colour NSW 4239	**Onsite:** ▪ Generally consistent with the 1983 photograph **Offsite:** ▪ The Swansea open cut coal mine site and the two clay pit sites have revegetated. ▪ The new Pacific Hwy has been constructed to the west of the site ▪ Increased residential development to the east of the site.
2010	Colour Nearmap	**Onsite:** ▪ Generally consistent with the 1994 photograph **Offsite:** ▪ The Swansea open cut coal mine site and the two clay pit sites have increased in vegetation. ▪ Clay pits to the west of the site have been largely revegetated. ▪ Increased residential development to the east and west.

4.2 Summary of Site History

Based on the available historical data, Cardno Site inspections and public searches, the Site was not undergone any significant changes in landuse since aerial dated 1954. It is understood that Old Pacific Highway was discommission in the early 1980's / early 1990's and barraicaded since.

The surrounding areas of the Old Pacific Highway and Scenic Drive have undergone open cut mining, clay mining and landfill / waste storage.

5 Areas and Contaminants of Potential Concern

The assessment has identified several potential sources of contamination (and related Contaminants of Potential Concern – COPC), which are summarised in the **Table 5-1** below.

Table 5-1 Site Activities and Potential Contaminants of Concern

Area of Environmental Concern (AoEC)	Site Activity / Potential Source	Contaminants of Potential Concern (CoPC)	Comments
Onsite Sources			
Site levelling and trenching	▪ Cut and fill operations	▪ Heavy Metals, PAH, TRH, BTEXN & OCP/OPP ▪ Asbestos	▪ Potential for uncontrolled fill material present onsite. ▪ Given the topography of the Site, it is likely fill was Site won.
Road Corridor	▪ Public use of roads ▪ Fly tipping ▪ Illegal dumping ▪ Maintenance of road corridor	▪ Heavy Metals, PAH, TRH, BTEXN & OCP/OPP ▪ Foreign materials (fly tipping). ▪ Asbestos	▪ The presence of contamination would likely be associated with localised spills associated with motor vehicles. ▪ Fly tipping of domestic refuse by passing motorists / public. ▪ Illegal dumping. ▪ Potential use of pesticides and machinery during maintenance of the corridor. ▪ Use of coal tar containing asphalts and tars
Access Tracks	▪ Surficial clearing ▪ Fly tipping ▪ Illegal dumping	▪ Heavy Metals, PAH, TRH, BTEXN & OCP/OPP ▪ Foreign materials (fly tipping). ▪ Asbestos	▪ Surficial disturbance onsite associated with access tracks. ▪ Fly tipping and illegal dumping
Offsite Sources			
Landfill and former clay pits	▪ Dumping of waste in Swansea South landfill site ▪ Uncontrolled filling	▪ Heavy Metals, PAH, TRH, BTEXN & OCP/OPP ▪ Asbestos ▪ Foreign materials ▪ Soil Gas	▪ Given the topography and locality of the alignment, it is unlikely the landfill will impact the assessment area (road corridor)
Swansea Open Cut Mine	▪ Potential uncontrolled filling ▪ Open cut works	▪ Heavy Metals, PAH, TRH, BTEXN & OCP/OPP ▪ Asbestos ▪ Foreign materials	▪ Unlikely to impact the assessment area (road corridor)
Waste storage	▪ Waste storage at Swansea quarry	▪ Heavy Metals, PAH, TRH, BTEXN & OCP/OPP ▪ Asbestos ▪ Foreign materials	▪ A former EPL permitted storage of waste at Swansea quarry, including general waste and asphalt waste.

6 Conceptual Site Model

6.1 Preliminary Conceptual Site Model

Generally, a conceptual site model (CSM) provides an assessment of the fate and transport of COPCs relative to site-specific subsurface conditions with regard to their potential risk to human health and the environment. The CSM considers site-specific factors including:

- Source(s) of contamination,
- Identification of contaminants of potential concern (COPCs) associated with past (and present) source(s),
- Vertical, lateral and temporal distribution of COPCs,
- Site specific lithological information including soil type(s), depth to groundwater, effective porosity, and groundwater flow velocity,
- Actual or potential receptors considering both current and future land use for both the site and adjacent properties, and any sensitive ecological receptors.

Based on the information sourced in this report, a preliminary CSM has been developed and is outlined in **Table 6-1** below. Additional details are included in the sections that follow as necessary.

Table 6-1 Preliminary Conceptual Site Model

Conceptual Site Model Element	Description
Site History	▪ Site formed part of the Old Pacific Highway and is now redundant due to realignment of the highway
Site Current and Future Use	▪ The alignment is redundant and is not currently in use. ▪ Proposed to form part of the proposed residential development.
Site Geology	▪ No intrusive investigation was undertaken. Based on site conditions and published data, the Site is likely to comprise of residual clays, weathered bedrock and fill materials sourced locally.
Site Hydrogeology	▪ Groundwater assessment was not undertaken as part of the scope.
AoEC - Onsite	▪ Potential contamination associated with minor areas of filling and surficial disturbance. ▪ Potential asbestos containing materials (ACM) within areas of illegal dumping ▪ Fly tipping and illegal dumping ▪ Potential hydrocarbon contamination with machinery use. ▪ Potential pesticide and herbicide use.
Media Potentially Impacted	▪ Potentially contaminated surficial soils onsite. ▪ Potentially contaminated underlying soils onsite. ▪ Potentially contaminated fill materials onsite.
Potential Human Receptors	▪ Future Site users / workers / employees (onsite) ▪ Site Construction workers (onsite) ▪ Local rural residents and surrounding properties (offsite)
Potential Environmental Receptors	▪ Nearby waterbodies – unnamed creek lines / drainage lines, south of Site. ▪ Flora and fauna.
Potential Exposure Pathways	▪ Air – inhalation of dusts and fibres. ▪ Soil – dermal / direct contact. ▪ Lateral migration via surficial runoff

6.2 Data Gaps

Based on the inspection, the potential for contamination at this site is not considered to present a significant constraint on the proposed redevelopment of subject site. However, it must be appreciated that assessment was limited to Site walkover within the subject site and no intrusive sampling was undertaken.

The following data gaps and uncertainties regarding the assessment are detailed below:

- No intrusive sampling spatially and vertically.
- No groundwater samples collected.
- No dangerous goods search was undertaken for the site however; it is unlikely to be present.

7 Conclusions and Recommendations

Cardno has completed a Preliminary Site Investigation for a section of Old Pacific Highway (2.0 km) and Scenic Drive (0.5 km) at Pinny Beach, NSW. For Site extent refer to **Figure 1**, attached in **Appendix A**

The objectives of the investigation were to assess:

- The potential for the past and present activities undertaken on and adjacent to the site to have affected soil and groundwater at the Site.
- The need for any further assessment or remedial works before definitive conclusions could be made on the suitably of the site for use.

7.1.1 Summary of Contamination Potential

Based on the review of the Site history and Site inspection, Cardno identified the following potential sources of contamination at or adjacent to the site:

- Potential contamination associated with areas of filling and surficial disturbance on Site
- Potential hydrocarbon contamination with vehicle use
- Potential contamination with fly tipping and illegal dumping
- Potential asbestos containing materials (ACM)

7.1.2 Potential Acid Sulfate Soil

Review of the Department of Land and Water Conservation Acid Sulfate Soil Risk Map – Swansea Edition 2 [4] indicates that the Site is situated within area of no known occurrence.

7.2 Recommendations

Given the results of this assessment, Cardno recommends the following:

- Where applicable removal of anthropogenic materials as General Solid Waste in accordance with the NSW EPA (2014) Waste Classification Guidelines.
- Removal of potential asbestos containing materials as Special Waste (asbestos) in accordance with the NSW EPA (2014) Waste Classification Guidelines.
- A site clearance by a suitably qualified environmental consultant following the removal of potential asbestos containing materials.
- An unexpected finds protocol developed.
- If potential contamination is encountered, Site works will be ceased and suitable environmental consultant will be engaged for assessment.
- The recommendations may be undertaken during construction phase of the development
- Classification in accordance with the NSW EPA (2014) Waste Classification Guidelines of all soil stockpiles prior to offsite disposal.

7.3 Conclusions

Based on Site history and Site inspection, no indication of gross contamination has been identified on the Site. The Site is considered to be low risk of potential contamination based on investigation findings and the identified data gaps. As there is a low risk for contamination an unexpected finds protocol should be developed during the removal of anthropogenic materials

8 Standard of Assessment and Limitations

This investigation has been undertaken in general accordance with the current "industry standards" for a site investigation for the purpose, objectives and scope identified in this report. These standards are set out in:

- National Environment Protection Council (NEPC) (1999) *National Environment Protection (Assessment of Site Contamination) Measure*, as amended (registered on 15 May 2013) [2]. This is referred to from here on as "the NEPM" or "NEPM".
- Standards Australia (2005) *AS4482.1- 2005: Guide to the investigation and sampling of sites with potentially contaminated soil Part 1: Non-volatile and semi-volatile compounds*. [5].
- NSW EPA "*Guidelines for Consultants Reporting on Contaminated Sites*" [1].

The agreed scope of this investigation has been limited for the current purposes of the Client. The investigation may not identify contamination occurring in all areas of the site, or occurring after sampling was conducted. Subsurface conditions may vary considerably away from the sample locations where information has been obtained.

This site investigation report is not any of the following:

- An Environmental Audit Report as defined under NSW Site Auditor Scheme [6].
- A detailed site investigation (DSI) report sufficient for an Environmental Auditor to be able to conclude a statutory or non-statutory environmental audit.
- A geotechnical report, and the bore logs or test pit logs may not be sufficient as the basis for geotechnical advice.
- A detailed hydrogeological assessment or an assessment of groundwater contaminants potentially arising from other sites or sources nearby.
- A waste classification report of soil analytical results from the Site.
- A total assessment of the site to determine suitability of the entire parcel of land at the site for one or more of the beneficial uses of land set out in State Environmental Protection Policy (Prevention and Management of Contamination of Land) and its variation.

9 References

[1] NSW EPA, “NSW EPA, “Consultants reporting on contaminated land Contaminated land guidelines, NSW Environment Protection Authority, Sydney,” NSW Environmental Protection Authority, April 2020.

[2] National Environment Protection (Assessment of Site Contamination) Measure 1999, “Schedule B1 Guidelines on Investigation Levels For Soil and Groundwater,” National Environment Protection Council (NEPC), 16 May 2013.

[3] Gosford-Lake Macquarie Geology Map, “1:100,000 Geological Series Sheet 9131, and part of 9231 (Edition 1),” Geological Survey of NSW, Department of Mineral Resources, 1995.

[4] Department of Land And Water Conservation, “Acid Sulfate Soil Risk Map for Swansea (Edition 2),” NSW Department of Natural Resources, December 1997.

[5] Standards Australia, “Australian Standard - Guide to the investigation and sampling of sites with potentially contamainted soils - PArt one: Non-volatile and semi-volatile compounds,” Standards Australia, 2005.

[6] NSW DEC, “Contaminated Sites: Guidelines for the NSW Site Auditor Scheme (3rd Edition),” Department of Environment and Conservation NSW, 2017.

Draft Remediation Action Plan

Lot 3 - Northern Precinct, Wallarah Peninsula

82220067.003.1

Prepared for

Wakefield Ashurst Developments Pty Ltd and Northern Managers & Construction Pty Ltd

20 May 2020

Cardno

Contact Information

Cardno (NSW/ACT) Pty Ltd
ABN 95 001 145 035

Unit 1
10 Denney Street
Broadmeadow NSW 2292
Australia

www.cardno.com

Phone +61 2 4965 4555
Fax +61 2 4965 4666

Document Information

Prepared for	Wakefield Ashurst Developments Pty Ltd and Northern Managers & Construction Pty Ltd
Project Name	Lot 3 - Northern Precinct, Wallarah Peninsula
File Reference	82220067.003.1 Draft RAP Lot 3 - Northern Precinct, Wallarah Peninsula .docx
Job Reference	82220067.003.1
Date	20 May 2020
Version Number	1

Author(s):

Dimce Stojanovski

Geotechnical Scientist

Effective Date 20/05/2020

Approved By:

Ian Piper

Principal Technical Officer

Date Approved 20/05/2020

Document History

Version	Effective Date	Description of Revision	Prepared by	Reviewed by
0	14/05/2020	Draft Issue	Dimce Stojanovski	
1	20/05/2020	Revision – Lot Identifications	Dimce Stojanovski	IGP

Table of Contents

Appendices

Tables

1 Introduction

1.1 Overview

Cardno was engaged by Wakefield Ashurst Developments Pty Ltd (Client) to review available information and prepare a Draft Remediation Action Plan ('RAP') for the proposed residential development known as Northern Precinct, Wallarah Peninsula, located at 532 Old Pacific Highway, Pinny Beach NSW ('the Site').

The subject Site is irregular in shape and approximately 6.7 ha in size. The Site is identified as Lot 3 DP1240365 (comprised of former allotments: Lot 2 DP337960 and Lot 1 DP344160)

For site locality and site boundaries, refer to **Figure 1** supplied ADW Johnson drawing (dwg 239475-(N)-PSK-004) **,** attached in **Appendix A.**

The assessment was limited to Lot 3 (which encompasses the former landfill area) of the proposed development. It excludes the remaining proposed lots. For the proposed lot identification numbers and extent, refer to the supplied drawing referenced ADW Johnson "Proposed Lots, Mawsons Ridge North" dwg ref 239475-(N)-PSK-004, dated 23.11.17, attached in **Appendix A.**

Based on the previous report undertaken by RCA Australia *"Environmental Site Assessment and Remedial Action Plan – Former Swansea Landfill Wallarah North Precinct, 2008"* [1], and review of available data the site comprised of a clay pit that was in operation within the site from the early 1950s. The site is visible in the 1954 aerial photograph and ceased operations in the 1960s.

The former clay pit site began to be utilised by Lake Macquarie City Council (LMCC) in the 1960s to store waste. The site operated as an informal landfill up until the mid-1970s. In 1976 the landfill was closed, although fly dumping occurred for some time afterwards. It was noted in the RCA report [1] that the waste comprised predominantly of non-putrescible domestic waste, building waste, car bodies and tyres. The Site has remained vacant since operations ceased on the Site.

The Initial proposal was the removal of impacted materials (landfill) within the residential footprint and consolidated within the recreational footprint for onsite encapsulation. However, following discussions with council, it is understood that the intent and remedial methodology will remain the same but the area of onsite capsulation is now proposed for commercial use. It is proposed that public recreation will be located adjoining the landfill site, to the east.

This draft RAP is preliminary in nature and is based on information and data of the previous investigations undertaken by RCA. A Sampling Analysis and Quality Plan (SAQP) for Lot 3 was prepared by Cardno and is attached as **Appendix G**. It must be appreciated that the RAP may require amendments following the results and findings of the SAQP.

1.2 Objectives

The objective of the RAP is to review the existing RAP [1] and available information, and develop an appropriate strategy for remediation of the contamination previously identified at the Site.

1.3 Scope of Work

The scope of work for the RAP comprised of the following:

1. Review all of the existing documentation and analytical data collected at the Site.
2. Identify and characterise any contamination from identified potential sources with respect to the proposed redevelopment of the Site for future residential use.
3. Review of available remediation technologies and methodologies.
4. Review of previous Investigation and report undertaken by RCA.
5. Analysis data with current guidelines.
6. Current Site inspection undertaken by Cardno.
7. Prepare a RAP in accordance with the requirements of the Office of Environment and Heritage (OEH) Guidelines for Consultants Reporting on Contaminated Site (2011) [2].

2 Site Identification

The Site identification details are presented in **Table 2-1** below.

Table 2-1 Site Identification

Site Identification	
Site Address	▪ 532 Old Pacific HWY Pinny Beach (**Figure 1** – **Appendix A**)
Legal Description	▪ Lot 3 DP 1240365 ▪ The Site comprised of former allotments: Lot 2 DP337960 and Lot 1 DP344160.
Approximate Site Area	▪ 6.7 ha (former landfill area 4.3 ha and 2.4 ha vegetated).
Elevation	▪ Elevation ranges from approximately 40 m AHD to 55 m AHD across the Site. ▪ The highest point of elevation is situated within the north eastern portion of the Site
Site Owner	▪ Wakefield Ashurst Developments Pty Ltd and Northern Managers & Construction Pty Ltd.
Municipality	▪ Lake Macquarie City Council

For site locality, please refer to **Figure 1** attached in **Appendix A**.

3 Site History

3.1 Previous Investigations

Previous investigations undertaken at the subject site and reviewed as part of the preparation of the RAP are:

> Wallarah Peninsula Geotechnical Review - Sinclair Knight Mertz (SKM), 2002 [3].

> Environmental Site Assessment and Remedial Action Plan Former Swansea Landfill Wallarah North Precinct – RCA Australia (RCA), 2008 [1].

> Review Advice No. 5 – Former Swansea South Landfill RAP Review, Swansea, NSW – Environ Australia, 2008 [4]

3.1.1 Wallarah Peninsula Geotechnical Review - Sinclair Knight Mertz (SKM), 2002

SKM conducted a review of available geotechnical information, related to the Wallarah Peninsula project. The report [3] contains historical information relevant to the current subject site. This includes:

> A clay pit was in operation on the site from the 1950s to the 1960s. Council used the clay pit site as a landfill up to 1975.

> Two clay pits were in operation to the west and south of the site, respectively, from the 1950s to the 1970s.

> The Swansea open cut coal mine site is located to the north of the Site, east of the Old Pacific Hwy. Much of the Site is covered with dumped mine spoil, which appears to be largely uncontaminated.

3.1.2 Former Swansea South Tip Site, Geotechnical and Contamination Report – SKM, 2003

SKM conducted a geotechnical and contamination assessment of the Former Landfill Site in 2003 [5]. This report was reviewed and summarised within the RCA Australia (RCA) [1] report mentioned below, however, Cardno has not been provided with the original SKM report.

The SKM (2003) [5] investigation, as described by RCA (2008) [1] comprised of the following:

> Excavation of eleven (11) test pits.

> A total of nine (9) soil samples were selected and analysed for TRH, PAH, OCP, OPP, PCB, BETX and 8 heavy metals.

Fill materials at the site were found to comprise of general household waste, not including putrescible waste, and scrapped motor vehicle parts including tyres. It was estimated that these materials constituted about half of the volume of the landfill. The remainder of the fill was soil cover comprising of gravel and clay. Test pits were not excavated to the full depth of fill due to the limits of machinery reach.

The results generally satisfied the NEPC NEPM Guideline on Investigations Levels for Soil and Groundwater 1999 for the most sensitive uses. One analyte, Benzo(a)pyrene, for one soil sample exceeded the Health based investigation levels (HIL) A limit for standard residential use, but was within the limits for HIL E for Parks, recreational open space playing fields.

3.1.3 Environmental Site Assessment and Remedial Action Plan – Former Swansea Landfill Wallarah North Precinct – RCA Australia (RCA), 2008

An environmental site assessment was conducted, and remedial action plan prepared, for the Former Landfill Site by RCA Australia (RCA) in September 2008 [1]. The study area comprised Lot 2 DP337960 and Lot1 DP344160. The investigation included assessment of potential contaminants that might be present within spoil piles.

The investigation comprised a field investigation and review of previous investigation undertaken be SKM (2003) [5], which is summarised above.

The RCA (2008) investigation comprised of the following:

> Excavation of 27 test pits to the base of fill material.

> Installation of three (3) groundwater monitoring wells to a maximum depth of 5.0m within the fill profile.

- Soil samples were collected from all test pits at depths ranging from 1.0m to 4.0m and analysed for volatile halogenated compounds, PCB, OCP, phenols, metals, PAH, BTEX and TPH.
- Surface soil sample were collected from six (6) locations across the site and analysed for volatile halogenated compounds, metals, PAH, BTEX, TPH and ammonia.
- Two (2) surface soil samples were collected from locations adjacent to bonded fibro asbestos containing fragments and analysed for asbestos fibres.
- Groundwater samples were taken from the three (3) well locations and from four (4) surface water locations up and down gradient from the site.
- Soil gas sampling was conducted at 23 locations across the site. Percentage concentrations of methane and CO_2 were logged at each location.

Results from the additional investigations indicated HIL A (standard residential) exceedances in analytes Benzo(a)pyrene (2 total), Sum of reported PAH (1 total), Toluene (1 total), Zinc (1 total) & Lead (8 Total) and HIL E (parks, recreational open space and playing fields) exceedances in Zinc (1 total), Lead (2 total), Benzo(a)pyrene (1 total), Toluene (1 total) & Sum of reported PAH (1 total).

Perched groundwater sample data recovered from the wells when compared to the groundwater investigation levels (GILs) for 95% protection of aquatic ecosystems ANZECC and ARMCANZ Guidelines – 2000, indicated elevated concentrations of some metals including cadmium, chromium, copper, iron, lead and zinc. TPH and total phenols were also elevated above the adopted GILs, although results indicated that there had been no impact on the down gradient surface water.

Asbestos fibres were not detected in surface soil samples, although fragments of asbestos containing materials were detected across the site surface and within fill materials. Soil gas monitoring returned non-detectable readings for methane and CO_2 at all locations.

The report concluded the following:

- The presence of soil contaminants, including PAH and lead, pose long-term human health risks for potential site occupants.
- Impacts on perched groundwater within the landfill are minor and have been shown not to impact on down gradient surface water.
- Remediation by encapsulation with the footprint of a proposed recreation area was the preferred remediation strategy. This would require excavation of impacted materials on the proposed residential footprint and relocation to the recreational footprint, before capping.

The RCA report is attached as **Appendix B.**

3.1.4 Review Advice No.5 – Former Swansea South Landfill RAP Review, Swansea, NSW – Environ Australia, 2008

Environ Australia, has undertaken a review of the “RCA – Environmental Site Assessment and Remedial Action Plan, 2008” [1].

The review concluded the following:

- The remediation goal outlined by RCA was considered suitable.
- RCA outlined the extent of remediation was limited to site soils and is required to remove risk to human health from isolated areas of asbestos fragments, PAH and lead contamination within soils.
- The proposed remedial option selected by RCA was onsite encapsulation within the proposed recreational footprint. The proposed remedial option comprises the removal of all impacted fill materials and placed into the encapsulation works within the proposed recreational footprint. The preferred remedial option selected was considered appropriate.
- RCA outlined that validation sampling of the excavations following the removal of unsuitable materials would consist of discrete soils sample collected within an approximate 15 m grid and where excavation walls are greater than 0.2 m depth, a rate of 1 sample per 10 m lineal metres to be adopted. RCA also

advised that capping and other materials imported to site will be sampled. Environ deemed the validation testing appropriate.

Based on the review advice undertaken by Environ Australia, the Remedial Action Plan is considered suitable for the proposed development of the site.

The report is attached as **Appendix C**.

3.2 Section 149 Planning Certificate

3.2.1 Lake Macquarie Council Section 149 Planning Certificates

Cardno has conducted a review of Section 149 Planning Certificates for existing lots within the study area. The documents were supplied by the Client. It should be noted that the documents were dated January 2016, and the information contained therein and this review are restricted to that date. The certificates are attached as **Appendix D**

The Site is known as Lot 3 DP 1240365 (formerly comprised Lot DP337960 and Lot 1 DP344160). The review of the Section 149 Planning Certificates revealed no significant differences between lots. The below summary of Section 149 Planning Certificates applies to the entire site:

- Draft Local Environmental Plans that affect the site include:
  - Lake Macquarie Local Environmental Plan 2014 (Amendment No. F2014/01451)
  - Lake Macquarie Local Environmental Plan 2014 (Amendment No. RZ/3/2014)
- The Land is zoned R1 – General Residential.
- The land does not comprise critical habitat.
- The land is not in a conservation area.
- The land contains no listed items of heritage conservation.
- The land is excluded land for the purposes of complying development relating to general housing, new commercial and industrial buildings, and rural housing, being land identified by an environmental planning instrument as being environmentally sensitive or within an ecologically sensitive area.
- The land is within the defined coastal zone, but is not the subject of notifications under the *Coastal Protection Act 1979.*
- The land is within a proclaimed Mine Subsidence District.
- The land is not affected by road widening or realignment.
- The land is affected by a Council policy that restricts development because of the likelihood of land slip or subsidence.
- The land is affected by a Council policy that restricts development because of the likelihood of bushfire.
- The land is affected by a Council policy that restricts development because of the likelihood of acid sulfate soils.
- The land is affected by a Council policy that restricts development because of the likelihood of contaminated or potentially contaminated land.
- The land is not affected by flood related development controls.
- The land has not been reserved for acquisition.
- The land is subject to The Lake Macquarie Section 94 Contributions Plan No. 5 – North Wallarah (2204)
- The land is not biodiversity certified.
- The land is not subject to a biobanking agreement.
- The land is bushfire prone land.
- The land is not subject to a property vegetation plan.

- The land is not affected by an order under the *Trees (Disputes Between Neighbours) Act 2006*
- The land is not affected by any site compatibility certificates.
- There are no prescribed matters under section 59(2) of the *Contaminated Land Management Act 1997.*
- Consent must be obtained to clear any tree or vegetation under the *Lake Macquarie Local Environment Plan 2014*.
- The land is not affected by an outstanding notice/order issued under the following:
  - *Local Government Act, 1993*
  - *Environmental Planning and Assessment Act, 1979*
  - *Swimming Pools Act, 1992*
  - *Noxious Weeds Act, 1993*
  - *Protection of the Environment Operations Act, 1997*
- The NSW Government Coastal Policy, 1997 must be taken into account when determining Development Applications on the land.
- The land is not affected by a Voluntary Planning Agreement.

3.3 Historical Land Ownership

Cardno has reviewed the land ownership summary presented in the RCA report [1], which relates to the Former Landfill Area, previously comprising of Lot 1 DP344160 and Lot 2 DP337960 (now Lot 3 DP 1240365). The land ownership summary is as follows:

- Lot 1 DP 344160: The property was formed by Council approval in 1940, by Clerk's Certificate 570. It has been owned by the Lake Macquarie City Council (LMCC), who unsuccessfully applied to operate the site as a licensed land fill in the mid 1970s. The current owner are Wakefield Ashurst Developments Pty Ltd and Northern Managers & Construction Pty Ltd
- Lot 2 DP337960: The property was created by gazettal of Crown Land, Subdivision Plan 37960 in 1937. The site was previously owned by Parbury Estate Pty Ltd and before that, Northern Stoneware Pipe Pty Ltd (operating as the Belmont Pipe Company). The current owner are Wakefield Ashurst Developments Pty Ltd and Northern Managers & Construction Pty Ltd

3.4 Review of Historical Aerial Photos

Cardno has conducted a review of historical aerial photograph descriptions contained in the RCA report [1], which includes aerial photograph review from the SKM report cited by RCA. Additionally, Cardno has reviewed aerial photographs supplied by the Department of Finance Services and Innovation covering dates from 1954 to 1994. In addition, Cardno have undertaken review of available Google Earth and Nearmap aerial imagery post 2010.

Overall, Cardno's historical aerial review was based on historical aerial imagery, current site inspection, previous investigations and knowledge of the area. Aerials are attached as **Appendix A.**

A summary of the interpreted site features is provided in Table 3-1 below.

Table 3-1 Aerial Imagery Review

Date	Reference	Observations
March 1954	Black and White NSW 3341 357	**Onsite:** ▪ A clearing scar approximately 100m across, 1ha in area exists in the eastern portion of the site immediately west of a prominent bend on the Old Pacific Hwy. Historical records and previous investigations indicate that this site was owned by the Belmont Pipe company and that this was likely a brick clay pit or small open cut coal mine used to supply clay and/or coal for pipe production ▪ The remainder of the site is vegetated with moderately dense tree cover. **Offsite:** ▪ The Swansea open cut coal mine is located to the north of the study area and east of the Old Pacific Hwy. It is characterised by extensive clearing and excavation and extending for approximately 1.5km. ▪ An area of approximately 0.5ha has been cleared to the south-west of the site, west of the Old Pacific Hwy for a clay pit. ▪ An area of approximately 1.5ha has been cleared to the west of the site for a clay pit. ▪ The Old Pacific Hwy runs along the northern and eastern boundaries of the site, oriented approximately north-west to south-east. ▪ Several tracks and smaller areas have been cleared to the south-west and west of the site. ▪ Two areas of approximately 8 ha each have been cleared of trees to the east of the site. ▪ The former Swansea Quarry site is located approximately 1km to the north of the site. ▪ The remainder of the surrounding land comprises of moderately dense tree cover.
1965	Black and White NSW 1403-5147	**Onsite:** ▪ Generally consistent with the 1954 photograph detailed above. ▪ The clearing scar in the eastern portion of the site has expanded in area, potentially due to clay mining, and piles of material are visible, indicating that it had begun to be use as a landfill. Ground level photographs referenced by SKM (2003) indicate that the material was largely non-putrescible domestic waste. **Offsite:** ▪ Generally consistent with the 1954 photograph detailed above. ▪ The clay pits to the south and west of the site have expanded in area. Increased residential development to the north-east, including construction of new roads.
August 1971	Colour NSW 2403-49	**Onsite:** ▪ The site has been largely cleared of vegetation. SKM (2003) indicate that car bodies and tyres were a large component of material being dumped to this time. **Offsite:** ▪ The Swansea open cut coal mine has expanded approximately 300m southward.

		▪ The area south-east of the site, immediately to the west of the Old Pacific Hwy, has been cleared of trees. ▪ Trees have been cleared to the south of the site in the vicinity of a newly constructed house. ▪ A dam has been constructed approximately 100m to the south of the site. ▪ Several clay pits have been established to the west of the site. ▪ Residential development has increased to the north east of the site
August 1980	Black and White NSW 2879-141	**Onsite:** ▪ Generally consistent with the 1971 photograph detailed above. ▪ The SKM (2003) report indicates that Council landfill operations had ended in 1976, although illegal dumping continue on the site for years afterward. **Offsite:** Increased residential development to the north east.
November 1983	Black and White NSW 3341-357	**Onsite:** ▪ Generally consistent with the 1980 photograph detailed above. **Offsite:** ▪ Generally consistent with the 1980 photograph detailed above
September 1994	Colour NSW 4239	**Onsite:** ▪ The site has been substantially revegetated. **Offsite:** ▪ The Swansea open cut coal mine site and the two clay pit sites have revegetated. ▪ The new Pacific Hwy has been constructed to the west of the site ▪ Increased residential development to the east of the site.
March 2010	Colour Nearmap	**Onsite:** ▪ The western portion of the Swansea South tip site has been cleared of vegetation and has visible piles of material. **Offsite:** ▪ The Swansea open cut coal mine site and the two clay pit sites have increased in vegetation. ▪ Clay pits to the west of the site have been largely revegetated. ▪ Increased residential development to the east and west.
September 2017	Colour Nearmap	**Onsite:** ▪ Increased vegetation on the site. **Offsite:** ▪ Generally consistent with the 2010 photograph detailed above. ▪ The house to the south of the site has been demolished. ▪ Increased residential development to the west.

3.5 EPA records Search

3.5.1 Contaminated Land Record of Notices

A search of NSW EPA Record of Notices conducted on 23 January 2018 revealed no notices listed within 1 km of the site.

Search results are provided in **Appendix D.**

3.5.2 PoEO Public Register

The PoEO Public Register under Section 308 of the Protection of the Environment Operations (PoEO) Act 1997 contains Environment Protection Licences (EPLs), applications and notices issued by the EPA.

The Public Register was searched on 23 January 2018 to identify any issues of relevance to the Site. The search revealed no licensed activities within a 1 km radius of the site.

One (1) licensed activity now revoked or surrendered was found within 1 km of the site. This is summarised in Table 3-2 below.

Table 3-2 Former Licensed Activities under the PoEO Act 1997, now revoked or surrendered

EPL	Organisation	Location	Date Issued	Activity	Distance
13424	Lake Macquarie City Council	Swansea Quarry 465 Pacific Hwy Swansea NSW	17 November 2011	Waste storage	750m north of subject site

Search results are provided in **Appendix D**.

3.5.3 List of NSW Contaminated Sites Notified to the EPA

A search of the List of NSW Contaminated Sites Notified to the EPA conducted on 23 January 2018 revealed no sites listed on the list of notified sites within 1 km of the site:

Search results are provided in **Appendix D**.

3.6 Summary of Site History

With reference to previous investigations, review of available data, the history of the Site is summarised below;

> Based on the SKM (2002) report [3], it is understood that a clay pit was in operation on the Site from the early 1950s. This site is visible in the 1954 aerial photograph. The site ceased operation in the 1960s and began to be utilised by Lake Macquarie City Council (LMCC) to store waste.

> The site operated as an informal landfill up until the mid-1970s. In 1976 the landfill was closed, although fly dumping occurred for some time afterwards. It has been noted in the RCA report [1] that the waste comprised predominantly of non-putrescible domestic waste, building waste, car bodies and tyres.

> Based on the SKM (2002) report [3], and the 1954 aerial photograph, two clay pits were in operation to the south and west of the site, respectively, from the early 1950s until the 1960s.These sites have since been filled and revegetated.

> An onsite track was evident between 1965 to 1994 on the western portion of the site, traversing north-south. It appears, to have been used as access to the former landfill area. The track has since been vegetated / overgrown.

> The Swansea open cut coal mine, located to the north of the subject site, east of the Old Pacific Hwy, began operations in approximately 1950. Mining had ceased by 1975 and no spoil rehabilitation has been carried out, with much of the site covered in spoil piles that have become overgrown with vegetation.

4 Site Condition and Surrounding Environment

4.1 Current Land use and Layout

The Site is currently vacant and consists of bushland and vegetation regrowth on the former cleared areas and landfill area.

4.2 Proposed Future Land Use

The proposed future land use at the Site includes a mixture of residential and commercial area. The layout plans is presented in **Figure 1**, attached in **Appendix A**. It is understood that the commercial area will be limited to the former landfill area. It is proposed that an area of public recreation will be adjoining the landfill site, to the east.

For construction plans, refer to **Appendix E**.

4.3 Proposed Site Cutting and Filling

The proposed residential development will involve cut and fill operations on site. The proposed earthworks plans are attached as **Appendix E**.

It is anticipated that the western portion of landfill area that encompasses a portion of the residential development will be excavated and incorporated into the encapsulation works within the commercial footprint (current eastern portion of landfill).

4.4 Surrounding Land Use

The Site is located within an area of residential land use and currently undeveloped bushland, much of which is situated on former extractive industrial sites such as former clay pits and coal mines. As of January 2018, surrounding land uses comprise the following:

Land use to the North

> Northern portion of Swansea open cut coalmine site
> Residential development; and
> Bushland.

Land use to the South

> Former clay pit site
> Bushland; and
> Pacific Hwy.

Land use to the East

> Old Pacific Hwy;
> Southern portion of Swansea open cut coalmine site
> Bushland; and
> Residential development.

Land use to the West

> Pacific Hwy;
> Former clay pit sites;
> Bushland; and
> Residential development.

4.5 Off-Site Sources of Contamination

The Site is located within an area surrounded by road alignments, residential development and undeveloped bushlands. No obvious off-site potential contamination sources were noted within the overall vicinity of the Site in terms of current land use. However, several sites of former extractive industrial activities such as clay pits and coal mines are located within the vicinity of the site and are considered potential offsite sources of contamination, which could impact the site through potentially contaminated groundwater should there be a contamination issue located up-hydraulic gradient.

4.6 Topography and Drainage

4.6.1 Site Topography and Drainage

The site is located on the western face of a moderately sloping ridgeline. Elevation ranges from 40 m AHD to 60 m AHD across the Site. The highest point of elevation is situated within the north eastern portion of the Site adjacent to the Old Pacific Hwy. The site grades generally to the west with the lowest point located on the western most site boundary. Undulations within the topography occur as a result of uneven landfilling.

Based on the topography of the Site, drainage is expected to comprise of surficial flows following the existing contours of the Site towards the west, entering a large natural drainage path extending to the north-west and ultimately discharging into Lake Macquarie via Galgabbee Creek.

4.6.2 Off-Site Topography and Drainage

The site is located within regionally hilly terrain comprising predominately undeveloped eucalypt woodland, with topography characterised by large ridgelines/spurs generally trending southwest to northeast ranging from 10 – 20 degrees. The steep slopes to the south of the site generally fall to the southwest towards a valley area defined by a large natural drainage path extending northwest from a man-made dam to the south of the site.

Offsite topography tends to decrease in height in all directions, with the exception of the ridgeline to the north of the site. The Old Pacific Hwy located to the north of the site has an adequate drainage system that diverts stormwater from entering the site from that direction. As such, surficial flows entering the site are expected to be minimal.

4.7 Published Geology

Reference to the Gosford-Lake Macquarie 1:100,000 geological map [6] indicates that the site is situated within two distinct geological formations:

> The Moon Island Beach Subgroup of the Newcastle Coal Measures, comprising Late Permian age deposits of conglomerate, tuff, siltstone, claystone and black coal and soils derived from the weathering of these rock types.

> The Munmorah Conglomerate of the Narrabeen group, comprising Early Triassic aged deposits of conglomerate, pebbly sandstone and shale and soils derived from the weathering of these rock types.

4.8 Subsurface Geology

The subsurface profile identified within the test pits and boreholes within the Site in the investigation undertaken by RCA [1] comprised the following:

> Topsoil; silty sand;

> Residual clays, conglomerate and siltstone below fill material.

The depth of filling within the site ranged from 2.8m to greater than 4.8m below ground level. The predominant fill types identified on the Site consisted of the following:

> Building rubble;

> Non-putrescible domestic waste;

> Decomposed tyres;

> Gravel and clay.

The encountered natural profile was generally consistent with the published geological mapping [6].

4.9 Hydrogeology

A search of the NSW Groundwater Database from Department of Primary Industries indicates that no monitoring wells were present onsite; however, seven (7) monitoring wells are present within 1km and are described in Table 4-1 below. Standing water level in these wells is >6m below ground. Given that these wells are generally located at lower elevations than the study site, it is expected that the water table at the Site is greater than 6m below ground level.

Perched groundwater was encountered during the field investigation undertaken by RCA within the Site. Perched groundwater was not present in all areas of the Site, indicating discontinuities between perched water and the deeper water table.

Based on the review data, topography of the site and previous RCA report [1], the regional groundwater flow regime is likely within the conglomerate bedrock and aquifers within weathered coal seams. Groundwater flow is likely to follow the coal seam decline. Surface run-off is likely to follow the natural and altered topography across the site, towards the south-west of the site. A dam is located south of the site and would be run-off would also be expected to flow towards the dam.

Table 4-1 Registered Groundwater Bores

Bore ID	Distance from the Site	Intended Purpose	Latitude[1]	Longitude	Depth of bore (mbgs[2])	Standing Water level (mbgs)	Screened Section (mbgs)	Water Bearing Zones (mbgs)
Registered Groundwater Bores								
GW065867	800m west	Ground Water Exploration	33° 6' 45.3" S	151° 37' 12.1" E	19.10	-	-	-
GW065866	800m north	Ground Water Exploration	33° 6' 22.3" S	151° 37' 48.1" E	27.50	6.00	-	11.00-13.00 20.00-27.00
GW065865	650m west	Ground Water Exploration	33° 7' 4.3" S	151° 37' 23.1" E	34.00	14.40	-	29.00-32.00
GW065864	1km west	Ground Water Exploration	33° 6' 57.3" S	151° 36' 58.1" E	15.0	-	-	-
GW065863	850m west	Ground Water Exploration	33° 6' 43.3" S	151° 37' 0.1" E	9.80	9.20	8.00-9.20	8.00-9.40
GW065861	1km west	Ground Water Exploration	33° 6' 43.3" S	151° 37' 0.1" E	18.20	-	-	-
GW065860	900m west	Ground Water Exploration	33° 6' 43.3" S	151° 37' 0.1" E	10.10	6.50	8.00-10.00	8.40-9.90

[1] Longitude and latitude for unknown bores inferred from Google Earth.
[2] mbgs – metres below ground surface

4.10 Acid Sulfate Soils

Review of available published data, indicates that the Site is within no known occurrences of acid sulfate soils, with reference to the “Department of Land and Water Conservation, Swansea Acid Sulfate Soil Risk Map”, Edition 2, dated December 1997 [7].

Further review of the “Lake Macquarie City Council - Local Environmental Plan 2014 Acid Sulfate Soils Map”, Sheet CL2_010D, dated 2014 [8] and Sheet CL2_010B, dated 2014 [9] indicates that the Site is located on land with no acid sulfate soils related development controls.

The review of the risk maps indicated that the site is situated within no known occurrence of acid sulfate soil materials and it is considered that acid sulfate soils on site is highly unlikely.

4.11 Site Observations

A Site inspection was conducted by RCA in 2008 [1]. A summary of these observations follows:

> The site was fenced and padlocked restricting site access.

> The site is well vegetated, with the exception of areas of recent spoil placement, consisting of grasses and exotic regrowth. Vegetation surrounding the landfill site comprise of eucalypt forest.

> The site surface appears disturbed, with some visible waste, predominantly comprising building rubble.

> No signs of erosion or soil instability were noted.

> Visible signs of contamination included building waste such as roof tiles and concrete and potential asbestos containing materials. No other visual or olfactory signs of contamination were evident.

> Vegetation regrowth appears healthy and no signs of plant stress was noted.

A Principal Technical Officer and a Geoetchnical Engineer from Cardno inspected the Site in October 2017. At the time of inspection, the site contained overgrown grass cover and was difficult to observe current site conditions in comparison to past site investigations undertaken by RCA.

During the Cardno inspection, it was observed that the site had undergone impacts from previous land use as seen summarised below.

> Disturbances associated with the old Swansea Landfill comprising a combination of general household rubbish, building materials, excess soil and rock excavation material from the Wallarah interchange construction project.

> Cut and fill embankments associated with the Old Pacific Highway and Scenic Drive road pavements.

> Fly tipping comprised of household and building refuse and was predominately located within the vicinity of the existing access tracks, Old Pacific Highway & Scenic Drives road alignment, outside the subject area.

> Vegetation of the site comprised predominantly and thick underbrush and grass, with some baron areas of disturbance throughout the site associated with previous site landfill activities. Drainage over the site is predominately via surface runoff, with most ridge slopes being generally well drained with low lying areas associated with the valley floor containing heavy high plasticity clays with poor drainage.

> The site inspection was limited to existing access tracks and isolated cleared areas. The ability to discern site features was limited due to the overgrown vegetation cover and accessibility.

5 Previous Sampling and Analysis Methodology

5.1.1 Environmental Site Assessment and Remedial Action Plan – Former Swansea Landfill Wallarah North Precinct – RCA Australia (RCA), 2008

The RCA report included data from a previous investigation conducted by SKM (2003) and the investigation conducted by RCA.

The SKM (2003) investigation comprised of excavation of eleven (11) test pits (LF 1-11), for locations refer to **Figure 2** attached in **Appendix A**. A total of nine (9) soil samples were selected and analysed for TRH, PAH, OCP, OPP, PCB, BETX and 8 heavy metals.

The sampling methodology employed by RCA within the Swansea South landfill site was as follows:

All samples were collected by an RCA environmental consultant and analysed by a NATA accredited laboratory. Samples were collected using a 12 tonne excavator with long reach capability and selected to provide appropriate sampling depth.

Surface Soils

Surface samples were collected from six (6) locations across the filled area of the site. Samples were collected from the immediate surface to a maximum depth of 0.05m using a stainless steel trowel and nitrile gloved hand. The RCA report states that all samples were analysed for volatile halogenated compounds, metals, PAH, BTEX, TPH and ammonia, however, only results for ammonia are contained in the report

Decontamination of the sampling trowel was undertaken between sampling rounds using Decon 90 and washing with potable water.

Soils at Depth

Samples were collected from 27 test pits excavated in an approximate 25m grid formation across the filled area of the site (for locations refer to **Figure 2**, **Appendix A**). Sample depths ranged between 1.0 and 4.0m from the surface. All test pits were excavated to the base of fill to ascertain the depth of fill and investigate all fill materials present. Samples were collected by single use nitrile gloved hands from within the bulk soil contained in the excavator bucket. Samples were analysed for volatile halogenated compounds, PCB, OCP, phenols, metals, PAH, BTEX and TPH.

The method of sampling did not require decontamination of excavation equipment.

Asbestos Fibres in Soil

Sampling of soil for asbestos fibres was undertaken on two surface samples collected adjacent to bonded fibre fragments. Samples were collected from the surface using a stainless steel trowel and placed within double lined plastic bags.

Decontamination of the sampling trowel was undertaken between sampling rounds using Decon 90 and washing with potable water.

Soil Gas

Soil gas sampling involved a near surface ambient air gas monitoring survey of landfill gas (methane, CO_2 and CO) following a method known as landfill sweeping. The sampling technician walked over the landfill surface in a random pattern with the inlet probe of the landfill gas analyser positioned within 50 to 100mm from the ground surface at each sampling location. Measurement of gas was recorded over a 20-second duration at each location, with percentage concentrations of each gas logged into the internal memory of the landfill gas analyser. A total of 23 landfill gas readings were collected from across the site, for locations refer to **Figure 3**, attached in **Appendix A**. Meteorological conditions at the time of monitoring were ideal for landfill gas monitoring, with an ambient air temperature of 23°C and calm wind conditions.

Groundwater and Surface Water

Groundwater monitoring was undertaken from three groundwater monitoring wells installed at locations BH 1, BH2 and BH4, for locations refer to **Figure 2**, attached in **Appendix A**. Monitoring wells were installed to a maximum depth of 5.0m and all were contained within the fill profile. Wells were constructed of 50mm diameter PVC machine slotted pipe. The slotted section was installed above and below the phreatic surface and the bores were backfilled to within 1.0m of the surface. A bentonite seal was constructed around the bore collar to restrict surface water ingress. Bores were developed at the time of drilling and allowed to stabilise prior to sampling.

Groundwater bores were sampled approximately two months after installation. Sampling was undertaken by hand bailer following the removal of one bore volume and additional volumes until pH and EC readings were within 0.1, to ensure a representative perched groundwater sample was collected. Decontamination of the hand bailer was undertaken between sampling rounds using Decon 90 and washing with potable water. Samples were field filtered through a 0.45 µm filter for metals analysis.

Surface water sampling was undertaken by filling sampling bottles directly from the surface water source. Samples were not filtered for metals analysis.

5.1.2 Analytical testing

The sampling and analytical strategy undertaken is summarised in the table below:

Table 1-1 Sampling and Analytical Strategy

Media	Number of Sampling locations	Number of Samples analysed[3]	Location IDs	Area of Concern	Number of Analytes for Primary Analysis (excluding QA/QC)
Soil	44 grid	49	RCA (2008) Test pits: TP1-1,TP1-2,TP2-1,TP2-2,TP3-1,TP3-2,TP4-1,TP4-2,TP6-2,TP7-1,TP7-2,TP8-1,TP8-2,TP9-1,TP10-1,TP10-2,TP10-3,TP11-2,TP12-1,TP12-2,TP13-1,TP13-2,TP14-1,TP15-1,TP15-2,TP16-1,TP17-1,TP17-2,TP18-1,TP19-1,TP20-1,TP21-1,TP21-2,TP25-2 Surface: S1. S2, S3, S4, S5, S6 SKM (2003): S1 (LF1),S2 (LF2),S3 (LF3),S5 (LF5),S6 (LF6),S7 (LF7),S8 (LF8),S10 (LF10),S11 (LF11)	Former Landfill	TRH, BTEX, PAH, - 42 samples Heavy Metals (As, Cd, Cr, Cu, Ni, Pb, Hg and Zn), - 43 samples Heavy Metals (Be, Co and Mg) – 33 samples OCP and PCBs – 11 samples Phenols – 2 samples Asbestos (w/w %) – 2 samples Ammonia – 6 samples
Groundwater and surface water	7	7	RCA (2008) BH1, BH2, BH4, SW1-4	Former landfill	TRH, BTEX, PAH, Metals (As, Ba, Cd, Cr, Co, Cu, Fe, Ni, Pb, Hg, Va and Zn), OCP, OPP, PCB, Alkalinity, Sulfate, Ammonia, Chloride, Nitrate, Nitrite, Flouride, pH, Sodium, Calcium, Magnesium, Potassium, Phenols. – 7 samples
Soil Gas	23	23	RCA (2008), 1-23	Former landfill	CH_4 (%), CO_2 (%), O_2 (%) – 23 samples

[3] Excludes QA/QC duplicate and triplicate samples.

6 Areas and Contaminates of Potential Concern

The assessment has identified several potential sources of contamination, which are summarised in the table below.

Table 6-1 Site Activities and Potential Contaminates of Concern

Area of Environmental Concern	Site Activity / Potential Source	Contaminants of Potential Concern	Comments
Onsite Sources			
Landfill	▪ Dumping of waste in Swansea South landfill site	▪ Petroleum hydrocarbons (Polycyclic Aromatic Hydrocarbons [PAHs]) ▪ Total Recoverable Hydrocarbons (TRH) ▪ Benzene, Toluene, Ethyl-benzene, Xylenes and Napthalene (BTEXN) ▪ Organochlorine and Organophosphate Pesticides (OCP/OPP) ▪ Asbestos ▪ 8 Metals – As, Cd, Cr,Cu, Pb, Hg, Ni, Zn ▪ Foreign materials ▪ Soil Gas – Methane & Carbon Dioxide	▪ Based on observations during test pitting, non-putrescible domestic waste, building waste, car bodies and tyres were disposed as landfill.
Hydrocarbons	▪ Hydrocarbon storage, use and refueling activities associated with excavation of clay and other extractive operations	▪ TRH ▪ BTEX ▪ PAH ▪ 8 metals	▪ Use of heavy machinery
Surficial disturbance and filling	▪ Potential minor cut and fill operations	▪ PAHs ▪ TRH ▪ BTEXN ▪ 8 Metals ▪ OCP/OPP ▪ Asbestos ▪ Foreign materials	▪ Uncontrolled fill material is present onsite (construction of access track) ▪ Overburden and spoil as a result of previous clay excavation operations ▪ Contaminated soils and waste products were commonly used for filling purposes in the time period in which the site was developed.
Uncontrolled filling within the former clay pits area.	▪ Backfilling with uncontrolled materials	▪ PAHs ▪ TRH ▪ BTEXN ▪ OCP/OPP ▪ Asbestos ▪ 8 Metals ▪ Foreign materials	▪ Uncontrolled fill materials used within the backfilling of the former clay pit site.
Anthropogenic Materials	▪ Illegal dumping	▪ Building refuse ▪ Domestic refuse	▪ Illegal dumping has been reported to have occurred on site subsequent to landfill activities ceasing. Potential soil

		▪ Asbestos containing materials (ACM) ▪ Asbestos fibres in soils ▪ 8 Metals ▪ TRH ▪ PAHs	contamination within the immediate vicinity and near surface.
Offsite Sources			
Uncontrolled filling within the former mining areas, including Swansea quarry, former clay pits and Swansea open cut coal mine.	▪ Potential uncontrolled filling	▪ PAHs ▪ TRH ▪ BTEXN ▪ OCP/OPP ▪ Asbestos ▪ 8 Metals ▪ Foreign materials	▪ Uncontrolled fill materials used for backfilling
Waste storage	▪ Waste storage at Swansea quarry	▪ PAHs ▪ TRH ▪ BTEXN ▪ OCP/OPP ▪ Asbestos ▪ 8 Metals ▪ Foreign materials	▪ A former EPL permitted storage of waste at Swansea quarry, including general waste and asphalt waste.
Hydrocarbons	▪ Hydrocarbon storage, use and refueling activities associated with mining and other extractive operations.	▪ TRH ▪ BTEXN ▪ PAHs ▪ 8 Metals	▪ Use of heavy machinery
Potential pre-existing buildings and structures	▪ Potential hazardous building materials ▪ Remnants of former buildings.	▪ ACM ▪ Lead paint	▪ It is likely that buildings and structures existed offsite associated with mining operations. ▪ Age of any potential former structures indicate that ACM may have used in construction materials.
Anthropogenic Materials	▪ Illegal dumping	▪ Building refuse ▪ Domestic refuse ▪ ACM ▪ Asbestos fibres in soils ▪ 8 Metals ▪ TRH ▪ PAHs	▪ Illegal dumping has been observed off site along roads and access tracks. Potential soil contamination within the immediate vicinity and near surface.

7 Basis for the Remediation Criteria

7.1 Relevant Guidelines

The relevant guidelines used to assess the Site's contamination status and guide remediation works are those made or approved by the NSW EPA under Section 105 of the CLM Act 1997 as follows:

> Australian and New Zealand Guidelines for Fresh Water Quality – 95% protection for slightly disturbed to moderately disturbed ecosystems ANZECC (2000) [10].

> DEC NSW (2017) Contaminated Sites: Guidelines for NSW Site Auditor Scheme, 3rd Edition [11].

> NEPC (1999) National Environment Protection (Assessment of Site Contamination) Measure 1999 (2013) [12].

> NHMRC/NRMMC (2004) Australian Drinking Water Guidelines, National Health and Medical Research Council and Agriculture and Resource Management Council of Australia and New Zealand, 2004 [13].

> NSW EPA (1995) Contaminated Sites: Sampling Design Guidelines [14].

> NSW EPA (2014) Waste Classification Guidelines, Part 1: Classifying Waste [15].

> NSW EPA (2015) Guidelines on the Duty to Report Contamination under the Contaminated Land Management Act 1997 [16].

> NSW DECC, (2007) Guidelines for the Assessment and Management of Groundwater Contamination [17].

> OE&H (2011) Contaminated Sites: Guidelines for Consultants Reporting on Contaminated Sites, August 2011 [2].

7.2 Soil Investigation and Remediation Levels

The current assessment criteria used in NSW to evaluate soil analytical results are based on the DEC NSW, *Guidelines for the NSW Site Auditor Scheme, 2nd Ed.* (2006) and the *National Environment Protection (Assessment of Site Contamination) Amendment Measure 1999* (ASC NEPM, 2013). These combined guidelines present a range of Health-Based Soil Investigation Levels (SILs), sensitive land use thresholds and expected background concentration ranges for urban redevelopment sites in NSW. Application of these guidelines is briefly described below.

> **Health-based Criteria for the current and proposed land use**: ASC NEPM (2013) HILs for Residential and recreational land use, the Health Screening Levels (HSLs) and the CRC Care (2011) Soil Health Screening Levels for Direct Contact (SHSLs).

> **Environmental Criteria**: ASC NEPM (2013) Ecological Screening Levels (ESLs) and Ecological Investigation Levels (EILs) for Urban Residential/Public Open Space.

> **Aesthetics**: The consultant should also consider the need for remediation based on the 'aesthetic' contamination as outlined in Schedule B (1) of the ASC NEPM (2013) that states '*there are no numeric Aesthetic Guidelines however site assessment required balanced consideration of the quality, type and distribution of foreign material or odours in relation to the specific land use and its sensitivity*'. Soil odour and discolouration will need to be assessed during remediation.

> **General**: Although the ASC NEPM (2013) guidelines indicate that site-specific risk based remediation criteria should be developed as remediation criteria in preference to use of investigation levels (as they may be more conservative than required) the guidelines referenced above are considered appropriately conservative to be used for site remediation criteria based on the proposed Residential land use.

7.2.1 Health-based Soil Remediation Criteria

With consideration to the proposed residential land use, the following health-based remediation criteria in the tables below.

Table 7-1 Health Investigation Levels for Soil Contaminants

Analyte	HIL A Residential with garden / accessible soil	EIL/ESL for Urban Residential and Public Open Space Land Use (mg/kg)
Arsenic	100	100[1]
Cadmium	20	-
Chromium (VI)	100	190[2]
Copper	6,000	60[2]
Nickel	400	30[2]
Lead	300	1100[1]
Zinc	7,400	70[2]
Mercury (inorganic)	40	-
Hexachlorobenzene (HCB)	10	-
Heptachlor	6	-
Total Chlordane	50	-
Endosulfan	270	-
Endrin	10	-
Methoxychlor	300	-
Aldrin + Dieldrin	6	-
Sum of DDD + DDE + DDT	240	-
Chlorpyrifos	160	-
PCBs Total	1	-
Asbestos Containing Material (%w/w)	0.01	-
Friable Asbestos (as Asbestos in Soil) (%w/w)	0.001	

Table 7-2 Health Screening Levels for Soil Contaminants

Chemical	HSL A & HSL B Residential				HSL C recreational / open space				ESL
	0 to <1 m	1 to <2 m	2 to <4 m	4 m+	0 to <1 m	1 to <2 m	2 to <4m	4 m+	-
Sands									
Toluene	160	220	310	540	NL	NL	NL	NL	-
Ethyl benzene	55	NL	NL	NL	NL	NL	NL	NL	-
Xylenes	40	60	95	170	NL	NL	NL	NL	-
Naphthalene	3	NL	NL	NL	NL	NL	NL	NL	-
Benzene	0.5	0.5	0.5	0.5	NL	NL	NL	NL	-
F1	45	70	110	200	NL	NL	NL	NL	180
F2	110	240	440	NL	NL	NL	NL	NL	120
$>C_{16}$ - C_{34}	-	-	-	-	-	-	-	-	300
$>C_{34}$ – C_{40}	-	-	-	-	-	-	-	-	2800
Silts									
Toluene	390	NL	NL	NL	NL	NL	NL	NL	-
Ethyl benzene	NL	NL	NL	NL	NL	NL	NL	NL	-
Xylenes	95	210	NL	NL	NL	NL	NL	NL	-
Naphthalene	4	NL	NL	NL	NL	NL	NL	NL	-
Benzene	0.6	0.7	1	2	NL	NL	NL	NL	-
F1(9)	40	65	100	190	NL	NL	NL	NL	-
F2(10)	230	NL	NL	NL	NL	NL	NL	NL	-
$>C_{16}$ - C_{34}	-	-	-	-	-	-	-	-	1300
$>C_{34}$ – C_{40}	-	-	-	-	-	-	-	-	5600
Clay									
Toluene	480	NL	NL	NL	NL	NL	NL	NL	-
Ethyl benzene	NL	NL	NL	NL	NL	NL	NL	NL	-
Xylenes	110	310	NL	NL	NL	NL	NL	NL	-
Naphthalene	5	NL	NL	NL	NL	NL	NL	NL	-
Benzene	0.7	1	2	3	NL	NL	NL	NL	-
F1	50	90	150	290	NL	NL	NL	NL	-
F2	280	NL	NL	NL	NL	NL	NL	NL	-
$>C_{16}$ - C_{34}	-	-	-	-	-	-	-	-	1300
$>C_{34}$ – C_{40}	-	-	-	-	-	-	-	-	5600

7.2.2 Asbestos Soil Remediation Criteria

With respect to asbestos, Health screening levels are based on scenario specific likely exposure levels and are adopted from the NEPC (2013) Amendment. In accordance with these guidelines, the following remediation criteria presented below has been adopted.

Table 7-3 Asbestos Remediation Criteria

Health-Based Screening Level		
Form of Asbestos	**Residential**	**Recreational**
Bonded ACM	0.01%	0.02%
FA and AF[4]	0.001%	
All forms of asbestos	No visible asbestos for surface soil	

All asbestos monitoring should be undertaken in accordance with the Guidance Note on the Membrane Filter Method for Estimating Airborne Asbestos Fibres, 2nd Edition [NOHSC: 3003(2005)], Australian National Occupational Health and Safety Commission. The following types of air monitoring are proposed:

> Daily Control Monitoring during the entire period of the asbestos removal and placement work.

> Clearance Monitoring of an area at the completion of asbestos removal works.

The following control levels outlined in the table below not health-based guideline levels and should be used for determining the effectiveness of control measures.

Table 7-4 Airborne Asbestos Remediation Criteria

Control Level (airborne asbestos fibres/mL)[5]	Control/Action
< 0.01	Continue with control measure
≥ 0.01	Review control measure
≥ 0.02	Stop removal work and find the cause

The details of the monitoring program will be documented in an Asbestos Removal Control Plan developed by the licensed asbestos removal contractor.

[4]The screening level of 0.001% w/w asbestos in soil for FA and AF (i.e. non-bonded/friable asbestos) only applies where the FA and AD are able to be quantified by gravimetric procedures. This screening level is not applicable to free fibres.
[5]Obtained from Table 2 in the Australian Government National Occupational Health and Safety Commission, *Code of Practice for the Safe Removal of Asbestos 2nd Edition [NOHSC: 2002 (2005)].*

8 Conceptual Site Model

A conceptual site model (CSM) has been developed based upon the information provided in the previous reports and review of available data.

8.1 Sources and Mechanisms of Contamination

A number of potentially contaminating activities have been undertaken at the Site as follows:

> Based on the SKM (2002) report [3], it is understood that a clay pit was in operation in the eastern portion of the site from the early 1950s. The site ceased operations in the 1960s. Contaminated soils and waste products were commonly used for filling purposes at the time.

> The former clay pit site was operated as an informal landfill up until the mid-1970s by Lake Macquarie City Council (LMCC). In 1976 the landfill was closed, although fly dumping occurred for some time afterwards. It has been noted in the RCA report [1] that the waste comprised predominantly of non-putrescible domestic waste, building waste (including potential asbestos containing materials), car bodies and tyres.

8.2 Contamination Status

8.2.1 Soil – Health Based

The following samples contained concentration levels above the adopted threshold limits for Residential as detailed in National Environment Protection Measure (NEPM) for the Assessment of Site Contamination, 2013 [12], during the DSI conducted by RCA [1]. Sampling locations are shown on **Figure 2**, attached in **Appendix A**. For comparative analysis tables refer to **Appendix F.**

Health Investigation Levels (HILs):

> TP2-1 (2.0m) - Benzene (a) pyrene;

> TP12 – 1 (1.8m) - Lead;

> TP15-1 (1.5m) - Lead ;

> TP16-1 (0.6m) - Lead and Zinc;

> TP21-1 (2.0m) – Lead.

It should be noted that due to the previous TRH results expressed in superseded fractions, F2, F3 and F4 could not be expressed / determined. For the purpose of assessing results, C10 - C14 was used as F2 Fraction and C15 - C28 & C29 - C35 were summed together to calculate F3 fraction and due to the provided fraction range limited to C6- C36, F4 could not be assessed.

During the RCA [1] field investigation asbestos fibres were not detected within surface soil samples, although fragments of ACM (asbestos containing materials) were detected at site surface and within fill materials.

8.2.2 Soil – Ecological Based

The following samples contained concentration levels above the Residential Ecological Investigation Levels (EILs) as detailed in National Environment Protection Measure (NEPM) for the Assessment of Site Contamination, 2013 [12];

> Zinc – samples TP1-2, TP2-2, TP3-1, TP6-2, TP7-2, TP9-1, TP12-1, TP13-1, TP15-1, TP16-1, TP17-1, TP19-1, TP21-1, S3 (LF3), S5 (LF3), S8 (LF8) & S10 (LF10);

> Copper – samples TP2-2, TP9-1, TP12-1, TP15-1 & TP16-1; and

> Nickel – sample TP12-1.

The following samples contained concentration levels above the Residential Ecological Screening Levels (ESLs) as detailed in National Environment Protection Measure (NEPM) for the Assessment of Site Contamination, 2013 [12]:

> TP2-1 (2m) – Benzene (a) Pyrene, TRH F3;

> TP2-2 (4m) – TRH F3;

> TP3-2 (4.5m) – Benzene (a) Pyrene;

> TP7-2 (2.6m) – TRH F3;

> TP9-1 (2m) – TRH F3;

> TP15-1 (1.5m) – Benzene (a) Pyrene; and

> S6 / LF6 (unknown depth) - Benzene (a) Pyrene.

It should be noted that due to the previous TRH results expressed in superseded fractions, F2, F3 and F4 could not be expressed / determined. For the purpose of assessing results, C10 - C14 was used as F2 Fraction and C15 - C28 & C29 - C35 were summed together to calculate F3 fraction and due to the provided fraction range limited to C6- C36, F4 could not be assessed.

Sampling locations are shown on **Figure 2**, attached in **Appendix A**. For analysis tables refer to **Appendix F.**

8.2.3 Groundwater

Laboratory groundwater assessment was undertaken by RCA [1]. Based on the RCA data and review of the receptors the use of groundwater for irrigation or personal use is unlikely with the proposed residential land use. The potential groundwater contamination is considered an incomplete pathway and not a risk to human health. Therefore, drinking water guidelines are not relevant and ecological guidelines have been adopted. The receiving water bodies are Galgabbee Creek and Lake Macquarie, located approximately 1.5km north-west offsite.

A tri-linear plot was created by RCA and the plot demonstrates close relationships in water chemistry for bore BH1 and surface water sample SW4. Close relationships were also observed for SW1, SW2 and SW3. Based on the plot, bores BH2 and BH4 do not correlate with any of the other samples.

The following samples contained concentration levels above the NEPM (2013) Groundwater Investigation Levels for Fresh Water (95%) [12]:

> Cadmium – samples BH2, BH4, SW1, SW3 and SW4;
> Chromium – samples SW1, SW2 and SW3;
> Copper – samples BH1, BH2 and SW1 - SW3;
> Iron – samples BH1, BH2, BH4 and SW1-SW3;
> Nickel – samples BH4 and SW3;
> Lead – sample SW3;
> Vanadium – sample SW3; and
> Zinc – samples BH1, BH2, BH4 and SW1 – SW4.

Where no concentration level was given and insufficient data was stated in the ANZECC NWQMS (2000) a low to moderate or ECL trigger value was adopted from Section 8.3.7 of ANZECC (2000). For both Beryllium and Vanadium, the adopted guideline values retrieved from Section 8.3.7 as a result of insufficient data were less than the limit of reporting of the results. As a result, it should be conservatively considered that it is possible that the contaminants were at levels above the adopted guideline limiting values for the following samples:

> Beryllium – samples BH, BH2, BH4 and SW1-SW4; and

> Vanadium – samples BH, BH2, BH4, SW1, SW2 and SW4.

TRH was detected in all samples with the exception of SW1 & SW4, and total phenols were present in samples BH1, BH4, SW2 and SW3.

Sampling locations are shown on **Figure 2**, attached in **Appendix A**. For analysis tables see **Appendix F.**

8.2.3.1 Groundwater Impacts and Discussion

Based on the field investigation undertaken by RCA [1], perched water was not encountered across the extent of the Site, which indicates discontinuities with the deeper aquifer on site. The tri-linear plot prepared by RCA demonstrates no relationship between BH2 and BH4, indicating that perched water within the Site is not continuous. It is considered that the perched water is sourced and dependent on rainfall events. The deeper (actual) groundwater table was not sampled or analysed and was outside the scope of works of the RCA [1] investigation.

It is expected that the depth of groundwater is likely to be at depths greater than 10m from the surface based on hydrology, topography and review of past reports. The anticipated depth of natural groundwater and topography indicate that perched water would have a greater impact on surface water than the deeper groundwater.

The tri-linear plot demonstrated that surface water samples SW1, SW2 and SW3 are similar in water chemistry and are independent of other samples analysed. Based on the topography, location of these samples and RCA report [1], it is considered that they represent down gradient water quality from the Old Pacific Highway road alignment and are not impacted by leachate or run-off from the landfill area.

SW4 sample was collected further down gradient and the tri-linear plot demonstrates a relationship with BH1. This indicates that potentially the perched water from the landfill is extending to this point.

As SW1, SW2, SW3 are representative of surface water that is not indicated by landfill, the elevated concentration levels of metals and pH appear to be associated with background concentration levels.

TRH as identified in all samples and the highest concentration levels were detected within the landfill. The TRH concentrations are not considered to represent any health or environmental impact based on the down gradient sample (SW4) not containing elevated TRH concentration levels. Based on the Environ review, no further groundwater analysis was required.

8.2.4 Soil Gas

Soil gas sampling of landfill gas (methane, CO_2 and CO) was undertaken by RCA and a total of 23 landfill gas readings were collected from across the Site. Sampling locations are shown on **Figure 3**, attached in **Appendix A**.

The results indicated non-detectable readings for methane and carbon dioxide at all sampling locations.

8.3 Affected Media

Soils at the Site generally comprised of;

> Topsoil; silty sand; and

> Residual clays.

> Extensive filling at the site has been observed by RCA [1], comprising of building rubble, non-putrescible domestic waste, car bodies and tyres.

Other identified areas of uncontrolled filling include access tracks;

8.4 Human and Ecological Receptors

The current and future human receptors are considered to be the following

> Sales staff for land release.

> Potential customers inspecting the site.

> Residents to the north and east.

> Future maintenance and construction workers.

> Future residents and visitors

The current and future ecological receptors are considered to the be the following:

> Galgabbee Creek and Lake Macquarie, located approximately 1.5km north-west offsite.

> Wallarah National Park to the south-east.

> Current and proposed flora at the Site.

> The Pacific Ocean, located approximately 1km to the east of the site.

> Riparian zone located to the south-west of the site (traverses south-east/north-west)

8.5 Potential and Complete Exposure Pathways

The Site is currently secured and limited access is obtained by current site staff and trespassers. There is considered to a low risk to current site users given the limited exposure duration, the age and location of contamination and limited access.

The following exposure pathways are considered incomplete:

> Groundwater extraction for irrigation and personal use will be unlikely, thus dermal contact and ingestion of groundwater containing any potential elevated contaminants is considered an incomplete pathway.

The likely exposure pathways and exposed populations for the current and proposed future development are presented in Table 8-1 below.

Table 8-1 Potential Exposure Pathways

Sources	Media	Release Mechanism	Pathway	Licensed Groundwater bores in the vicinity of the Site	Future and Current Flora at the Site	Pacific Ocean located to the east	Lake Macquarie located to the north-west	Sales Staff and Customers	Current Residents to the East of the Site	Future Construction and Maintenance Workers	Future Residents
Petroleum hydrocarbon and heavy metal contaminated soils associated with landfill	Soil	Fugitive Dust	Air – ingestion	No	No	No	No	Yes	Yes	Yes	Yes
		Direct Contact	Soil – Dermal contact	No	No	No	No	Yes	No	Yes	Yes
			Soil – Ingestion	No	No	No	No	Yes	No	Yes	Yes
		Vapour intrusion	Vapour – inhalation	No	No	No	No	Yes	No	Yes	Yes
	Groundwater	Direct Contact	Groundwater – Dermal contact	No	No	No	No	No	No	No	No
			Groundwater – Ingestion	No	No	No	No	No	No	No	No
		Vapour intrusion	Vapour – inhalation	No	No	No	No	No	No	No	No
		Discharge to surface water	Groundwater discharge	No	No	No	No	No	No	No	No
		Bioaccumulation	Uptake by plants	No	No	No	No	No	No	No	No
	Stormwater	Overland flow	Surface water and sediments	No	No	Yes	Yes	No	No	No	No
			Ingestion by fish / shellfish	No	No	Yes	Yes	No	No	No	No
Asbestos contamination within soils	Soil	Direct Contact	Soil - Inhalation	No	Yes	No	No	Yes	No	Yes	No

Yes Yes

9 Remediation Objectives and Options

9.1 Remediation Objectives

The remediation objectives are outlined as follows:

> Undertake remediation to render the Site suitable for the proposed residential and commercial development;

> Validate the remedial works in accordance with the relevant guidelines; and

> Document the validation process.

9.2 Remedial Options

Remediation and/or management of the contaminated soil is required so that the Site does not pose an unacceptable risk to human and/or ecological health with respect to the proposed residential land use.

Remedial options that may achieve the remedial objectives are listed in the following order in *DEC Guidelines for the NSW Auditor Scheme, 2006*:

> On-site treatment utilising ex-situ bioremediation for hydrocarbon impacted material.

> Off-site disposal to licensed disposal facility lawfully able to accept the waste.

> Onsite encapsulation

The three options were assessed with consideration towards minimising risk to human health and the environment. A summary of the three (3) options, including an assessment of the advantages and disadvantages of each, are presented in **Table 9-1**.

Table 9-1 Comparison of Remedial Options

	Option	Strategy	Advantages	Disadvantages	Option Comparison
1.	Excavation, screening / segregation, recycling, stockpiling and on-site bioremediation and re-use.	On-site treatment of contamination	▪ No off-site disposal to landfill. ▪ Mitigates exposure pathways to future Site users and occupiers of adjacent land. ▪ Sufficient space is available for the stockpiled material to be placed in a bioremediation pad within the portion of the Site proposed for the wastewater treatment plant. ▪ No ongoing management required. ▪ Environmentally sustainable.	▪ Longer remediation time period required given that high chain hydrocarbons are encountered. ▪ Management of odours and dust required. ▪ Not a suitable remediation method for lead and chromium impact. ▪ Most of the material is unsuitable to stay on site	▪ Does not address all contaminates
2.	Excavation, screening / segregation, recycling, waste classification and off-site disposal to a waste management facility lawfully permitted to accept the material.	Source removal	▪ Removes potential future liability. ▪ Mitigates exposure pathways to future Site users and occupiers of adjacent land. ▪ No ongoing management required.	▪ Soil would need to be classified as a waste. ▪ Potential to generate dust. ▪ Shifts the contamination without removing it from the environment. ▪ Expensive	▪ Large costs associated with removal ▪ Large amount of material
3.	Excavation, segregation, cap and Contain of soil material	On-site encapsulation	▪ No off-site disposal to landfill. ▪ Mitigates exposure pathways to future Site users and occupiers of adjacent land. ▪ Environmentally sustainable. ▪ The engineered barrier cell can be located in the portion of the development proposed for commercial use	▪ Long time management and monitoring required. ▪ May not be acceptable to future tenants.	▪ Environmentally sustainable but would require ongoing management and monitoring costs.

9.3 Remedial Strategy

9.3.1 Preferred Remedial Option

Based on the three feasible remedial options presented in **Table 9-1** for the landfill area, on site encapsulation would be the most prudent options to remediate the site due to large volume of material onsite and costs associated to remove the material offsite. The recommended remedial option and remedial action plan for the area was undertaken by RCA [1] and was reviewed and endorsed by Environ [4].

The proposed remedial option within the proposed commercial footprint of the area is onsite encapsulation. The proposed remedial option selected for the residential area is the removal of all impacted fill materials and incorporation of the material into the encapsulation works within the commercial footprint.

The option to remediate the landfill area was previously reviewed and endorsed, the proposed capping strategy adopted by RCA [1] and with Cardno input is detailed below:

> Over excavation of natural materials within the proposed commercial footprint to provide enough volume to accommodate the placement of waste materials sourced within proposed residential areas.
> Removal of existing capping materials overlying the former landfill area.
> Removal of landfill within proposed reclaimed residential area and encapsulated within the proposed commercial area.
> Potential recycling of waste metals and steel.
> Validation of reclaimed residential area including asbestos clearance report and validation of capping materials.
> Given the asbestos fragments identified, as a precautionary measure, a surface emu bob will be undertaken prior to the placement of the marker layer.
> Placement of a marker layer comprising high visibility geotextile or similar on top of the waste.
> Placement of 1.0m of compacted clean fill. Fill can comprise any environmentally (such as ENM / VENM or site won material) and geotechnical suitable material.
> The final capped surface should achieve 1% slope to promote surface water run-off..
> Surface water drainage will be placed around the capped area to promote surface water movement away from the encapsulated materials.
> Capping to continue approximately 1.0 m past the edges of the encapsulation area (proposed commercial footprint.

The RCA report [1] indicated that the proposed capping thickness was considered valid for the following reasons:

> Fill materials (including soils) at the site comprised low contaminate concentrations.
> Risk of contamination is primarily asbestos and fibres. No asbestos fibres were detected within the limited sampling however; asbestos fragments were identified. The capping will ensure that the guideline of “no asbestos fibres or fragments in surface soils” is met.
> A high visibility marker layer will be placed. The playing field design will incorporate placement of engineered fill and drainage.
> A management plan is required and the high visibility marker will control any site works penetrating the capping material and provide protection to the capping layer.

It is noted that the most western portion and southern portion of the landfill area falls within the proposed residential footprint. The excavation of the impacted materials (former landfill) within the proposed residential footprint will be relocated to the commerical footprint where capping and onsite encapsulation will be undertaken.

The 1.0m capping will cover the extent of commercial area. The reclaimed residential area will be validated. The final areas illustrating the approximate extent of commercial and residential are shown (Dawing ID 503) on the construction plans**,** attached in **Appendix E**. It is likely that perched water will be encountered within the waste materials during earthworks operations. Seepage will be collected and irrigated back across the landfill.

It must be noted that a Sampling Analysis and Quality Plan (SAQP) is proposed for areas not previously assessed within Lot 3 and the remedial strategy may change depending the findings of the investigation. The SAQP is attached as **Appendix G**.

As no gas wells were previously installed and previous gas sampling was limited to “gas sweeping” at the surface, installation of gas wells shall be undertaken and sampled during remediation works to confirm the presence and aid in long term maintenance. Gas monitoring locations and methodology are detailed within the SAQP, attached as **Appendix G**.

This remedial assessment is based on the lowest potential long-term impact on the community and future users of the Site, highest environmental sustainability and net cost-benefit and is in accordance with the hierarchy for preferred remedial options.

9.3.2 Remedial Option Scope

The scope of work associated with the preferred remedial option can be broken down into the following stages:

1. Assigning roles and responsibilities.
2. Regulatory approval.
3. Preparation of construction (short-term) management controls, work health and safety (WHS) plans, Construction Environmental Management Plan (CEMP).
4. Development of an Unexpected Finds Protocol (UFP).
5. Site establishment.
6. Installation of gas wells for gas sampling and long term maintenance
7. Removal of vegetation / clearing.
8. Removal of existing capping layer – potential reuse.
9. Over excavation of natural materials within the proposed commercial area to accommodate the volume of impacted waste materials to be placed from residential area
10. Removal of current known contamination under environmental consultant supervision and placed within the commercial area for onsite encapsulation.
11. Removal of recyclable materials if appropriate.
12. Excavation of impacted materials within proposed reclaimed residential areas.
13. Placement of materials within the encapsulation area (commercial area)
14. Validation of the impacted soil excavation areas (reclaimed residential area). An asbestos clearance report of remaining underlying soils is required.
15. Emu bob potential asbestos fragments.
16. Placement of marker layer and 1.0 m capping layer.
17. Validation of encapsulation
18. Final site walkover to confirm the no presence of any potential contamination
19. Demobilisation.

9.3.3 Assigning Roles and Responsibilities

For the purposes of the remedial work, the roles and responsibilities are presented in **Table 9-2**.

Table 9-2 Roles and Responsibilities

Role	Party	Responsibilities
Principle/Owner	Wakefield Ashurst Developments Pty Ltd and Northern Managers & Construction Pty Ltd	▪ To engage the consultants and contractors and undertake all stakeholder management.
Contractor	To be confirmed	▪ To carry out the civil works associated with the remediation and ensure compliance with WHS controls and CEMP. Require contractors to maintain written records of activities undertaken each day and manage any unexpected findings.
Environmental Consultant	Cardno (NSW/ACT) Pty Ltd	▪ Confirm compliance with RAP ▪ To validate all excavations and remediated soils for reuse at the Site. ▪ To prepare a validation report.

9.4 Regulatory Approval

Prior to commencing the remedial works, all relevant approvals shall be obtained from the relevant landowners and regulatory authorities.

It is a requirement of the EMP that Council agree to noting the EMP on the Section 149 Certificates for onsite encapsulation.

9.5 Preparation of Construction Management Plans and Site Establishment

Prior to commencing the remedial works, all documentation must be finalised with staff and any other affected stakeholders informed. The likely documentation required would include:

> All regulatory and landowner approvals and notifications.

> Up to date Insurance certificates.

> A WHS plan.

> CEMP.

> Soil management and tracking.

> Sediment and erosional control.

> Groundwater and surface water protection

> Air quality including dust, noise and odour control.

> A construction Quality Assurance Plan.

Following approval of all the required documentation, the contractor can mobilise all plant, equipment and amenities as required, to complete the remedial works.

The works areas must be delineated with temporary fencing with adequate warning signage and restricted access including the adoption of appropriate induction procedures.

9.6 Approximate Extent of Remediation

The approximate proposed aerial extent of excavation of the landfill area is shown in shown and outlined in **Figure 1,** attached in **Appendix A**. The approximate final footprint of the reclaimed residential and commercial area within the former landfill area is shown on **Drawing ID 503** of the construction plans, attached in **Appendix E**.

It must be appreciated due to the presence of dense vegetation on site; it was difficult to assess the extent of fly tipping areas. Fly tipping appears to be predominately located within the vicinity of access tracks, Old Pacific Highway and Scenic Drive, which are outside the subject site.

An unexpected finds protocol will be required and put in place during remedial and earthworks operations shall any additional potential contamination be identified.

9.7 General Excavations and Earthworks Operations

The civil/remediation contractor will be required to develop the methodology for the works that should include at a minimum the following:

> All necessary environmental controls conforming at a minimum with those outlined in the CEMP for the Project are implemented prior to commencing the remedial works and appropriately maintained throughout the works period.

> All excavation, loading and transport of soil must be undertaken in a manner to minimise the generation of dust, odours and cross-contamination of uncontaminated areas of the Site.

> Monitoring for odours at the boundary of the work area.

> A suitably experienced environmental engineer/scientist to confirm that the visual and olfactory characteristics of the excavated materials are consistent with the remediation criteria will inspect excavations.

> Where field screening identifies potentially contaminated soil in the walls or base of the excavation, additional chase out of impacted soil will be undertaken.

> Imported fill for backfilling the excavations may include either:

-ENM/VENM and should be characterised in accordance with remediation criteria or the revised ENM exemption (2014) [18] as appropriate prior to being imported to Site.

9.8 Uncontrolled Fill Materials

From a geotechnical perspective, any uncontrolled fill materials (excluding identified waste materials) are required to be excavated, recondition, placed and compacted in accordance with AS3798 [19]. During this process, the fill materials will be visually assessed and determined whether additional testing of the fill materials will be required based on any olfactory indications of potential contamination i.e. staining, fibro fragments and odour. If the material is proposed to be utilised as the capping layer or within proposed residential areas, it will need to be assessed for suitability.

9.9 Aesthetic Considerations

Cardno recommends that housekeeping including the screening / segregation, recycling of anthropogenic materials should be undertaken to the extent practicable to address any aesthetic issues at the Site. Domestic refuse will be placed within the encapsulation.

However as the remedial option comprises of onsite encapsulation, the capping layer would address aesthetic considerations. The playing field design will incorporate placement of engineered fill and drainage. The surface will be vegetated and appropriate drainage will be in place to alleviate potential aesthetic issues associated with iron and groundwater.

9.10 Sampling Analysis and Quality Plan (SAQP)

Cardno have prepared a Sampling Analysis and Quality Plan (SAQP), attached in **Appendix G**. The SAQP was prepared to provide a sampling and analysis plan that will enable adequate characterisation of contamination at the Site and address any potential data gaps.

The SAQP recommends the installation of landfill gas monitoring wells, groundwater monitoring wells and soil sampling within the vegetated area of Lot 3. For the details of the proposed sampling locations, assessment criteria and methodology, refer to the SAQP, attached in **Appendix G**.

9.11 Contingencies

The following contingences should be considered for unexpected findings and issues:

> Additional excavation may also be required where unexpected contamination is identified during earthworks and further investigation and/or remediation is required.

> Should any contamination not identified in the RCA report [1] be uncovered then the unexpected finds protocol should be adopted by the civil contractor.

> The purpose of the unexpected finds protocol is to evaluate any unexpected situations that could occur during the project, and to specify measures that can be implemented to manage such circumstances. The UFP essentially refers subcontractors to inform authorities and consultants if there is unexpected find (skeletal, archaeological, asbestos etc.) after documentation and remediate f required.

> With reference to the RCA report [1], any unexpected materials (such as highly odorous or putrescible waste) will be designated to a separate stockpile for characterisation prior to placement within the encapsulated area. Materials not suitable for placement within the encapsulated area, offsite disposal to a licenced waste facility will be considered.

10 Unexpected Finds Protocol

10.1 Purpose

An Unexpected Find Protocol should be considered and be prepared to manage any unexpected occurrences that may arise during disturbance works. The purpose of the Unexpected Finds Protocol is to evaluate any unexpected situations that could occur during the project, and to specify safety measures that can be implemented to manage such circumstances and prevent any adverse environmental and human health impacts.

10.2 Procedure

The following procedure should be used to assess any unexpected Finds that are encountered throughout the duration of the project. Unexpected find may include but are not limited to heritage items, unidentified filling, odorous or stained contaminated soils, and suspected asbestos materials. All site personnel are required to report any unexpected finds to the site manager if observed during the course of their works.

10.2.1 Training and Induction of Personal

Personnel involved in earthworks operations on site are to be inducted and discussed at “toolbox” meetings on the unexpected finds protocol and awareness.

Site inductions would include the possibility of unexpected findings to make workers and personnel aware. Inductions will also include the immediate course of actions to be taken by workers if they were to find anything, including stopping work, notifying their supervisor immediately and completing the Incident Report forms.

10.2.2 Initial Response

If any unexpected/unidentified material is uncovered during disturbance works, the following procedure should be followed:

- Cease all works in the immediate area.
- Identify the category of the find (Contaminated Soils, Heritage, uncovering of Asbestos Materials etc.).
- Suspend work in that area of the site
- Delineate and restrict access to the area using fencing and /or appropriate barriers and signage.
- Ensure appropriate PPE is available for any persons required to enter the area.
- Document the nature of the find.
- Engage a suitably qualified consultant to assess the unexpected find. If in the event a Site Auditor has been engaged, the Site Auditor will be informed if considered necessary of the proposed assessment and / or management approach.
- The consultant will assess the unexpected find and provide advice regarding the preliminary assessment which will include the following:
    - The need for further immediate management controls if required;
    - Further assessment and / or remediation works required in accordance with relevant guidelines;
    - Amendment of this Remediation Action Plan (RAP) if required or provide clean up advice;
    - If required, clean up strategies of the affected site will be implemented following correspondence with the appointed Site Auditor.
- Works within the affected area are not to recommence until it is deemed safe and suitable for works to continue, following appropriate advice and clean up procedures.

10.2.3 Contaminated Soils

In the event that any odorous, stained or unidentified soils are uncovered during the disturbance works, a suitable qualified environmental consultant should be engaged to assess the material and the following procedures should apply:

> Excavation works at that part of the site where suspect soil material was encountered should cease until an inspection by an environmental consultant is carried out;
> Based on a visual inspection, Cardno will provide interim advice on health and safety of remedial works, soil storage and soil disposal to allow construction works to proceed if possible;
> Based on sampling and analysis Cardno will provide advice as to any additional requirements (i.e. managed on site or any offsite disposal requirements).

10.2.4 Asbestos Containing Materials (ACM) and Soils

Contingency measures should be utilised to evaluate any unexpected occurrences that could occur during asbestos clean-up works or general excavations, and to specify safety measures that can be implemented to manage such circumstances and prevent any adverse environmental and human health impacts.
Unexpected finds and appropriate contingency measures in relation to asbestos impacted soils include:

> Excavation works at that part of the site where suspect asbestos material was encountered should cease until an inspection by an environmental consultant is carried out;
> Any isolated dumping areas that appear to have fibrous sheeting should be inspected by an environmental consultant.
> Based on a visual inspection, Cardno will provide interim advice on health and safety of remedial works, soil storage and soil disposal to allow construction works to proceed if possible;
> Based on sampling and analysis Cardno will provide advice as to any additional requirements (i.e. managed on site or any offsite disposal requirements).

Following an inspection and sampling for laboratory testing (where required), works can continue following advice.

11 Validation of the Remedial Works

11.1 Data Quality Objectives

To identify the requirements for Site validation, Cardno has adopted the data quality objectives (DQOs) planning process as recommended in ASC NEPM (2013) [20], required in the DEC (2006) [11] and with consideration to technical details outlined in US EPA (2006) [21] and AS 4482.1 (2005) [22]. A review of all soil and groundwater data collected from the Site was undertaken to develop a preliminary CSM. Details of the DQOs process are presented below.

11.1.1 State the Problem

The site has undergone clay-mining activities and housed the Swansea open cut mine operations. The central former clay pit site began to be utilised by Lake Macquarie City Council (LMCC) in the 1960s to store waste. The site operated as an informal landfill up until the mid-1970s. In 1976, the landfill was closed, although fly dumping occurred for some time afterwards.

The Site requires remediation/management to ensure that there is no current or future ecological or health risk posed to future Site users or occupiers of adjacent land.

The stakeholders identified for the remediation project are:

> Lake Macquarie City Council (LMCC) ;

> The NSW EPA;

> Wakefield Ashurst Developments Pty Ltd and Northern Managers & Construction Pty Ltd the Site owner;

> Civil and remediation contractor (contractor to be confirmed).

11.1.2 Identify the Decision

The decision entails whether remediation of the impacted soil can render the Site suitable for the proposed residential and commercial development. Based on the remediation options review, it is considered that this will be best achieved by site encapsulation of the former landfill area.

11.1.3 Identify Inputs into the Decision

The inputs required to make the decision include the following:

> Results of analytical testing of the COPC in soil, fill from excavations, and remediated soil.

> Visual observations of the removal of anthropogenic materials.

In relation to the on-site encapsulation area, RCA [1] provided the following inputs:

> Confirmation that all materials have been excavated from the residential footprint.

> Confirmation that the waste materials are contained beneath the capping layer.

> Confirmation that placement of capping is undertaken in accordance to the RAP requirements.

> Confirmation materials imported to site are validated for its intended purpose.

11.1.4 Define the Boundaries of the Study

The site is identified as the proposed residential development known as Northern Precinct, Wallarah Peninsula development, located at 471 & 573 Pacific Highway, 523, 532 & 534 Old Pacific Highway, Pinny Beach NSW ('the Site'). The subject site is limited to Lot 3. The approximate boundaries of the former landfill area is identified in **Figure 1**, attached in **Appendix A**

The site boundaries will be determined by survey and marked on site, including the delineation of the residential footprint.

11.1.5 Develop a Decision Rule Identify the Decision

The statistical parameters of interest are the COPC and the validation criteria are presented in Section 7. These criteria have been used as validation criteria for residential development to determine suitability of the Site for residential development. The following decision statements for analysis of the results were adopted with respect to the adopted criteria:

11.1.5.1.1 Soil Health-based Validation Criteria

i. Where the data sets are not sufficiently populated to allow calculation of the 95% UCL_{mean} then the individual results must be less than the adopted criteria. If all the individual results are below the adopted criteria then no additional assessment and/or management is required. Where individual results exceed that adopted criteria, then further assessment and/or management is required.

ii. In accordance with the ASC NEPM (2013), where 95% UCL_{mean} of the average concentration for each soil analyte can be calculated, then the 95% UCL_{mean} must be below the adopted criteria; no single analyte concentration exceeds 250% of the adopted criteria; the standard deviation of the results must be less than 50% of the adopted criteria; and the normal distribution will only be used where the coefficient of variance is not greater than 1.2. Where 95% UCL_{mean} results exceed the aforementioned criteria, then further remediation is required.

11.1.5.1.2 Soil Ecological Validation levels

Soil ecological validation levels are taken from the ASC NEPM (2013) Ecological Screening Levels (ESLs) and Ecological Investigation Levels (EILs) for Urban Commercial/Industrial. The standard application depth of the NEPM Ecological Screening Levels (ESL) is 2 m or less. However due to the following reasons, this application depth is considered overly conservative for the Site in an residential setting, and that hydrocarbon impacts at 1 m or greater do not pose an unacceptable risk to ecological receptors at the Site:

> The Site is located within an area fronting a former major highway, therefore the redeveloped Site, and will continue to be a highly disturbed ecosystem. As a result, ecological receptors existing (other than man made garden beds from eventual redevelopment) are highly unlikely;

> No rationale is provided in NEPC (1999, as amended 2013) for the derivation of the 2 m application depth;

> Potential adverse effects on which ESLs are based are related to reduced shoot and root length at germination (Stephenson et. al. 2000). Many plants (including grasses and herbaceous plants) establish roots in surface soils typically less than 1 m depth (enHealth 2003) and therefore will not be adversely impacted by contamination at a depth of greater than 1 m;

> Invertebrates such as earthworms feed in the litter layers in the upper layers of the root zone and typically burrow to depths of 0.6 m. Some invertebrates may burrow to depths of 2 m to 3 m however they return to the surface to feed;

> Microbial organisms will not be negatively impacted by petroleum hydrocarbons (Lui et. al. 2014, Wu et. al. 2014). Conversely, petroleum hydrocarbons stimulate microorganism activity as it serves as a food source;

> The toxicity of aged petroleum hydrocarbons is typically less than for fresh petroleum hydrocarbons on which the ESL are based (enHealth 2003, CCME 2010); and

> ESLs are considered to be either low reliability guidelines (benzene, toluene, ethyl benzene, xylenes, F2 Fraction, F3 Fraction and F4 Fraction) or a medium reliability guideline (F1 Fraction) because the method for deriving ESLs was based on a statistical approach which used data from three to five species from two different trophic levels (plants and invertebrates). However, for high reliability, ecological criteria should be derived with five or more species from three trophic levels (including bacteria and/or soil processes) (Warne 2010a, Warne 2010b).

> Therefore, based on the above justification, a 1 m application depth for ESLs is used for assessing soil analytical results from the Site.

11.1.6 Specify Acceptable Limits of Decision Errors

The acceptable limits will be as follows:

i. Individual or 95% UCL $_{mean}$ concentrations are below the adopted criteria.

ii. 95% of the data will satisfy the data quality indicators (DQIs) which were determined for completeness, representativeness, precision and accuracy of both field and laboratory data. Therefore, the limit on the decision error will be 5% that a conclusive statement may be incorrect.

iii. A comprehensive quality assurance/quality control (QA/QC) program will be undertaken including representative sampling and sampling at an appropriate density for the purpose of the investigation.

The acceptable limit of error for sampling techniques and laboratory analysis is defined by the DQIs as follows:

11.1.7 Data Representativeness

Expresses the accuracy and precision with which sample data represents and an environmental condition. Data representativeness is achieved by the collection of samples at an appropriate pattern and density as well as consistent and repeatable sampling techniques and procedures.

11.1.8 Completeness

Refers to, the percentage of data that can be considered valid data. Sufficient data is required to enable an assessment of the decision rules.

11.1.9 Comparability

A qualitative comparison of the confidence with which one data set can be compared to another. This is achieved through consistent sampling and analytical testing and reporting techniques.

11.1.10 Precision

Precision is the quality of reproducibility of measurements under a given set of conditions. The relative percent difference (RPD) has been adopted to assess the precision of data between duplicate sample pairs according to the following equation.

$$RPD\% = \frac{[\mathrm{Cp} - \mathrm{Cd}]}{\mathrm{Cp} + \mathrm{Cd}} \times 200$$

Where:
Cp = Primary sample
Cd = Duplicate Sample

An acceptance criterion of ±30% had been adopted for inorganic field duplicates, triplicates, and ±50% for organic field duplicates and triplicates. However, it should be noted that exceedances of these criteria are common for heterogeneous soil or fill or for low analyte concentrations.

11.1.10.1 Accuracy

Is a measure of the bias in the analytical results and can often be attributed to field contamination; insufficient preservation or sample preparation; or inappropriate analytical techniques. Accuracy of the analytical data is assessed by consideration of laboratory control samples, laboratory spikes and analytical techniques in accordance with appropriate standards. Accuracy of the fieldwork is assessed against an assessment of field blank, field trip and rinsate results.

11.1.11 Optimise the Design for Obtaining Data

The site has undergone clay-mining activities and housed the Swansea open cut mine operations. The central former clay pit site began to be utilised by Lake Macquarie City Council (LMCC) in the 1960s to store

waste. The site operated as an informal landfill up until the mid-1970s. In 1976, the landfill was closed, although fly dumping occurred for some time afterwards.

11.2 Data Quality Indicators

The DQOs, requirements and indicators for the assessment are presented in **Table 11-1** below.

Table 11-1 Data Quality Objectives, Requirements and Indicators

Data Quality Objective	Requirement	Data Quality Indicator
Precision		
Intra-laboratory Duplicates	1 per 20 samples	RPDs < 50%
Inter-laboratory Duplicates	1 per 20 samples	RPDs < 50%
Laboratory Duplicates	Minimum of 1 per batch per analyte.	RPDs < 50%
Accuracy		
Laboratory Matrix Spikes	1 per batch per volatile/semi-volatile analyte	Recoveries 50% to 150%
Laboratory Surrogate Spikes	1 per volatile/semi-volatile analyte sample (as appropriate)	Recoveries 70% to 130%
Laboratory Method Blanks	At least 1 per batch per analyte tested for	Result < Limit of reporting
Laboratory Control Samples	At least 1 per batch per analyte tested for	Result < Limit of reporting
Trip Blanks	1 per lab batch for volatile analytes	Result < Limit of reporting
Trip Spikes	1 per lab batch for volatile analytes	Recoveries 60-100%
Rinsate samples	1 per each sampling day	Result < Limit of reporting
Representativeness		
Sampling methodology	Appropriate for the sample type and analytes	Meet Requirement
Samples extracted and analysed within holding times	Specific to each analyte	Meet Requirement
Comparability		
Sampling approach	Consistent for each sample	Meet Requirement
Analysis methodology	Consistent methodology for each sample	Meet Requirement
Handling conditions and sampler	Consistent for each sample	Meet Requirement
Field observations and analytical results	Field observations to support analytical results	Meet Requirement
Consistent laboratory Limit of Reporting (LOR)	Consistent between primary and secondary laboratories	Meet Requirement
Completeness		
Chain of Custody Documentation	Appropriately completed	Meet Requirement
Field Sampling Documentation	Appropriately completed	Meet Requirement
Satisfactory quality assurance/ quality control procedures	In accordance with relevant guidance	Meet Requirement

11.3 Validation Works and Testing

The methodology to validate all soils, which will remain on the Site, will be undertaken according to the methodology in the sections below.

11.3.1 Landfill – Capping Validation Programme

As the capping validation programme prepared by RCA was reviewed and endorsed, the proposed capping validation by RCA [1] is detailed in table below:

Table 11-2 Proposed Validation Sampling – Proposed by RCA

Validation Component	Validation Programme
Residential footprint (reclaimed)	▪ Sampling across the site is to be undertaken on a 15m triangular grid spacing. This sampling programme is in accordance with the NSW EPA Sampling Design Guidelines. ▪ Samples to be analysed for metals (As, Cd, Cr, Cu, Ni, Hg, Pb and Zn), TRH, BTEXN and PAH. ▪ Approximately 25% of the samples will additionally be analysed for OCP, PCB and asbestos fibres. ▪ Asbestos clearance certificate required after remediation and prior to placement of Fill ▪ Laboratory analysis shall be assessed in accordance with the NEPM Residential Guidelines.
Monitoring of fill placement	▪ Routine monitoring will be undertaken during placement of fill on the commercial site. ▪ Monitoring records will include photographic logs, gas monitoring to 0.05% (methane, carbon dioxide, carbon monoxide) by landfill meter of fill materials and field logs of material descriptions via gas sweeping. ▪ Asbestos air monitoring will need to be undertaken daily and four (4) pumps will be placed along the boundaries of site works and potentially within a high traffic area ▪ Asbestos cowls would be recovered daily and analysed ▪ Monitoring is to be undertaken at least daily throughout the exaction and placement programme at the direction of the Environmental Superintendent. ▪ Monitoring shall be undertaken by a suitable qualified environmental consultant.
Content of the soil capping layer and other clean fill	▪ Soil material used within the capping layer must be suitable for use. Soils are to be analysed for (As, Cd, Cr, Cu, Ni, Hg, Pb and Zn), TRH, BETX and PAH. ▪ Approximately 25% of the samples will additionally be analysed for OCP, PCB and asbestos fibres. ▪ As a guide, soil sampling should be undertaken at a rate of one (1) sample per 250 m^3 and a minimum of three (3) samples per stockpile (can calculate UCL for each domain). However, sampling should consider the material origin and site history and the statistical guidelines for sampling from the NSW EPA Sampling Design Guidelines. ▪ Variations to this may occur where clean fill is to be validated in situ. In this instance, a site-specific sampling plan will be developed by an appropriately qualified environmental consultant. ▪ Laboratory analysis shall be assessed in accordance with the NEPM Public Open Space Guidelines for materials proposed to be used as capping.
Placement of soil capping structure / layer	▪ Compilation of soil tracking logs which indicate the placement of impacted material beneath capping structure / layer. ▪ Compilation of photographs with the location drawing and date verifying the placement of the marker layer. ▪ Verification by survey of the placement of the 1.0 m filling of suitable material (as validated according to the above point). ▪ Final landform surface verifying surface slope. ▪ Compaction records.

11.3.2 Air Monitoring

Clearance air monitoring will be undertaken across the works areas where asbestos was excavated and placed.

11.3.3 Imported Fill

It is envisaged that imported construction materials such as pavement gravel or pipe backfill will be required as part of the development. On the basis, that these materials are sourced from natural quarries or have been subjected to assessment under an appropriate waste exemption no further validation will be required.

If any general filling material is imported to the Site (that is, filling other than imported construction materials such as pavement gravel or pipe backfill sourced from natural quarries) will need to be validated prior to importation. Imported materials must be classified as either ENM or VENM and documentation provided by the supplier. Confirmatory testing of ENM / VENM materials may be required based on the quality of materials delivered to Site (indications of foreign materials, staining, odours etc.) or where it is sourced.

11.3.4 Validation Reporting

At the completion of the remedial works a Validation Report should be prepared in accordance with the requirements of the OEH (2011) Contaminated Sites: Guidelines for Consultants Reporting on Contaminated Sites [2], including:

> A description of the works undertaken.

> A presentation of the laboratory analytical data.

> Comparison of the analytical results against the adopted validation criteria.

> Recommendations for further investigation and/or remediation works required at the Site (if required).

12 Construction Environmental Management Plan

12.1 Overview

A contractor prepared CEMP will be required prior to commencing the remediation works.

12.2 Hours of Operation

Remediation works shall be undertaken during the following hours:

> Monday to Friday: 7:00 am to 5:00 pm.

> Saturday: 8:00 am to 1:00pm.

> Public Holidays and Sunday: No work permitted.

Emergency work is permitted to be completed outside of these hours.

12.3 Soil and Water Management

To prevent the off-site migration of impacted soil, silt fences shall be constructed at the down-gradient boundaries of the works. Any material which is collected behind the sediment control structures shall be tested to confirm suitability to remain at the Site or for off-site disposal.

In a storm event, the on-site sediment control structures will need to be monitored and replaced or altered if necessary. Collected material will need to be managed in accordance with the remediation works.

12.4 Disposal of Contaminated Soil

Should there be surplus soil that cannot be accommodated within the Site; the spoil will then need to be classified in accordance with the NSW EPA (2014) Waste Classification Guidelines, Part 1 Classifying Waste [15].

12.5 Site Access

The remediation work area perimeter will need to be secured to restrict access to authorised persons only.

12.6 Noise and Vibration

All machinery and equipment used will be in good working order and will be fitted with appropriate silencers when necessary and all equipment will be operated in an efficient manner. The contractor will adopt suitable methodology to ensure that vibrations will not cause damage to structures located at the Site and on adjoining land.

12.7 Air Quality

12.7.1 Dust Control

Dust emissions should be confined within the Site boundary. The following dust control procedures will be employed to comply with this requirement as necessary:

> Erection of dust screens around the perimeter of the Site.

> Securely covering all loads entering or exiting the Site.

> Use of water sprays across the Site to suppress dust.

> Covering of all stockpiles of contaminated soil remaining on-site more than 72 hours.

> Keeping excavation and stockpile surfaces moist.

12.7.2 Odour Control

If significant odours are identified at the boundary of the Site, then appropriate actions will be taken to reduce the odours, which may include increasing the amount of covering of excavations/stockpiles; mist sprays; odour suppressants or maintenance of equipment.

12.8 Imported Fill

The conditions regarding the importation of filling material onto the Site as discussed in Sections 8.9.2 and 9.3.2 shall be applicable. Any materials proposed to be imported onto the must be classified as VENM or ENM and an appropriate report for the material must be made available to the environmental consultant prior to importation of the material.

12.9 Long Term Management of Capping Layer

A Long term Environmental Management Plan (LEMP) will be required to incorporate the management and maintenance of the capping layer. With reference to the RCA report [1], the LEMP should be developed to:

> Maintain the integrity of the capping layer;
> Ensure the appropriate management of any waste soils generated from beneath the cap;
> Provide protection to workers who may penetrate the cap during construction or maintenance activities; and
> Describe a management strategy should unexpected waste materials are encountered following completion of capping.

The RCA report [1] also indicated that the EMP should comprise but not restricted to the following;

> Surveyed diagram of the site;
> Description of contamination remaining on site;
> Discussions of the potential for unknown contamination;
> Controls implemented for the protection of human health and the environment;
> Measures that must be implemented or maintained to continue the protection of human health and the environment; and
> Responsibility for the implementation of the EMP.

13 Health and Safety

Health and safety during the remediation works will be the responsibility of the contractor, including the preparation of a Health and Safety Plan and a hazard assessment.

13.1 Work Health and Safety Plan

A WHS plan will be prepared for the remedial works by the contractor. The purpose of the WHS plan is to provide all relevant information to all Site personnel to ensure that they are aware of the hazards and the protective measures adopted to mitigate the identified hazards.

13.2 Hazard Assessment

All hazards associated with the remedial works should be identified by the contractors and incorporated into the WHS plan.

13.3 Safe Work Practices

The WHS plan will document all safe work practices required to protect personnel at the Site involved in the remedial works.

14 Conclusions

The site has undergone clay mining activities and housed the Swansea open cut mine operations. The central former clay pit site began to be utilised by Lake Macquarie City Council (LMCC) in the 1960s to store waste. The site operated as an informal landfill up until the mid-1970s. In 1976, the landfill was closed, although fly dumping occurred for some time afterwards, which were limited to the vicinity of access tracks and Old Pacific Highway.

RCA have previously prepared a DSI/ RAP report [1] for the former landfill area, which was reviewed and endorsed by Environ [4]. As such, the RAP adopts data and remedial strategies from the above previous reports.

A remedial action plan was developed and the preferred strategy was on-site encapsulation of the former landfill area. It is noted that the western and southern portion of the landfill area falls within the proposed residential footprint.

It is proposed that excavation of the impacted materials (former landfill) within the proposed residential footprint will be relocated to the commercial footprint where capping and onsite encapsulation will be undertaken. Over excavations of natural material will be undertaken within the proposed commercial area to accommodate the volume of waste materials within the proposed the residential footprint. 1.0 m cap will placed across the commercialarea following placement of waste materials.

The former landfill area is predominately located within the proposed commercial area. The reclaimed residential area will be validated.

An SAQP was prepared by Cardno to address any potential data gaps, attached in **Appendix G.** The RAP may require amendments following the investigation and findings of the SAQP investigation.

Cardno Pty Ltd considers that following implementation of the remedial measures and associated activities documented in the RAP and provision of a validation report, the Site can be made suitable for the proposed residential and commerical development.

15 References

[1] RCA Australia, “Environmental Site Assessment and Remedial Action Plan Former Swansea Landfill Wallarah North Precinct,” 2008.

[2] OE&H, “Contaminated Sites: Guidelines for Consultants Reporting on Contaminated Sites,” Office of Enviromental and Heritage, 2011.

[3] Sinclari Knight Mertz, “Wallarah Peninsula Geotechnical Review,” 2002.

[4] Environ Australia Pty Ltd, Review Advice No.5 - Former Swansea South Landfill RAP Review, Swansea, NSW, Ref AS130198, 2008.

[5] Sinclai Knight Mertz, “Former Swansea South Tip Site, Geotechnical and Contamination Report, Final,” 2003.

[6] NSW Trade and Investment Resources and Energy, “Gosford-Lake Macquarie 1:100 000 Geological Map Sheets 9131, 9231.”.

[7] Department of Land and Water Conservation, “Swansea Acid Sulfate Soil Risk Map, Edition 2,” December 1997.

[8] Lake Macquarie City Council, “Lake Macquarie Local Environment Plan, Acid Sulfate Soils Map - Sheet CL2_010d,” 2014.

[9] Lake Macquarie City Council, “Lake Macquarie Local Environment Plan, Acid Sulfate Soils Map - Sheet CL2_010B,” 2014.

[10] ANZECC National Water Quality Management Strategy, “Australian and New Zealand Guidelines for Fresh and Marine Waters Volume 1,” Australian and New Zealand Environment and Conservation Council , October 2000.

[11] NSW DEC, “Contaminated Sites: Guidelines for the NSW Site Auditor Scheme (2nd Edition),” Department of Environment and Conservation NSW, April 2006.

[12] National Environment Protection (Assessment of Site Contamination) Measure 1999, “Schedule B1 Guidelines on Investigation Levels For Soil and Groundwater,” National Environment Protection Council (NEPC), 16 May 2013.

[13] NHMRC/NRMMC, National Water Quality Management Strategy: Australian Drinking Water Guidelines 6 2011 (Version 2.0, December 2013), National Health and Medical Research Council (NHMRC) and the Natural Resource Management Ministerial Council (NRMMC), December 2013.

[14] NSW EPA, Contaminated Sites, Sampling Design Guidelines, NSW Environment Protection Authority, September 1995.

[15] NSW EPA, “Waste Classification Guidelines - Part 1: Classifying Waste,” NSW Environment Protection Authority, Sydney, November 2014.

[16] NSW EPA, Guidelines on the Duty to Report Contamination under the Contaminated Land Management Act 1997, NSW Environment Protection Authority, 2015.

[17] NSW DECC, Guidelines for the Assessment and Management of Groundwater Contamination, NSW Department of Environment and Climate Change, 2007.

[18] NSW EPA, “The Excavated Natural Material Order 2014,” NSW Environment Protection Authority, 2014.

[19] Australian Standard AS3798-2007, “Guidelines on Earthworks for Commercial and Residential Structures,” Standards Australia, 2007.

[20] National Environment Protection (Assessment of Site Contamination) Amendment Measure 2013 (No. 1), “Schedule B2 Guidelines on Site Characterisation,” National Environment Protection Council (NEPC), 2013.

[21] EPA/240/B-06/001, Guidance on Systematic Planning Using the Data Quality Objectives Process, EPA QA/G-4, US Environmental Protection Agency (USEPA), 2006.

[22] Australian Standard AS4482.1-2005, Guide to the Investigation and Sampling of Sites with Potentially Contaminated Soil, Part 1: Non-Volatile and Semi-Volatile Compounds, Standards Australia, 2005.

Lot 3 - Northern Precinct, Wallarah Peninsula

APPENDIX B

RCA REPORT

ENVIRONMENTAL SITE ASSESSMENT AND REMEDIAL ACTION PLAN

FORMER SWANSEA LANDFILL WALLARAH NORTH PRECINCT

Prepared for

Mr Daryl Fidge

On behalf of

Stockland Wallarah Peninsula Pty Limited

Prepared by

RCA AUSTRALIA

RCA ref 6621-402/2

September 2008

RCA Australia
92 Hill Street, Carrington NSW 2294

Telephone: (02 4902 9200
Fax: (02) 4902 9299
Email: administrator@rca.com.au
Internet: www.rca.com.au

DOCUMENT STATUS						
Rev No	Comment	Author	Reviewer	Approved for Issue (Project Manager)		
				Name	Signature	Date
/0	Draft	F Robinson	P Noonan	F Robinson		12.06.08
/1	Draft	F Robinson	P Noonan	F Robinson		20.06.08
/2	Final	F Robinson	P Noonan	F Robinson	Robinson	16.09.08

DOCUMENT DISTRIBUTION				
Rev No	Copies	Format	Issued to	Date
/0	1	Electronic (email)	Stockland Wallarah Peninsula Pty Limited - Daryl Fidge	12.06.08
/0	1	Electronic report	RCA – job archive	12.06.08
/1	1	Electronic (email)	Environ – Phil Hitchcock	20.06.08
/1	1	Electronic (email)	Stockland Wallarah Peninsula Pty Ltd – Mr Daryl Fidge	20.06.08
/1	1	Electronic	RCA – job archive	20.06.08
/2	9	Bound	Stockland Wallarah Peninsula Pty Limited – Lewis Bird	16.09.08
/2	1	Electronic report	Stockland Wallarah Peninsula Pty Limited – Lewis Bird	16.09.08
/2	1	Electronic report	RCA – job archive	16.09.08
/2	1	Bound	Environ – Phil Hitchcock	16.09.08

RCA ref 6621-402/2

RCA AUSTRALIA
GEOTECHNICAL • ENVIRONMENTAL

Geotechnical Engineering
Engineering Geology
Environmental Engineering
Hydrogeology
Construction Materials Testing

16 September 2008

Stockland Wallarah Peninsula Pty Ltd
11 Shoreside Row
MURRAYS BEACH NSW 2281

Attention: Mr Lewis Bird

ENVIRONMENTAL SITE ASSESSMENT AND REMEDIAL ACTION PLAN FORMER SWANSEA LANDFILL – WALLARAH NORTH PRECINCT

EXECUTIVE SUMMARY

This report presents a Phase 2 Environmental Site Assessment (ESA) and Remedial Action Plan (RAP) for the Former Swansea South Landfill. The site is located beside the Old Pacific Highway approximately 2km south of Swansea and is approximately 4.04Ha in size.

The area of site investigation is shown on **Drawing 1**, **Appendix A**. The site is within the Wallarah Peninsula Estate, North Precinct subdivision. The site is currently not used and is an abandoned informal landfill. The proposal is to develop the site as a community oval and residential subdivision as part of the overall Wallarah Peninsular development.

The report is required as part of the Development Application for this precinct. The objective of the investigation was to determine the existing characteristics of this area and develop a RAP for remediation of the site prior to final development.

This report was requested Mr Daryl Fidge of Stockland Wallarah Peninsula Pty Limited.

The scope of work for the environmental site assessment involved a site walkover, shallow and deep soil sampling, gas survey and soil and groundwater sampling. Historical and current data review was then undertaken to ascertain the site contaminants and the risks to human health and the environment represented by the site and on that basis determine a suitable remedial strategy.

The site assessment found that asbestos fragments are present within fill materials. Isolated areas of PAH and lead contamination have also been identified. Impacts to perched water within the landfill are minor and have not been shown to impact on the down gradient surface water. Human health risks were identified for site occupants due to the presence of soil contaminants. The presence of filling and waste materials at the surface also diminishes the local amenity, and aesthetic considerations were included in the development of the remedial strategy.

A remedial action plan is required to address human health risks and it was determined that remediation by on site encapsulation within the recreational footprint was the preferred remedial strategy. The strategy requires the excavation of impacted materials on the proposed residential footprint and relocation to the recreational footprint. Capping is then undertaken by the placement of a marker layer and 0.2m of clean soils. Future management of the capping layer will be undertaken through an EMP.

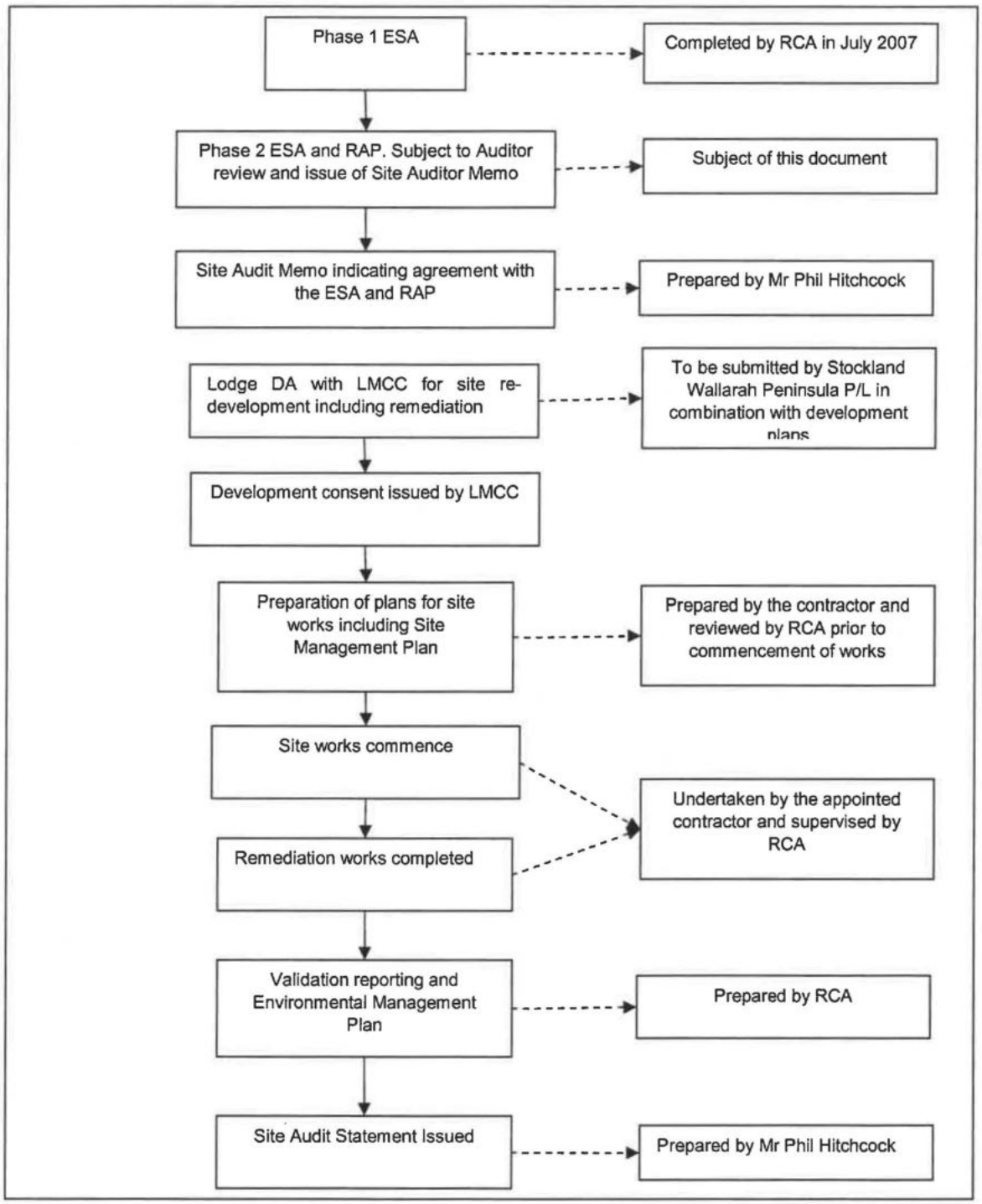
Contents

1 SCOPE OF WORK

This ESA has involved a review of available information including historical, soil, water and soil gas sampling, data interpretation and reporting. The data analysis programme then allowed for development of a RAP to make the site suitable for the proposed mixed residential and recreational use.

2 SITE ASSESSMENT PROCESS

The site assessment process for the development is outlined in the following flow chart. The process is in accordance with DECC and LMCC requirements.


Phase 1 ESA
Completed by RCA in July 2007
Phase 2 ESA and RAP. Subject to Auditor review and issue of Site Auditor Memo
Subject of this document
Site Audit Memo indicating agreement with the ESA and RAP
Prepared by Mr Phil Hitchcock
Lodge DA with LMCC for site re-development including remediation
To be submitted by Stockland Wallarah Peninsula P/L in combination with development plans
Development consent issued by LMCC
Preparation of plans for site works including Site Management Plan
Prepared by the contractor and reviewed by RCA prior to commencement of works
Site works commence
Undertaken by the appointed contractor and supervised by RCA
Remediation works completed
Validation reporting and Environmental Management Plan
Prepared by RCA
Site Audit Statement Issued
Prepared by Mr Phil Hitchcock

3 SITE IDENTIFICATION

The Wallarah Peninsula North Precinct project area is 180Ha in area and is situated on a ridge between Lake Macquarie and the Tasman Sea (Pacific Ocean). The former Swansea Landfill occupies a 4.04Ha land area in the southern portion of the precinct.

The former Swansea Landfill site ('the site') comprises Lot 1 in DP344160 and Lot 2 in DP337960 as outlined in **Table 1**. These Lots describe the eastern and western parcels of an approximate 'boomerang' shaped land parcel that formed the former landfill.

The site is situated approximately 2km south of Swansea on the south western side of the Old Pacific Highway. The site can be accessed from the Old Pacific Highway by a track approximately 100m in length and branching downslope from the highway. The site location is shown on **Drawing 1, Appendix A.**

Table 1 *Site Identification – Swansea Landfill*

East Parcel	
Street Address	6A Pacific Highway, Pinny Beach NSW 2281
Lot and DP Number	Lot 1 DP 344160
Site Area	2.02 hectares (~five acres)
Geographical Coordinates	Latitude 33° 3' 25" S, Longitude 151° 31' 17" E
Owner	Stockland Wallarah Peninsular Pty Ltd
Zoning	10 (a) Special Development – Sustainable Mixed Use
Local Government Area	City of Lake Macquarie
Parish	Kahibah
County	Northumberland
West Parcel	
Street Address	6A Pacific Highway, Pinny Beach NSW 2281
Lot and DP Number	Lot 2 DP 337960
Site Area	2.02 hectares (five acres)
Geographical Coordinates	Latitude 33° 3' 28" S , Longitude 151° 31' 22" E
Owner	Stockland Wallarah Peninsular Pty Ltd
Zoning	10 (a) Special Development – Sustainable Mixed Use
Local Government Area	City of Lake Macquarie
Parish	Kahibah
County	Northumberland

4 SITE HISTORY

4.1 ZONING

The current zoning of the Site is 10 (a) Special Development – Sustainable Mixed Use Development (Lake Macquarie Local Environmental Plan 2000 - North Wallarah Peninsula). Previous zoning of the site included 7(a) Environment Protection (Scenic) (Lake Macquarie Local Environmental Plan 1984).

The objectives of Zone No 10 (a) as taken from LMCC LEP 2000 are as follows:

(a) To achieve a planned urban outcome, based on principles of ecological sustainability, at a village settlement scale, enhancing quality of lifestyle, social equity, and ecological awareness.

(b) To promote development that is compatible with the amenity of adjoining and surrounding residential development, does not adversely affect the capacity and safety of road networks and can connect to a water supply, and a sewerage and drainage system.

(c) To ensure that development contributes to a sustainable, vibrant community, and reflects holistic consideration and integration of social, economic and environmental design issues.

(d) To promote the ecological compatibility of development with conservation outcomes identified for the land in the North Wallarah Peninsula Local Environmental Study, copies of which are available from the office of the Council.

(e) To provide for a range of development types identified in the Conservation and Land Use Management Plan, and described in Schedule 1.

(f) To achieve favourable land use outcomes by focussing on environmental, social, economic, community and amenity factors rather than individual land use types.

(g) To provide a wide range of housing and accommodation choices through a variety of urban settlement forms.

Specifically, the site is to be developed for residential and recreational land use. This land use is permissible under the current site zoning.

A future land use layout is shown on **Drawing 2**, **Appendix A**.

4.2 LAND OWNERSHIP

4.2.1 LOT 1, DP 344160

The current owner is the Stockland Wallarah Peninsula Pty Ltd. The property was formed by Council approval in 1940, by Clerk's Certificate 570. It has been owned by the Lake Macquarie City Council (LMCC), who unsuccessfully applied to operate the site as a licensed land fill in the mid 1970s. The site operated informally as a landfill prior to this period.

4.2.2 LOT 2, DP 337960

The current owner is the Stockland Wallarah Peninsula Pty Ltd. The site was previously owned by Parbury Estate Pty Ltd and before that, Northern Stoneware Pipe Pty Ltd (operating as the Belmont Pipe Company). The property was created by gazettal of Crown Land, Subdivision Plan 37960 in 1937. The site operated informally as a landfill up until the mid 1970s.

4.3 LAND USE

The previous land use summary was taken from an existing report by Sinclair Knight Merz prepared for this site in April 2003 (Ref [1]). Given the recent and well documented site activities that have been presented in this report, additional historical site information was limited to a review of aerial photos and discussions with the current land owners. This level of review is considered sufficient for the purpose of the ESA and RAP development.

The SKM site history summary was compiled from a review of:

- a Bureau of Mineral Resources coal exploration report dated 1952 which included the first detailed maps of the area;
- review of aerial photos from the Department of Land and Water Conservation dated March 1954, August 1966, May 1975, April 1984 and March 1986; and
- Lake Macquarie City Council records of health inspectors' visits and other correspondence for the period between January 1965 and April 1989.

This data was supplemented by a review of aerial photos as follows:

- August 1965, August 1976, May 1996, 1999 (month unknown) and October 2001.

An extract from the SKM report is presented in the following. RCA Australia's (RCA) review of additional aerial photos supports the information presented herein.

> *The Swansea South tip site appears to have come into existence as a brick clay pit or small open cut coal mine prior to 1954. Clay was certainly mined here by the Belmont Pipe Company, and low-grade coal from this site may have been used as a fuel for their kilns. An air photo dated March 1954 shows a clearing scar about 100m across and 1ha in area at this location, immediately west of a prominent bend in the old Pacific Highway.*

Council records obtained under a Freedom of Information application suggest that the LMCC commenced dumping at the site in the early 1960s and appointed a caretaker/ranger in January 1965. From the correspondence it is obvious that the site has been operating as a public tip for some time previous to 1965, but that ownership remained with the Belmont Pipe Company. Later documents suggest that the company had only approved dumping of non-putrescible materials, and that the site had not been licensed by the NSW Health Commission as a sanitary landfill.

The 1965 photo shows surface disturbance but it is unclear as to whether this is attributed to landfilling or mining operations.

An August 1966 air photo revealed the area of disturbed land to have doubled since 1954, to about 2ha. Some of this expansion may have been a result of clay mining, which is believed to have been active in the pit during this period. Ground level photos from 1966 show that tipping was occurring at the eastern end and that most of the material was non-putrescible domestic rubbish. The photos also reveal the quarried face immediately below the old Pacific Highway to have been about 5m high, with white clay in the top half and 2-3m of coal (probably the lower split of the Wallarah seam) below this to the pit floor.

From 1965 to 1969 most of the correspondence of the Council file is taken up with problems caused by lack of site supervision. Car bodies and tyres were becoming major components of the tipped materials and tipping space was being used up. Expansion westwards to a new dump site along Galgabbee Creek was proposed in July 1969, but apparently never implemented. A large garbage-receiving landfill was planned by Council further downstream along Galgabbee Creek in 1971, but was opposed by the Department of Main Roads and later rejected by the State Planning Authority.

From about 1970 the main issue confronting Council at the Swansea South site was the volume of tyres being dumped, which reached 3000 per month in 1974. Large fires were repeatedly lit among the tyre mounds and burned for several days at a time. Smoke from these fires was affecting traffic on the nearby Pacific Highway in January 1975 and regularly blowing into Swansea, to the extent that a formal complaint was received from the Department of the Environment.

The May 1975 air photo shows the tip at its maximum extent, about 350m long and about 2.4ha in area, several months before it closed. The top surface is fairly level and the eastern end is already overgrown. In October 1974 the NSW Health Commission objected to Council dumping garbage in a non-approved site and required that it be registered as an unhealthy site for building purposes. At this time Council was tipping about three truckloads of domestic garbage per week. The tip was eventually closed by order of the Commission in February 1976, though fly dumping apparently continued for years afterwards.

A bushfire in September 1982 ignited a deep-seated fire within the dump, possibly fuelled by tyres, which burned for more than six months and necessitated fortnightly visits from the local fire brigade. The April 1984 air photos reveal the tip to be within its 1975 limits, but not overgrown. Large-scale (1:8000) colour air photos dated March 1986 confirm that the site had been inactive for some time and had become revegetated. There are no signs of the 1982-83 fire. Mounds at the western and south eastern ends seem to indicate that heavy dumping was carried out between the May 1975 air photos and the February 1976 closure, or that dumping continued after the cessation of Council control.

The final item on the Council file dealing with the Swansea South tip is a request dated April 1989 from the RTA, which seeks permission to dump construction spoil from the Swansea Bends deviation (the present-day alignment of the Pacific Highway). The RTA letter offered to cap, landscape and revegetate the site, but this proposal does not appear to have been followed up, since no sign of either the spoil or the landscaping was seen during the present investigation.

It was noted during RCA site investigations in 2008 that a stockpile of residual soils comprising local conglomerate rock had been placed in the eastern section of the site. The placement has raised this area of the site by approximately 2m in elevation compared to the western portion. The spoil is reported to have originated from the Wallarah Interchange construction works.

4.4 Site Photos

A series of site photos was taken during site assessment works by RCA in 2007 and 2008. These photos are presented in **Appendix B** and their approximate location marked on **Drawing 3, Appendix A.**

4.5 Inventory of Chemicals and Wastes Associated with Site Use and Their On Site Storage Location

Chemicals are not known to have been stored on the site, however there is potential that chemicals such as fuels, oils and lubricants would have been present on site as part of the mining operations.

Wastes associated with the former site history are outlined in Section 4.3 and include tyres, non-putrescible and putrescible wastes, building waste and construction wastes. A site walkover has identified the presence of bonded cement fibro fragments on the site.

More recently construction spoil including local conglomerate rock has been placed at the site during the construction of the Wallarah Interchange.

4.6 Possible Contaminant Sources and Potential Off Site Effects

Contaminants at the site potentially include potential organic and inorganic contaminants associated with putrescible and non-putrescible wastes and asbestos fragments and fibres present within former building rubble. The depth of fill and the local topography indicates that the fill material may support a transient water table that could transport contaminants to nearby surface water bodies.

Based on the history of activities on the site the potential contaminants of concern (PCOC) for the Landfill site are as follows:

- Asbestos.
- Metals.
- Hydrocarbons (eg, polycylic aromatic hydrocarbon (PAH), total petroleum hydrocarbon (TPH) and benzene, toluene, ethyl benzene and xylenes (BTEX)).
- Ammonia.
- Phenols.
- PCB.
- Volatile halogenated compounds.
- Pesticides
- Methane.

4.7 PREVIOUS SITE ASSESSMENT

Two previous investigations have been undertaken on the Swansea Landfill. The first comprised the Geotechnical and Contamination Report discussed in Section 4.3 and prepared by Sinclair Knight Merz in 2003 (Ref [1]). The second comprised a Phase 1 Environmental Site Assessment of the southern half of the Northern Precinct prepared by RCA in 2007 (Ref [2]). This Phase 1 included a review of the Former Swansea Landfill. Historical site information from both reports has been presented in the preceding section.

The site assessment undertaken by SKM included the excavation of eleven test pits. Test pitting found fill materials at the site to comprise of general household waste not including putrescible waste and scrapped motor vehicle parts including tyres. It was estimated that these materials constituted about half of the volume of the landfill. Test pits were not excavated to the full depth of fill due to the limits of machinery reach.

Soil analysis was undertaken on nine samples for metals, pesticides, polycyclic aromatic hydrocarbons (PAH), Polychlorinated Biphenyls (PCB) and phenols. The results generally satisfied the *NEPC NEPM Guideline on Investigation Levels for Soil and Groundwater 1999* for the most sensitive uses. One analyte for one soil sample exceeded the NEPM Health Investigation Levels (HIL) A for standard residential use. The substance, benzo(a)pyrene, was above the HIL A limit (1 mg/kg) but was within the 2 mg/kg limit for 'Parks, recreational open space and playing fields' (HIL E). These results are presented in more detail in Section 10.

4.8 INTEGRITY ASSESSMENT

The site history review is considered sufficient for the purpose of this ESA and provides a thorough outline of the known site history. However, due to the potential for uncontrolled and illegal site dumping to have occurred, a robust site investigation has been designed to enable the evaluation of other possible contaminant sources.

5 SITE CONDITION AND SURROUNDING ENVIRONMENT

5.1 TOPOGRAPHY

The site grades generally in a westerly direction from an elevation of approximately 60m AHD adjacent the Old Pacific Highway to approximately 40m AHD on the western most site boundary. Undulations within the topography occur as a result of uneven land filling and placement of spoil following the Wallarah Interchange Works. This later spoil placement has raised the elevation by approximately 2m relative to the remainder of the site.

Regionally, the site is situated on the western face of a moderately sloping conglomerate ridge line. The ridgeline decreases in elevation to form a drainage line through the valley floor. Surface water from this drainage line ultimately discharges via Galgabbee Creek into Lake Macquarie. Surface water drainage occurs via ephemeral drainage lines through the site which transfer discharge from the site to the creek.

5.2 SITE CONDITIONS

The site is currently fenced and padlocked restricting site access. With the exception of areas of recent spoil placement, the site is well vegetated with vegetation predominately comprising grasses and exotic regrowth. Vegetation surrounding the filled areas (both spoil and landfill) includes eucalypt forest.

The majority of the site surface appears disturbed and some waste is noted at the surface predominantly comprising building rubble. Bonded fibro asbestos containing cement sheeting was identified in surface soils. Surface soils also contained conglomerate rock and gravels.

There were no signs of erosion or soil instability evident during the site works.

5.3 VISIBLE SIGNS OF CONTAMINATION

Visible signs of waste such as building waste (roof tiles, concrete) and asbestos material were apparent during a site walkover. No other visual or olfactory signs of contamination were evident.

5.4 VISIBLE SIGNS OF PLANT STRESS

Clay extraction, waste land filling and spoil placement has removed the original vegetation across most of the site. Regrowth appears healthy and no visible signs of plant stress were evident.

5.5 PRESENCE OF DRUMS, WASTES AND FILL MATERIALS

Visible signs of waste were identified during test pitting. Test pit logs presented in **Appendix C** outline waste types encountered.

5.6 ODOURS

No odours were noted during site works. A gas survey was undertaken of the site as part of this assessment and these results are presented in Section 10.

5.7 CONDITION OF BUILDINGS AND ROADS

There are no buildings or roads on the site.

5.8 QUALITY OF SURFACE WATER

Surface water quality was evaluated as part of this ESA and results are presented in Section 10.

5.9 FLOOD POTENTIAL

There is no flood potential at the site due to the elevation of 40 to 60m AHD, moderate site slopes and the absence of a significant sized up gradient catchment. The Old Pacific Highway on the north of the site has an adequate drainage system that diverts stormwater from entering the site from that boundary.

5.10 LOCAL SENSITIVE ENVIRONMENT

The site is situated within the catchment of a tributary to Galgabbee Creek which discharges to Lake Macquarie approximately 2.5km from the site. Galgabbee Creek is described as a moderately disturbed fresh waterway. Lake Macquarie can be described as a moderately disturbed marine waterway.

6 GEOLOGY AND HYDROGEOLOGY

6.1 SOIL STRATIGRAPHY

The site is situated in an area underlain by Wallarah coal and Teralba Conglomerate. Originally, shallow clayey residual soils, typically less than 1m in depth, with potential for (weathered) coal, were present at or near the surface.

In the area of the old Swansea Landfill, the fill depth varies but is up to about five metres deep, with 2003 investigations identifying that about half of the material is domestic (eg, carpet, furniture) and other non-putrescible waste. There was no evidence in the site investigations (past and present) of the lesser quantities of putrescible waste apparently dumped at the site. The remainder of the fill is soil cover. This area has been inactive as a Council landfill for at least thirty years. It has also been identified that a series of fires culminating in the 1982 subsurface fire which burnt for around six months on the site may have carbonised much of the existing waste (including tyres). Compaction in this area was described as loose to very loose (Ref [1]).

Logs of all test pits and bores are contained in **Appendix C**.

6.2 HYDROGEOLOGY

The hydrogeological investigation has involved a review of registered groundwater bores on the Department of Natural Resources register. The nearest surrounding registered groundwater bores are shown on **Drawing 1**, **Appendix A**. There are no registered groundwater bores within the same groundwater catchment as the site. Bore GW065867 is at similar elevation to the site on the opposing ridge line. The log for this bore indicates a bore depth of 19.1m, however standing water level data is incomplete. Remaining bores are outside the same groundwater catchment as the site and are at lower elevations and situated within unconsolidated strata. Standing water levels in these bores are >6m from the surface.

The depth to the groundwater table at the site is expected to be greater than 6m below the surface and probably greater than 10m based on surrounding bore information and the site topography. Groundwater flow is likely within the conglomerate rock with main aquifers isolated within weathered coal seams. Groundwater flow will preferentially follow the coal seam decline.

Shallow perched groundwater is likely to occur within the fill materials following rainfall events. Perched groundwater flow is driven by strata and elevation. Perched water would be expected to discharge along the southern and western fill face to the surface water system.

6.3 DIRECTION OF SURFACE WATER RUN-OFF

The landfill site is located just below the former Pacific Highway, with the pit of the former Swansea Open Cut being upslope of the landfill site and the Old Pacific Highway. There is therefore relatively little run-on of surface water to the landfill site.

Surface water run-off is directed toward the south and west following the topography. A dam is located to the south west of the site which would be expected to receive surface water run-off from the site as well as from upper catchment reaches beyond the site. A drainage swale is present along the access track from the Old Pacific Highway which directs surface water from the site, as well as from the access track, to the drainage line at the valley floor.

6.4 BACKGROUND WATER QUALITY

Background surface water quality was undertaken as part of this ESA.

6.5 SUMMARY OF LOCAL METEOROLOGY

Local meteorology is taken from the Newcastle Nobby's Weather Station (site 061055) historical data averages (Ref [3]). This weather station is approximately 30km north east of the site and is considered representative of local meteorological conditions.

Average annual temperatures range between 14.2°C and 21.8°C. The mean annual rainfall is 1140mm/year with the highest rainfall months occurring between February and June.

7 SAMPLING AND ANALYSIS PLAN AND SAMPLING METHODOLOGY

This section outlines the sampling and analysis plan developed for further investigation of the site.

7.1 DATA QUALITY OBJECTIVES

In order to achieve the objectives and purpose of the investigation, both the field and laboratory programmes must be deemed representative of the actual extent of contamination in soil. As such, specific Data Quality Objectives (DQOs) were developed for the assessment of field and analytical data obtained during the investigation. The DQO process is a systematic, seven step process that defines the criteria that the sampling should satisfy in accordance with the requirements of DEC (2006) Guidelines for the NSW Site Auditor Scheme (2nd Edition).

7.1.1 STEP 1 – STATE THE PROBLEM

The purpose of the ESA was to adequately characterise the site to enable the development of a reliable RAP. In its current state the Swansea Landfill is not considered suitable for the proposed land use (residential/recreational) due to the potential for site contamination and geotechnical considerations. The site has been an informal landfill for Lake Macquarie City Council (LMCC) before being substantially closed in the 1976. It is proposed to be redeveloped for mixed recreational and residential uses.

Asbestos containing materials (ACM) have been identified on the site and it is expected that other contaminants will be present. SKM reported on eleven test pits which provided broad categorisation of the site, however the report stated that the horizontal and vertical extent and concentration of contaminants required further delineation.

7.1.2 STEP 2 – IDENTIFY THE DECISIONS

In order to achieve the remediation objectives and resolve the uncertainties identified at the site, decisions must be made as to the extent and type of contamination at the Swansea Landfill site, the validity of site data, the relevant remediation criteria and the appropriate procedures and the methods and controls for remediation (where necessary).

7.1.3 STEP 3 – IDENTIFY INPUTS TO THE DECISION

The following inputs into the decision making process for the Swansea Landfill site are required:

- *Evaluation of landfill characteristics:* Previously 11 test pits have been excavated on the site, however the depth of the reach did not allow for certainty that the natural surface had been reached. The verification of depth and filling types is required through the profile using a grid based sampling pattern. The site history information suggests largely inert filling will be present within the landfill site.

- Evaluation of surface water and groundwater water quality: There have been no previous investigations of groundwater or surface water quality. Impacts from the site to groundwater and surface water quality may occur, with the potential to cause impact to off site receptors. Evaluation of groundwater that is contained within the fill and surface water down gradient of the landfill is required.

- Evaluation of soil gas: There has been no previous evaluation of soil gas. Due to the possible presence of putrescible landfill the site has the potential to generate soil gas. A grid sampling programme across the site is required for soil gas evaluation.

Details of the present investigation programme are outlined in Section 7.1.7 and the relevant Site Guidelines are outlined within Section 9.

7.1.4 STEP 4 – DEFINITION OF THE BOUNDARIES OF THE INVESTIGATION

The investigation area extends to the boundaries of both Lots.

This investigation includes soils, primarily being the waste material, the capping/ construction spoil present within the landfill. Surface water, groundwater present within the fill, and landfill gas monitoring were also undertaken at the site.

7.1.5 STEP 5 – DEVELOPMENT OF DECISION RULES

The types of data quality required, appropriate field methods (including sampling procedure and preservation of samples) and the quality of analytical data undertaken by the commercial laboratories are summarised in the following.

- All sample analyses are to be conducted using National Association of Testing Authorities (NATA) registered methods in accordance with ANZECC (1996) and NEPC (1999) guidelines.

- All samples are to be extracted within the laboratory specified acceptable sample holding time.

- Samples are to be appropriately preserved and handled in accordance with the sampling methodology outlined in Step 7.

- Practical Quantitation Limits (PQL) are to be less than the adopted assessment criteria.

Duplicates, spikes, blanks, and control samples are to meet the Data Quality Indicators (DQI) presented in Step 6.

7.1.6 *STEP 6 – SPECIFICATION OF THE ACCEPTABLE LIMITS ON DECISION ERRORS*

Acceptable limits for decision errors are presented in Section 2 of the Quality Assurance and Quality Control Review presented in **Appendix D**.

7.1.7 *STEP 7 – OPTIMISATION OF THE DESIGN OF THE COLLECTION OF DATA*

The Sampling Analytical and Quality plan (SAQP) consists of the components described within the sections below.

7.1.7.1 SAMPLING METHODOLOGY

All samples were collected by an RCA environmental consultant and analysed by a NATA accredited laboratory. The sampling methodology that was followed for the site is outlined below. All samples locations are shown on **Drawings 3** and **4**, **Appendix A**. Samples have been located by hand held GPS. Samples were collected using a 12 tonne excavator with long reach capability and selected to provide appropriate sampling depth. Groundwater monitoring wells were installed using a truck mounted drilling rig.

Evaluation of Surface Soils

Surface samples were collected from six (6) locations across the filled area of the site. Samples were collected from the immediate surface to a maximum depth of 0.05m using a stainless steel trowel and nitrile gloved hand. All samples were analysed for volatile halogenated compounds, metals, PAH, BTEX, TPH and ammonia.

Decontamination of the sampling trowel was undertaken between sampling rounds using Decon 90 and washing with potable water.

Evaluation of Soils at Depth

Samples were collected from 27 test pits excavated in an approximate 25m grid formation across the filled area of the site. Sample depths ranged between 1.0 and 4.0m from the surface. All test pits were excavated to the base of fill to ascertain the depth of fill and investigate all fill materials present.

Samples were collected by single use nitrile gloved hands from within the bulk soil contained in the excavator bucket. Samples were analysed for volatile halogenated compounds, PCB, OCP, phenols, metals, PAH, BTEX and TPH.

The method of sampling did not require decontamination of excavation equipment to be carried out.

Evaluation of asbestos fibres in soil

Sampling of soil for asbestos fibres was undertaken on two surface samples collected adjacent to bonded fibro fragments. Samples were collected from the surface using a stainless steel trowel and placed within double lined plastic bags.

Decontamination of the sampling trowel was undertaken between sampling rounds using Decon 90 and washing with potable water.

Soil Gas

Soil gas sampling involved a near surface ambient air gas monitoring survey of landfill gas (methane, CO_2 and CO) following a method known as landfill sweeping. The sampling technician walked over the landfill surface in a random pattern with the inlet probe of the landfill gas analyser positioned within two to three inches from the ground surface at each sampling location. Measurement of gas was recorded over a 20 second duration at each location, with percentage concentrations of each gas logged into the internal memory of the landfill gas analyser. A total of 23 landfill gas readings were collected from across the site.

Meteorological conditions at the time of monitoring were ideal for landfill gas monitoring, with an ambient air temperature of 23°C and calm wind conditions.

Groundwater and Surface Water sampling

Groundwater monitoring was undertaken from three groundwater monitoring wells installed at locations BH1, BH2 and BH4. Monitoring wells were installed to a maximum depth of 5.0m and all were contained within the fill profile. Wells were constructed of 50mm diameter PVC machine slotted pipe. The slotted section was installed above and below the phreatic surface and the bores were backfilled to within 1.0m of the surface. A bentonite seal was constructed around the bore collar to restrict surface water ingress. Bores were developed at the time of drilling and allowed to stabilise prior to sampling.

Groundwater bores were sampled approximately two months after installation. Sampling was undertaken by hand bailer following the removal of one bore volume and additional volumes until pH and EC readings were within 0.1, to ensure a representative perched groundwater sample was collected. Decontamination of the hand bailer was undertaken between sampling rounds using Decon 90 and washing with potable water. Samples were field filtered through a 0.45μm filter for metals analysis.

Surface water sampling was undertaken by filling sampling bottles directly from the surface water source. Samples were not filtered for metals analysis.

Field sheets are attached in **Appendix E.**

Sampling Timeframe

The sampling timeframe is outlined in the following.

Sampling Date	Samples Collected	Sampling Purpose
25-26/2/08	TP1-1, TP1-2 TP2-1, TP2-2 TP3-1, TP3-2 TP4-1, TP4-2 TP6-2, TP7-1, TP7-2 TP8-1, TP8-2 TP9-1 TP10-1, TP10-2, TP10-3 TP11-2 TP12-1, TP12-2 TP13-1, TP13-2 TP14-1 TP15-1, TP15-2 TP16-1 TP17-1, TP17-2 TP18-1 TP19-1 TP20-1 TP21-1, TP21-2 TP24-1, TP24-2 TP25-1, TP25-2 TP26-1 TP27-1	Investigation of depth and contamination status of fill material.
8/4/08	S1-0/QC1 S2-0 S3-0 S4-0/QC2 S5-0 S6-0	Investigation of contamination status of surface soils.
9/5/08	S1 S2 S3 S4 S5 S6	
	BH1 BH2 BH4 SW1 SW2 SW3 SW4	Investigation of groundwater and surface water quality

7.1.7.2 Sampling Pattern, Frequency and Analysis

The objective of the sampling pattern is to demonstrate that the adopted sampling density is sufficient to characterise the site and enable development of a site specific remediation strategy. The sampling pattern and analysis undertaken are listed in **Table 2**.

Table 2 *Sampling Frequency*

Sample Type	Sample Frequency and Justification	Analytes
Surface soil investigation.	Surface sampling has not previously been undertaken as this material was considered to be clean capping material. To assess the concentrations of contaminants in surface soils sampling was undertaken at six representative locations within the site. This sampling density does not meet the *NSWEPA Sampling Design Guidelines* (Ref [4]) however, in combination with the deeper sampling programme, it is considered sufficient for material characterisation and civil works design.	All samples were analysed for TPH, PAH, metals, VHC. ammonia.
Evaluation of soils at depth.	There has previously been soil sampling at 11 locations on this site. For the current programme, sampling was undertaken at twenty-seven locations around the site. The purpose of this sampling is to evaluate the vertical extent and type of filling at the site. The sampling frequency was on an approximate sampling grid of 25m which is considered sufficient for the purpose of this investigation. This sampling programme is in accordance with the *NSWEPA Sampling Design Guidelines* (Ref [4]).	All samples were analysed for BTEX, PAH, TPH, metals. Six samples were additionally analysed for VHC, OCP, PCB.
Asbestos Fibres in Soil	Sampling was undertaken at two locations which are representative of building rubble on the site. The purpose of this sampling was to evaluate the likelihood of the presence of asbestos fibres in the fill. This sampling density is considered sufficient for material characterisation and civil works design.	Analysis of soil samples for asbestos fibres.
Surface Water	Sampling of surface water associated with the site was undertaken at four sites, with three up gradient of the site and one down gradient of the site. This sampling density is considered sufficient to confirm the characteristics of surface water associated with the landfill and identify impacts on surface water from the landfill.	Analysis of all samples for the landfill water suite.
Groundwater	Sampling was undertaken at three locations through the site from bores established in the perched groundwater present within the fill layer. This sampling was sufficient to evaluate the impact of land filling on perched water. Where an impact is identified further evaluation of the true deeper groundwater table is required.	All samples to be analysed for the landfill water suite.
Landfill Gas	Sampling to determine the presence of methane and other landfill gases released through the landfill's surface. This sampling is in accordance with the NSWEPA Solid Waste Landfill Guidelines (Ref [5]).	Field sampling for CH4, CO2, O2 and other gases.

8 QUALITY ASSURANCE AND QUALITY CONTROL

An assessment of the quality assurance and control results for the previous results from the SKM investigation (Ref [1]) has been undertaken and has identified a lack of documentation regarding sample preservation and storage, and the absence of any duplicates which would provide some information regarding the precision of the results. However, the purpose of the data is for characterisation in combination with additional sampling undertaken by RCA. The SKM data has been found to be consistent with the findings of the RCA investigation and therefore is considered to be reliable for the purpose of site characterisation. The absence of data quality information is therefore not considered to be significant when used for this purpose. The data is not considered to be suitable for the purpose of site validation.

An assessment of the quality assurance and control results for this project is presented in **Appendix D**.

In summary, internal and external quality control data for the soil and water samples complied with the RCA's quality protocols for the environmental assessment. The evaluation presented in **Appendix D** demonstrates that the results are free of systematic and method biases.

9 BASIS FOR SITE GUIDELINES

9.1 SOIL

9.1.1 NEPM – NATIONAL ENVIRONMENT PROTECTION (ASSESSMENT OF SITE CONTAMINATION) MEASURE (1999)

The criteria used for the assessment of the soil on site were sourced from the National Environment Protection Measure (NEPM) for the Assessment of Site Contamination, 1999 (Ref [6]). Schedule B(1) of this measure provides a table for the investigation concentrations for contaminants based on human health risk and certain exposure scenarios due to site use.

Based on information provided to RCA, the Swansea Landfill site is to be included as part of detailed planning for the Wallarah North Precinct. A residential estate is proposed to be developed on the eastern part of the site and a recreational field on the western side of the site. Therefore the results have been compared to the following guidelines:

- HIL 'A' Residential, access to soil, fruit and vegetable consumption <10%, no poultry, no groundwater consumption: This category includes children's day care centres, kindergartens, preschools and primary schools.
- HIL 'E' Parks, recreational open space and playing fields, includes secondary schools.

Results were also compared to the ecological investigation levels (EILs).

9.1.2 NSWEPA – SERVICE STATION GUIDELINES

The guidelines adopted for TPH C_6-C_9, TPH C_{10}-C_{36} and BTEX were the "Guidelines for Assessing Service Station Sites" produced by the NSWEPA, December 1994, (Ref [7]). These guidelines are applicable for soil and water concentrations on all sites where fuel has been stored or where the potential for hydrocarbons exists.

9.1.3 ASBESTOS

The guideline adopted for evaluating asbestos is that no asbestos fibres or fragments are permitted in soil at the surface, as stated in the *NSWEPA, Advice provided to EPA Accredited Site Auditors at the Site Auditors meeting, 1 March 2000.*

9.2 WATER

9.2.1 NSW DEC GROUNDWATER GUIDELINES 2007

The 2007 Groundwater Guidelines (Ref [8]) require that groundwater contaminant concentrations be compared to existing generic groundwater investigation levels (GILs). The guidelines cite the following documents as appropriate sources of GILs for contaminant assessment of groundwater:

- Drinking water - NHMRC and NRMMC 2004 (Ref [9]).
- Aquatic Ecosystems - ANZECC and ARMCANZ 2000a (Ref [10]).

A review of the receptors down gradient of the site indicates that there is no use of groundwater or surface water from the site for drinking water purposes and therefore these guidelines are not relevant and only ecological guidelines have been applied. The receiving water body in this instance is Galgabbee Creek which is a fresh water creek.

For the protection of aquatic ecosystems, the GIL for 95% protection (Ref [10]) should be used. Where the existing generic GIL is below the naturally occurring background concentration of a particular contaminant, the background concentration becomes the default.

Where the existing generic GIL for a particular contaminant is below the practical limit of reporting or below the detection limit, the quantitative limit of reporting or the detection limit should be used instead of the existing generic GIL.

Where a generic GIL does not exist for a particular contaminant or if the generic GILs are not considered stringent enough to protect the ecology or human health, guidance from the DEC is recommended.

9.3 LANDFILL GAS SAMPLING

Sampling for landfill gas, was undertaken using the methodology set out for surface sampling in the NSWEPA Solid Waste Landfill Guidelines (1996) (Ref [5]). The threshold concentration outlined in this document for closer investigation and potential action is 500 parts per million (v/v) of methane at any point on the landfill surface.

9.4 APPROPRIATENESS OF THE GUIDELINES

The NEPM document has been approved by the DECC for use on potentially contaminated sites and supersedes most of the preceding reference documents. The Service Station Guidelines are current for TPH and BTEX concentrations and are the only Australian guidelines available. These guidelines are commonly adopted on sites where these contaminants are expected and they are not exclusively applied to service stations.

The exposure settings on which the NEPM guidelines are based directly affect the investigation concentration used to assess the contamination status of the site. While the development at each site appears to fit into the listed categories it is possible that a change in the development may designate the site into a more sensitive land use and require site suitability to be reassessed.

The groundwater guidelines are valid for evaluation of groundwater at the site and are the most recent guidelines endorsed by the DECC for groundwater evaluation. Guidelines adopted for groundwater quality will be the 95% protection fresh water guidelines. Evaluation against drinking water guidelines is not relevant due to the absence of drinking water receptors.

The landfill gas screening level is endorsed by the DECC and is an appropriate indicator of landfill gas significance.

10 RESULTS

10.1 SUMMARY OF PREVIOUS RESULTS

Table 3 presents a summary of previous sampling results collected during the SKM investigation, (Ref [1]).

Table 3 *Previous (SKM) Results Summary*

Analyte	Guideline [1]			Number of samples	Concentration (mg/kg)			Number of samples above the guideline
	HIL 'A'	HIL 'E'	EIL		Min	Max	Arithmetic Average	
Hydrocarbons								
Benzene	1	1	n/a	9	<0.2	<0.2	n/a	0
Toluene	1.4	1.4	n/a	9	<0.2	<0.2	n/a	0
Ethylbenzene	3.1	3.1	n/a	9	<0.2	<0.2	n/a	0
Total Xylenes	14	14	n/a	9	<0.2	<0.2	n/a	0
TPH C_6-C_9	65	65	n/a	9	<2	<2	n/a	0
TPH C_{10}-C_{36}	1000	1000	n/a	9	<250	<250	n/a	0
Benzo(a) pyrene	1	2	n/a	9	<0.5	1.3	0.4	1 #
Sum of reported PAH	20	40	n/a	9	<4	5.05	4.1	0
DDT+DDD+DDE	200	400	n/a	9	<0.3	<0.3		0
Aldrin + Dieldrin	10	20	n/a	9	<0.1	6.25	0.1	0
Chlordane	50	100	n/a	9	<0.1	<0.1		0
Total PCBs	10	20	n/a	9	<0.1	0.4	0.1	0
Metals and metalloids								
Arsenic	100	200	20	9	2	17	7	0
Cadmium	20	40	3	9	0.5	3	0.8	0
Chromium	100	200	1	9	1	13	8	8 EIL only
Copper	1000	2000	100	9	0.5	37	16	0
Lead	300	600	600	9	8	181	61	0
Nickel	600	600	n/a	9	0.5	21	5	0
Zinc	7000	14000	200	9	2	1700	387	3 EIL only
Mercury	15	30	1	9	0.05	0.1	0.1	0

[1] Guidelines as discussed in Section 9. # Concentration marginally above HIL A but below HIL E.
n/a - no guideline/result applicable

10.2 ALL INCLUDING CURRENT SOIL RESULTS

All soil results from the recent evaluation are presented in **Appendix F**. A summary of all data, including previous data is presented in **Table 4**. All samples were taken from the body of filled soil and **Table 4** presents data for all filling types. All sample locations are shown on **Drawing 4**, **Appendix A**.

Table 4 *All Soil Data*

Analyte	Guideline [1]			Number of samples	Concentration (mg/kg)				Number of samples above the guideline
	HIL 'A'	HIL 'E'	EIL		Min	Max	Arithmetic Average	95% UCL_{ave}	
Organics									
Benzene	1	1	n/a	53	<0.2	<0.2			0
Toluene	1.4	1.4	n/a	53	<0.2	4.3	0.3	0.7	1
Ethylbenzene	3.1	3.1	n/a	53	<0.2	<0.5			0
Total Xylenes	14	14	n/a	53	<0.4	<0.5			0
TPH C6-C9	65	65	n/a	53	<2	<2			0
TPH C10-C36	1000	1000	n/a	53	<250	585	147	166	0
Benzo(a) pyrene	1	2	n/a	53	<0.5	6.2	2	0.9	2 HIL 'A' (1 HIL 'E')
Sum of reported PAH	20	40	n/a	53	4	82.25	6	8.4	1 HIL E
Total Phenols	8500	17000	n/a	6	<4	<4			0
DDT+DDD+DDE	200	400	n/a	14	<0.3	0.15	0.15		0
Aldrin + Dieldrin	10	20	n/a	14	<0.1	0.625	0.1		0
Chlordane	50	100	n/a	14		<0.1	<0.1		0
Total PCBs	10	20	n/a	14	<0.1	0.4	0.1		0
VHC			n/a	12	nd	nd			
Ammonia			n/a	6	<20	<20			
Metals and metalloids									
Arsenic	100	200	20	53	<5	18	6.5	9.1	0
Barium	n/a	n/a	300	39	<10	2560	209	355	6 EIL only
Beryllium	20	40	n/a	39	<1	2	<1	0.7	0
Cadmium	20	40	3	53	<1	8	1	2.3	7 EIL only
Chromium	100	200	n/a	53	<2	56	9	15	0
Chromium III	12%	24%	n/a	6	<1	9	5	7.8	0
Chromium VI	100	200	1	6	<1	<1	<1		0
Cobalt	100	200	n/a	39	<2	19	3	5	0
Copper	1000	2000	100	53	<5	256	33	76	4 EIL only
Lead	300	600	600	53	<5	2930	152	**523**	8 HIL 'A' (2 HIL 'E' & EIL)
Manganese	1500	3000	500	39	<5	870	128	194	1 EIL only
Nickel	600	600	n/a	53	<1	52	8	16	0
Vanadium	n/a	n/a	n/a	39	<5	43	15	18	0
Zinc	7000	14000	200	53	2	27000	1058	3325	1 HIL 'E' (13 EIL)
Mercury	15	30	1	53	<0.1	1	0.1	0.25	0

Analyte	Guideline [1]			Number of samples	Concentration (mg/kg)				Number of samples above the guideline
	HIL 'A'	HIL 'E'	EIL		Min	Max	Arithmetic Average	95% UCL_{ave}	
Other									
Asbestos	nil	nil	n/a	2	Nil	nil			0 *

[1] Guidelines as discussed in Section 9. * This relates to the evaluation of asbestos fibres in soil, not the presence of asbestos containing fragments.

In addition to the soil sampling presented above, bonded asbestos fragments were noted at the site surface during the site walkover and within excavations.

Surface soil samples are presented in **Table 5** and represents six samples collected from the surface of the site.

Table 5 *Surface Soil Data*

Analyte	Guideline [1]			Number of samples	Concentration (mg/kg)				Number of samples above the guideline
	HIL 'A'	HIL 'E'	EIL		Min	Max	Arithmetic Average	95% UCL_{ave}	
Organics									
TPH C6-C9	65	65	n/a	6	<10	<10			0
TPH C10-C36	1000	1000	n/a	6	<125	<125			0
Benzo(a) pyrene	1	2	n/a	6	<0.5	<0.5			0
Sum of reported PAH	20	40	n/a	6	4	5	4	4.5	0
Total VOCs				6	nd	nd	n/a		
Metals and metalloids									
Arsenic	100	200	20	6	<5	10	6	8	0
Cadmium	20	40	3	6	<1	1	1	0.75	0
Chromium	100	200	n/a	6	2	10	6	9	0
Copper	1000	2000	100	6	<5	49	18	31	0
Lead	300	600	600	6	7	309	67	**521**	1
Nickel	600	600	n/a	6	<2	14	6	9.6	0
Zinc	7000	14000	200	6	16	1880	353	3394	1 EIL
Mercury	15	30	1	6	0.05	0.1	0.06	0.08	0
Other									
Asbestos	nil	nil	n/a	2	nil	nil	n/a		0 *

[1] Guidelines as discussed in Section 9. * this relates to the evaluation of asbestos fibres in soil, not the presence of asbestos containing fragments.

Table 6 presents a statistical analysis of samples collected from natural soils underlying the fill materials.

Table 6 *Natural/Residual Soils Data*

Analyte	Guideline [1]			Number of samples	Concentration (mg/kg)				Number of samples above the guideline
	HIL 'A'	HIL 'E'	EIL		Min	Max	Arithmetic Average	95% UCL_{ave}	
Organics									
Benzene	1	1	n/a	10	<0.2	<0.2			0
Toluene	1.4	1.4	n/a	10	<0.5	<0.5			0
Ethylbenzene	3.1	3.1	n/a	10	<0.5	<0.5			0
Total Xylenes	14	14	n/a	10	0.5	0.5			0
TPH C6-C9	65	65	n/a	10	<10	<10			0
TPH C10-C36	1000	1000	n/a	10	125	585	190	477	0
Benzo(a) pyrene	1	2	n/a	10	<0.5	<0.5			0
Sum of reported PAH	20	40	n/a	10	4	4.35	4	4.1	0
Total Phenols	8500	17000	n/a	3	<4	<4			0
DDT+DDD+DDE	200	400	n/a	3	0.15	0.15			
Aldrin + Dieldrin	10	20	n/a	3	0.05	0.05			
Chlordane	50	100	n/a	3	0.05	0.05			
Total PCBs	10	20	n/a	3	<0.1	<0.1			
VHC			n/a	3	nd	nd			
Metals and metalloids									
Arsenic	100	200	20	10	<5	9	5	8	0
Barium	n/a	n/a	300	10	<10	90	33	60	0
Beryllium	20	40	n/a	10	<1	<1			0
Cadmium	20	40	3	10	<1	<1			0
Chromium	100	200	n/a	10	<2	10	5	7	0
Chromium III	12%	24%	n/a	3	<1	9	4	n/a	0
Chromium VI	100	200	1	3	<1	<1		n/a	0
Cobalt	100	200	n/a	10	<2	<2			0
Copper	1000	2000	100	10	<5	20	6	16	0
Lead	300	600	600	10	5	130	22	75	0
Manganese	1500	3000	500	10	<5	62	13	30	0
Nickel	600	600	n/a	10	<2	6	2	4	0
Vanadium	n/a	n/a	n/a	10	<5	43	20	26	0

Analyte	Guideline [1]			Number of samples	Concentration (mg/kg)				Number of samples above the guideline
	HIL 'A'	HIL 'E'	EIL		Min	Max	Arithmetic Average	95% UCL_{ave}	
Zinc	7000	14000	200	10	<5	447	54	489	1 EIL only
Mercury	15	30	1	10	<0.1	0.4	0.1	0.3	0

[1] Guidelines as discussed in Section 9. n/a – not applicable due to insufficient samples to compute statistic.

10.3 WATER

Water sampling results are presented on **Table F3, Appendix F.** A tri-linear plot, **Drawing 5, Appendix A**, was undertaken of the anion and cation data to evaluate water chemistry. The plot shows close relationships in water chemistry for bore BH1 and surface water sampling location SW4. A close relationship is also observed for SW1, SW2 and SW3. BH2 and BH4 do not correlate with any of the other samples.

Groundwater data indicates elevated concentrations of some metals including cadmium, chromium, copper, iron, lead and zinc. TPH and total phenols were also present.

Table 7 *All Groundwater Data*

Analyte	Guideline [1]	Number of samples	Concentration (mg/kg)		Number of samples above the guideline
	95% Fresh		Min	Max	
Organics					
Benzene	0.95	7	<0.001	<0.001	0
Toluene	*0.18*	7	<0.005	<0.005	0
Ethylbenzene	*0.08*	7	<0.002	<0.002	0
meta- & para-Xylene	*0.275*	7	<0.002	<0.002	0
Ortho-xylene	0.35	7	<0.002	<0.002	0
TPH C_6-C_{36}	0.007	7	0.11	0.495	5
Naphthalene	0.016	7	<0.001	<0.001	0
Phenanthrene	*0.002*	7	<0.001	<0.001	0
Anthracene	*0.0004*	7	<0.001	<0.001	0
Fluoranthene	*0.0014*	7	<0.001	<0.001	0
Benzo(a) pyrene	*0.0002*	7	<0.0005	0.0006	1
Ammonia	0.9	7	<0.01	0.226	0
Nitrite	0.7	7	<0.01	0.053	0
Total Phenols	0.32	7	<0.05	0.279	0
Heptachlor	0.00009	7	<0.0005	<0.0005	0
Aldrin	*0.000001*	7	<0.0005	<0.0005	0

Analyte	Guideline [1]	Number of samples	Concentration (mg/kg)		Number of samples above the guideline
	95% Fresh		Min	Max	
trans-Chlordane	0.00008	7	<0.0005	<0.0005	0
alpha-Endosulfan	0.0002	7	<0.0005	<0.0005	0
Dieldrin	*0.00001*	7	<0.0005	<0.0005	0
DDE	*0.00003*	7	<0.0005	<0.0005	0
Endrin	0.00002	7	<0.0005	<0.0005	0
DDT	0.00001	7	<0.002	<0.002	0
Methoxychlor	*0.000005*	7	<0.002	<0.002	0
Demeton-S-methyl	*0.004*	7	<0.0005	<0.0005	0
Dimethoate	0.00015	7	<0.0005	<0.0005	0
Diazinon	0.00001	7	<0.0005	<0.0005	0
Malathion	0.00005	7	<0.0005	<0.0005	0
Fenthion	0.0002	7	<0.0005	<0.0005	0
Chlorpyrifos	0.00001	7	<0.0005	<0.0005	0
Parathion	0.000004	7	<0.002	<0.002	0
Azinphos-methyl	0.0002	7	<0.0005	<0.0005	0
Metals and Metalloids					
Arsenic	0.013	7	<0.001	0.003	0
Barium		7	0.026	0.198	0
Beryllium	*0.00013*	7	<0.001	<0.001	0
Cadmium	0.0002	7	0.0002	0.0006	5
Chromium	0.001	7	<0.001	0.006	2
Cobalt	*0.09*	7	<0.001	0.016	0
Copper	0.0014	7	<0.001	0.009	5
Iron	*0.3*	7	0.29	9.2	6
Lead	0.0034	7	<0.001	0.016	0
Manganese	1.7	7	0.038	0.487	0
Mercury		7	<0.0001	<0.0001	0
Nickel	0.011	7	0.001	0.03	2
Vanadium	*0.006*	7	<0.01	<0.01	0
Zinc	0.008	7	0.026	1.12	7

[1] Guidelines as discussed in Section 9.

10.4 SOIL GAS SAMPLING

Soil gas sampling results are presented in **Table 8**. Results indicated non-detectable readings for methane and carbon dioxide at all locations.

Table 8 *Soil Gas Readings*

Location (refer Drawing 3)	Methane CH4 (%)	Carbon Dioxide CO2 (%)	Oxygen O2 (%)	Peak CH4 (%)	Peak CO2 (%)
1	0	0	20.1	0	0
2	0	0	20.1	0	0
3	0	0	20	0	0
4	0	0	20	0	0
5	0	0	20.1	0	0
6	0	0	20	0	0
7	0	0	20	0	0
8	0	0	20	0	0
9	0	0	19.9	0	0
10	0	0	20	0	0
11	0	0	20	0	0
12	0	0	20	0	0
13	0	0	20.1	0	0
14	0	0	20.1	0.1	0
15	0	0	20	0	0
16	0	0	20.1	0	0
17	0	0	20.2	0	0
18	0	0	20.2	0	0
19	0	0	20.3	0	0
20	0	0	20.3	0	0
21	0	0	20.3	0	0
22	0	0	20.3	0	0
23	0	0	20.5	0	0

11 SITE CLASSIFICATION

Site investigations identified that the waste materials within the landfill comprise predominately building rubble and non-putrescible waste. Tyres are present, however these appear substantially decomposed following large fires at the site. Putrescible waste that was present is also likely to have burned. The soil gas survey indicates the absence of volatile or decaying compounds within the filling structure and these results are consistent with site observations and analytical results.

Test pitting across the site identified that the depth of fill was variable from 2.8m to greater than 4.8m from the surface. Excavation of test pits to the full depth of fill profile, and survey of these sample locations has enabled a contour of the former quarry surface (ie, prior to land filling) to be interpolated. This contour and cross-sections through the landfill are shown on **Drawing Series 7284-LR01 to LR05.**

Soil sampling found low concentrations for most analytes tested. The exceptions were toluene at hotspot concentrations in one sample, benzo(a)pyrene identified above the guideline in one sample and at hotspot concentrations in a second sample, total PAH above the guideline in one sample, zinc above the guideline in one sample and lead above the guidelines in eight samples with one sample also being a hotspot. The $95\%_{average}$UCL for lead, including the hotspot sample, was 205mg/kg computed using the H-UCL formula for a lognormal distribution.

Asbestos fibres were not identified in soils in the limited soil sampling undertaken. Asbestos fragments were identified at the surface and within filling materials across the site.

The infrequency of elevated contaminant concentrations indicates that contaminants are not evenly spread within the filling materials but that small isolated pockets of contamination are likely to exist. An evaluation of contaminant concentrations in surface filling indicates that there is no observable distinction between concentrations in fill materials at the surface and at depth within the profile. Due to the random nature of site filling, remediation by isolating each contaminated area and segregating these for removal or treatment is not feasible or practical. The presence of asbestos fragments represents a potential health risk to future site occupants and remediation of these materials is required. Capping with clean imported fill is a suitable remediation technology for asbestos and would satisfactorily address the minor elevated concentrations of other analytes present. Remediation options are discussed further in the following sections.

The presence of waste fill at the site surface requires remediation to improve local amenity.

Concentrations of contaminants in natural soils underlying filling materials were below the criteria in all samples.

An evaluation of concentrations against EILs indicates that some metals exceed these criteria. Given the extent of apparently healthy vegetation on the site it is unlikely that impacts from elevated metals has occurred. Consideration of EILs is required for any remediation strategy.

11.1 WATER

Surface and perched groundwater (water identified within the waste profile) analysis was undertaken. Perched water was not present in all areas of the landfill and indicates discontinuities between the waste 'aquifer' and the deeper rock aquifer on site. Perched water is also likely to be transient and dependent on rainfall. Surface water ingress to the site, and potentially the perched water table, is limited by the location of the Old Pacific Highway on the up gradient boundary. Surface water diversions are present along this roadway which diverts water down gradient along the road alignment. The true groundwater table was not investigated and is expected to be present at depths greater than 10m from the surface. This depth to groundwater, in combination with the topography and presence of surrounding surface water channels indicates that perched water has greater impact on surface water than groundwater.

Surface water samples were collected in a surface water pool located up gradient of the site (SW3) and along the Tributary to Galgabbee Creek located to the south west of the site. Samples SW1, SW2 and SW4 were collected in order of decreasing elevation along this alignment, as identified on **Drawing 4**.

The trilinear plot prepared for water chemistry (**Drawing 5**), indicates that surface water samples SW1, SW2 and SW3 are closely related, and based on chemistry are independent of all other samples. A review of this water chemistry and topography shows that these samples are likely to be independent of any run-off or leachate from the landfill. Based on the position of these samples, it is considered likely that they represent down gradient water quality from the Old Pacific Highway road alignment.

Surface water sample SW4 is further down gradient and water chemistry indicates a relationship with BH1. The results indicate that perched water from the landfill is reaching the surface water body at this point. The unrelated data for BH2 and BH4 further indicates that perched water within the landfill is not continuous through the landfill.

In consideration that SW1, SW2 and SW3 are representative of surface water that is not impacted by the landfill, elevated concentrations of copper, iron, lead and nickel appear unrelated to the site. These metals are found in all samples at similar concentrations. In the case of copper, lead and iron concentrations were found to be lowest in sample SW4.

Zinc concentrations were found to be higher in the perched water table than in surface water samples. However, concentrations at SW4 were not noticeably higher than other surface water samples and indicate that down gradient contamination is not occurring as a result of elevated zinc in perched water. The adopted guideline for zinc can be corrected for water hardness where the guideline increases with increasing hardness (a factor of 5.2 is applied for very hard water). A review of the guideline indicates that concentrations within the perched water remain above the revised guideline, whereas concentrations at SW1, SW2 and SW4 are below or close to the revised guideline.

Phenols were not identified in site perched water or at surface water SW4. A minor elevated phenol concentration was identified in samples SW3 and is considered to be unrelated to the waste on site.

TPH was identified in all samples excluding SW1 and SW4. The highest concentrations were found within the landfill. Although the concentrations for TPH are above the guidelines they are not considered to represent a health or environmental risk on the following basis:

- The guideline adopted for TPH is a low reliability figure based on limited toxicological data. Previously, the Dutch guideline (Ref [11]) of 0.6mg/L has been adopted for TPH evaluation and is still widely used for site assessment. All concentrations are below the Dutch guideline.

- The down gradient SW4 sample does not contain elevated concentrations of TPH. Water at this point represents the quality of water leaving the site to down gradient receptors (Lake Macquarie).

11.2 CONTAMINANTS OF CONCERN

On the basis of the site characterisation, the following contaminant species have been identified as Contaminants of Concern for the site:

- Asbestos fibres in soil.

- PAH in soil.

- Lead and zinc in soil.

- Toluene in soil.

No human health or ecological risks from perched groundwater or surface water movement from the site is likely. Aesthetic issues also need to be considered in regard to future local amenity.

11.3 ASSESSMENT OF POSSIBLE EXPOSURE ROUTES

Possible exposure routes for contaminants at the site include inhalation of asbestos fibres from soils, if present at the site, and inhalation, ingestion or dermal contact with PAH and lead concentrations in soil. Asbestos fibre sampling has indicated the absence of asbestos fibres in soil, however uncontrolled burial of asbestos fragments increases the risk of asbestos fibres and therefore the presence of fibres should not be discounted.

On the basis of these potential exposure pathways, it is considered that site remediation is necessary to make the site suitable for its intended usage.

12 REMEDIAL ACTION PLAN

12.1 REMEDIATION GOAL

The goal for the remediation is to ensure that the site is remediated to a point where the risk to human health and the environment is minimised and the site is suitable for the proposed end use.

12.2 THE REMEDIATION EXTENT

Remediation of soils at the site is required to remove the risk to human health from asbestos fragments and isolated pockets of PAH and lead contamination. Remediation is also required to improve local aesthetic amenity.

Perched water within the landfill is not required to be remediated. However, any remedial solution should minimise impacts on perched water generation and flow.

12.3 POSSIBLE REMEDIAL OPTIONS

The following remediation options are applicable to contaminants (hydrocarbons, metals, and/or asbestos). The options are ordered in a hierarchy of most preferred to least preferred as outlined in *DEC Site Auditor Guidelines 2nd Ed 2006* (Ref [12]).

On and Off Site Treatment

These involve remediation solutions (treatment) that aim to remove or reduce the soil contaminant to a concentration that allows unrestricted use of the soil at the site.

Remediation of hydrocarbon contamination can be achieved either on or off site by techniques such as enhanced landfarming. Landfarming uses natural processes to promote biodegradation of the hydrocarbons. The timing and success depends on the nature of the hydrocarbon contamination as well as other required factors such as oxygen, a healthy microbe population, nutrients and water. This option is viable for some of the hydrocarbons present, however it would require designated handling and treatment locations as well as enhancement of the natural biodegradation processes to breakdown the long chain PAH present. The process is likely to be slow and time consuming. Substantial additional testing would also be required to delineate PAH contaminants and validate the remaining soil body.

Destruction of metal contamination in soil cannot be achieved, however contaminants can be transferred from one media to another. Such processes include soil washing, which concentrates the metal contamination in a liquid solution which can then be cleaned (by precipitation) for disposal. Treated soils are then able to be reused on site. Soil washing is a costly and slow process which utilises a pH adjusted solution to leach metals from the soil matrix. The success of the process is dependent on a number of factors including the porosity of the soil (which reduces the effectiveness of soil washing by limiting the movement of solution through the soil matrix). The process is likely to be slow and time consuming. Substantial additional testing would also be required to delineate lead contaminants and validate the remaining soil body.

Asbestos *fibre* contamination cannot be removed from soil with any certainty. On site treatment for soils containing asbestos cement *fragments* could be achieved through separation by hand picking or sieving. A rigorous validation programme would be required to verify that all asbestos fragments had been removed during the remediation and that no asbestos fibres remained in the tested soils. This process is costly but could be achieved within a short timeframe. Once validated the material would be suitable for re-use on site. There is a risk that validation could fail and repeat screening or alternate remedial method be required.

On Site Encapsulation

On site encapsulation would be a feasible remedial method. Encapsulation could be achieved through capping impacted areas with a layer of clean material. This option requires clean fill, possibly sourced off site, to be brought and placed across the site, in combination with the development of an Environmental Management Plan for the long-term management of capped site contaminants. The management plan would be noted on the Site Audit Statement and may also be noted on the Section 149 certificate for the site.

The capping layer thickness is dependent on the site use and the contaminants present. This method could be cost effective and completed within the project timeframe.

Off Site Encapsulation

Encapsulation of soils impacted by hydrocarbons, metals and asbestos can be undertaken off site at a licensed waste facility in an approved land fill cell. The cell is required to be appropriately designed to accommodate the contaminant concentrations expected and proposed soil volume, and additional requirements apply to soil with asbestos contamination. The classification of soil for disposal is based on the total and the leachable chemical concentrations. This method is expensive but could be completed within the project timeframe.

12.4 PROPOSED REMEDIAL OPTION

The proposed remedial option within the recreational footprint is on site encapsulation. Encapsulation is not a recommended remediation technique for residential development however, is suitable and widely accepted for use below recreational areas including playing fields. For the proposed residential development, the recommended remedial option is removal of all impacted fill materials and incorporation within the proposed recreational use area. The final site landform allows for this to occur and any excavated areas that do not meet the final landform will be filled with clean filling materials.

The contaminants present are not volatile and therefore will not result in odour or soil gas accumulation beneath the capping layer. The impact of soil contaminants on perched groundwater appears minimal, as evidenced by the perched groundwater review, and therefore infiltration controls at the site are not required. However, the proposed capping strategy does allow for a moderate permeability capping layer and surface gradient to minimise the infiltration of water at the site.

The proposed capping strategy is as follows:

- Placement of a marker layer comprising a high visibility geotextile or similar.
- Placement of 0.2m of compacted clean fill. Fill can comprise any geotechnically suitable material type.
- The final capped surface should achieve a 1% slope to promote surface water run-off.
- Placement of the recreational playing surface including drainage.

- Surface water drainage will be placed around the capped area to promote surface water movement away from the encapsulated materials.

The proposed final landform is presented in **Drawing Series 7284-LR01 to LR05**.

The proposed capping thickness of 0.2m varies from the ANZECC containment guidelines recommendation of 0.5m. However, the proposed capping thickness is considered valid for the following reasons.

Filling materials (including soils) at the site comprise generally low contaminant concentrations. The risk of contamination is primarily from asbestos, and the risk of asbestos fibres. No asbestos fibres have been identified in limited sampling, however the presence of bonded asbestos fragments gives rise to the risk of fibre presence. The purpose of the capping layer is to provide protection against possible asbestos impacted soils. The guideline for asbestos is 'no asbestos fibres or fragments in surface soils'. A cap thickness of 0.2m will ensure that this guideline is met.

The capping strategy comprises the placement of 0.2m of suitably validated fill over contaminated soils. Prior to placement of the capping layer the surface will be levelled and a high visibility marker layer placed. Final playing field design will incorporate placement of engineered fill, including drainage, to create the playing surface. It is also likely that an additional filling layer will be placed, prior to placement of the engineered playing surface, to achieve the required final design levels. In total it is estimated that a further 1.0m of fill depth will be placed above the capping layer.

A management plan is proposed to outline the protocols for excavating beyond the depth of the capping layer and to ensure the long-term integrity of the cap. The placement of a marker layer comprising high visibility geofabric will therefore be included in the capping strategy to provide a barrier/warning to personnel excavating below the capping layer. The management plan and the marker layer will control site works and provide long-term protection to the capping layer.

12.5 PROPOSED TESTING TO VALIDATE THE SITE AFTER REMEDIATION

A validation plan is presented in Section 13 outlining the validation protocol.

12.6 CONTINGENCY PLAN

The remedial strategy has been designed for maximum robustness given the nature of the contaminants on the sites. This has included proposing effective but relatively low-technology solutions to provide a high degree of engineering confidence.

Nevertheless, project contingencies for the remediation programme have been developed.

12.6.1 DISCOVERY OF UNEXPECTED MATERIALS

Any unexpected materials (such as highly odorous materials or putrescible waste) will be designated to a separate stockpile for characterisation prior to placement within the encapsulated area. Where the materials are not suitable for placement within the area, options for disposal off site to a licensed waste landfill facility or on site encapsulation in an engineered landfill cell will be considered.

12.7 INTERIM SITE MANAGEMENT PLAN

The site is currently fenced and access is controlled. Access to and risks posed by the presence of site contaminants are not considered to be significant. There is no requirement for interim site management beyond the maintenance of this security measure.

12.8 SITE MANAGEMENT PLANS

Site management plans will be required for the protection of human health and the environment during the remediation works. These plans will be prepared by the remediation contractor and approved by the Environmental Superintendent prior to commencement of works. Plans are to include, but not be limited to, provisions for:

- health and safety;
- incidents and emergency response;
- community complaints register and response;
- soil management and tracking;
- sediment and erosion control;
- groundwater and surface water protection;
- air quality including dust, noise and odour control.

The site management plans are to be made available to the staff working on the site to allow for understanding of the potential risks to site workers. The purpose of the site management plans is to assist in the appropriate handling of potentially contaminated material and provide measures which can be undertaken to mitigate those risks.

12.9 REGULATORY COMPLIANCE

Development approval for the remediation of the site will be sought from Lake Macquarie City Council as part of the Development Application for the Wallarah Peninsula North Precinct residential subdivision and redevelopment. Any relevant consent conditions from this development will be incorporated within this RAP and the RAP modified to reflect these conditions.

The site is subject to a non-statutory Contaminated Site Audit under Section 60 of the Contaminated Land Management Act. Interim advice from the Site Auditor has been incorporated within the RAP and Validation Plan.

It is a requirement of the EMP that Council agree to noting the EMP on the Section 149 certificate, or as an addendum to the Site Audit Report which will be attached to the Section 149 certificate.

12.10 REMEDIATION SCHEDULE

Remediation is to be undertaken at the site in 2009. Remediation is expected to take approximately 20 weeks to complete.

12.11 HOURS OF OPERATION

Hours of operation at the site are Monday to Friday from 7am to 6pm and Saturday from 8am to 12pm. No work would be undertaken on Sundays or Public Holidays.

12.12 RESPONSIBILITIES AND CONTACTS

The responsibilities and contact details for the various personnel to be involved in the remediation and validation works are yet to be determined. When these details have been finalised, appropriate signage, including contact names and numbers and an after hours contact, will be placed at the work sites.

12.13 LONG-TERM MANAGEMENT PLAN

A long-term Environmental Management Plan (EMP) will be required for the long-term maintenance of the capping layer. The EMP will be developed to:

- maintain the integrity of the capping layer;
- ensure the appropriate management of any waste soils generated from beneath the cap;
- provide protection to workers who may penetrate the cap during construction or maintenance activities;
- describe a management strategy should unexpected pockets of waste materials be encountered after capping is complete.

The EMP will comprise, but not necessarily be restricted to, the following information:

- Surveyed diagram of site.
- Description of contamination remaining on site.
- Location and depth of encapsulated contamination.
- Discussion of the potential for unknown contamination.
- Controls that have been implemented for the protection of human health and the environment.
- Measures that must be implemented or maintained to continue the protection of human health and the environment.
- Responsibility for the implementation of the EMP.

The EMP will require the approval of the Site Auditor and will be attached to the Site Audit Report and must be attached to the legal documents associated with the site (such as Section 149 certificate at a minimum) with the agreement of Lake Macquarie Council.

13 VALIDATION

The Validation Plan is to be endorsed by the Site Auditor as part of the RAP prior to its implementation. Any deviations from the endorsed Validation Plan will require review and approval by the site auditor.

13.1 OBJECTIVES

The objectives of this plan are to detail the validation requirements for the remediation project and to prescribe the data quality objectives (DQO). When followed throughout the remediation project these DQO ensure the integrity of the validation data set and hence the validation that the site is suitable for its intended uses.

13.2 DATA QUALITY OBJECTIVES

In order to achieve the objectives and purpose of the validation programme, both the field and laboratory programmes must indicate actual extent of contamination in soil. As such, specific data quality objectives have been developed for the validation of field and analytical data obtained during the validation works. As outlined above, the DQO process is a systematic, seven step process that defines the criteria that the sampling should satisfy in accordance with the requirements of DEC (2006) Guidelines for the NSW Site Auditor Scheme (2nd Edition) (Ref [12]).

13.2.1 STEP 1 PURPOSE OF THE VALIDATION PLAN

The purpose of the Validation Plan is to develop a framework for validation of remediation to verify that the site is suitable for a proposed end use.

13.2.2 STEP 2 – IDENTIFY THE DECISIONS

The validation plan is to verify that the adopted remediation strategy has been completed. This will inform decision making as to the suitability of the site for the proposed use following remediation. The validation plan is to ensure that:

- relevant contamination has been identified on the site;
- the contamination identified has been adequately assessed;
- an appropriate remediation strategy has been developed and implemented;
- the remediation strategy has been carried out successfully, as demonstrated by validation records and testing; and
- strategies are in place to prevent site recontamination.

The site will be considered to be remediated when:

- a review of existing data indicates that the site has been adequately assessed and that an appropriate remediation strategy has been developed; and
- the remediation programme has been carried out successfully.

Remediation is deemed to be successful when:

- validation of residential areas has been undertaken;
- validation sampling has demonstrated the placement of the capping layer as prescribed in this remediation plan;
- the capping layer $95\%_{average}$UCL contaminant concentrations in the capping soils are shown to be below the remediation acceptance criteria for all CoC and no analyte concentration is 250% of the remediation acceptance criterion;
- The EMP is detailed and approved by the site auditor.

Where the above criteria cannot be achieved due to site or project constraints, such as practical or economical limits, a risk based assessment of the contaminant may be required. Such risk based assessments should be undertaken in accordance with NSWEPA Guidelines for the Site Auditor's Scheme 2nd Edition (2006), Appendix VII and the National Environment Protection (Assessment of Site Contamination) Measure (1999) Schedule B(4) Guidelines on health risk assessment methodology.

The specific decisions to be made for each medium are as follows:

- Identified soil contamination as follows:
    - Verify that soils impacted with asbestos and hydrocarbons have been successfully moved to the burial location beneath the designed capping layer (comprising marker layer overlain by at least 0.2m suitable filling material) or legally disposed off site.
    - Verify the complete removal of contaminated (waste) fill from within the residential footprint.
    - Verify that re-contamination of the residential site, the surrounding natural environment, or contamination of the capping layer has not occurred.
- Other contamination issues as follows:
    - Verify that capping and other filling soils are suitable for use.
    - Verify that the marker layer is suitable for use and in place.

13.2.3 STEP 3 – IDENTIFY INPUTS TO THE DECISION

The following inputs into the decision making process are required for the site:

- Confirmation that all materials have been excavated from the residential footprint.
- Confirmation that waste materials are contained beneath a capping layer.
- Confirmation that the placement of capping layer has been undertaken according to the RAPs requirements.
- Confirmation that materials imported to site have been validated as suitable for the purpose.
- Confirmation that the environmental superintendent's observations and validation sampling verify that remediation has been successful.

Validation sampling protocol is outlined in Section 13.2.6.

Field screening equipment proposed for use during this project may include the photoionisation detector (PID). Data to date has not indicated the presence of volatile contaminants. The use of this meter is discussed in the following.

PID – the PID will be calibrated prior to commencing daily sampling. Calibration methodology is by standard calibration gas and following the equipment calibration instructions. The PID lamp ionisation potential will be appropriate to the ionisation potentials of the hydrocarbon contaminants expected on the site. Where PID screening is required a duplicate sample of the primary sample will be collected, allowing headspace within the sampling jar, and a perforation in the lid of the jar will be used to insert the PID probe. Testing will be undertaken five minutes after sample collection to allow for gas accumulation. Climatic conditions at time of the PID use will be recorded.

13.2.4 STEP 4 – DEFINITION OF THE BOUNDARIES OF THE INVESTIGATION

The site boundaries will be determined by a professional surveyor and marked in the field, including the delineation of the residential footprint. The site boundaries have been outlined and defined within this RAP and are presented in **Drawing 2**, **Appendix A**.

13.2.5 STEP 5 – DEVELOPMENT OF DECISION RULES

The decision making process to evaluate quality data will follow a set of standard rules outlined within Section 7.1.5.

13.2.6 STEP 6 – SPECIFICATION OF THE ACCEPTABLE LIMITS ON DECISION ERRORS

Acceptable limits and the manner of addressing possible decision errors are outlined in Section 7.1.6.

13.2.7 STEP 7 – OPTIMISATION OF THE DESIGN OF THE COLLECTION OF DATA

The Sampling Analytical and Quality plan (SAQP) consists of the components described within the sections below.

13.2.7.1 SAMPLING METHODOLOGY

Soil

Discrete sampling will be undertaken by collecting surface soil using a steel trowel. Discrete samples will be spaced in a 15m triangular grid formation across the sub-area to ensure that an even coverage of the site is achieved. Visual indications will also be used to confirm removal of waste.

Where walls of excavations are present and >0.2m in thickness, discrete sampling will be undertaken from each soil type at every 10 lineal metres.

All samples will be given a unique identifier and marked by survey peg for GPS survey.

Capping and Other Imported Fill Sampling

Stockpiles of capping and other imported fill will be sampled prior to transport to the site where possible. Sampling will be undertaken from the stockpile using either hand auger or excavator depending on the stockpile size. Sampling will be undertaken on an evenly spaced grid and at various depths in order to obtain a representative characterisation.

13.2.7.2 VALIDATION SAMPLING PATTERN, FREQUENCY AND ANALYSIS

All validation samples are to be collected in accordance with the DQO process outlined above. The objective of the sampling pattern is to demonstrate that the adopted sample density and total number of samples collected is suitable for the proposed land use. The excavations will be validated following removal of the material containing CoC.

The sampling densities outlined within the following tables are dependent on the homogeneity of the soil material sampled. All surfaces to be validated will be inspected visually before sampling and a determination of variability of the media will be made. Should the visual inspection show significant variability, an increased sampling density will be determined and a justification will be outlined within the Validation Report.

Table 9 *Proposed Validation Sampling*

Validation Component	Validation Programme
Residential footprint	Sampling across the site is to be undertaken on a 15m triangular grid spacing. This sampling programme is in accordance with the NSW EPA Sampling Design Guidelines (Ref [4]). All samples will be analysed for metals (As, Cd, Cr, Cu, Ni, Hg, Pb and Zn), TPH, BTEX and PAH. Approximately 25% of samples will additionally be analysed for OCP, PCB, and asbestos fibres.
Monitoring of fill placement	Routine monitoring will be undertaken during placement of fill on the recreational site. Monitoring records will include photographic logs, gas monitoring to 0.05% by landfill meter of fill materials and field logs of material descriptions. Monitoring is to be undertaken at least daily throughout the excavation and placement programme at the direction of the Environmental Superintendent.
Content of the Soil Capping Layer and Other Clean Fill	Soil material used within the capping layer must be suitable for use. Soils are to be analysed for (As, Cd, Cr, Cu, Ni, Hg, Pb and Zn), TPH, BTEX and PAH. Approximately 25% of samples will additionally be analysed for OCP, PCB, and asbestos fibres. As a guide, soil sampling should be undertaken at a rate of one sample per 1000m^3, however sampling should give consideration to the material origin and site history and the statistical guidelines for sampling from NSW EPA Sampling Design Guidelines (Ref [4]). Variations to this may occur where clean fill is to be validated in situ. In this instance a site specific sampling plan will be developed by an appropriately qualified environmental consultant.
Placement of Soil Capping Structure/Layer	• Compilation of soil tracking logs which indicate the placement impacted material beneath capping structure/layer. • Compilation of photographs with location drawing and date verifying the placement of the marker layer. • Verification by survey of the placement of the 0.2m filling of suitable material (as validated according to above point). • Final landform surface verifying surface slope. • Compaction records.

13.3 REGULATORY REQUIREMENTS

This validation plan has been prepared in accordance with the following:

- NSWEPA Sampling Design Guidelines (NSW EPA, 1995) Ref [4]).
- NEPC National Environment Protection (Assessment of Site Contamination) Measure (NEPC, 1999) Ref [6].
- DECC Guidelines for the NSW Site Auditor Scheme (2nd Edition) (December 2006) Ref [12].

13.4 REMEDIATION ACCEPTANCE CRITERIA

13.4.1 CONTAMINANTS OF CONCERN

Based on the history of activities on the site and the contaminants identified during site investigations, the location areas and potential contaminants of concern for the site include:

- metals (lead, zinc);
- fibrous asbestos cement fragments and asbestos fibres in soil;

- hydrocarbons, toluene, PAH.

Additional metals are above the EILs and may be considered potential contaminants of concern if located within areas of proposed vegetative growth.

Any observations by the Environmental Superintendent that indicate additional contaminants of concern will be addressed through sampling and analysis.

13.4.2 SOIL GUIDELINES

As long as they remain current, the site investigation criteria presented in Section 9 will be adopted as the remediation acceptance criteria based on the proposed end use for the site. In addition to these, the provisional phytotoxicity guidelines from the NEPM guidelines (Ref [6]) will be utilised to assess the suitability of soils located in the open space (landscaping) portions of the site, including within residential areas.

13.5 VALIDATION REPORT

A Validation Report will be compiled by the Environmental Superintendent on completion of the on site works. This report will contain an overview of the remediation activities conducted and details of the following:

- Site description.
- Details of the fieldwork undertaken including site capping.
- Volumes of imported capping materials, where utilised.
- Validation of the capping layer.
- Surveyed plan with GPS co-ordinates of sampling locations for each analyte.
- Analytical results of validation soil samples.
- Assessment of project quality assurance and quality control.
- 95% UCL_{ave} and standard deviation calculations for each of the remediation areas.
- A statement indicating the suitability of the site for the proposed land use.

Supporting factual evidence will be included in the report. This will include NATA-registered laboratory analysis certificates, photographic and field records, PID data (where obtained) and materials tracking data. The report will also include interpretative summary tables and an overview of the works carried out during the remediation process.

The validation report will be prepared in accordance with the NSWEPA Guidelines for Consultants Reporting on Contaminated Sites (NSWEPA 1997) and the Department of Environment and Conservation Guidelines for the NSW Site Auditor Scheme 2nd Edition (DEC 2006), as appropriate.

14 ONGOING SITE MONITORING

There are no presently perceived requirements for ongoing site monitoring.

15 CONCLUSION AND RECOMMENDATIONS

Asbestos fragments have been identified in fill materials placed within the landfill footprint. Isolated areas of PAH and lead contamination have also been identified. Impacts to perched water within the landfill are minor and have not been shown to impact on the down gradient surface water. Long-term human health risks were identified for site occupants due to the presence of soil contaminants.

A remedial action plan is required to address human health risks and it was determined that remediation by on site encapsulation within the recreational footprint was the preferred remedial strategy. The strategy requires the excavation of impacted materials on the proposed residential footprint and relocation to the recreational footprint. Capping is then undertaken by the placement of a marker layer and 0.2m of clean soils. Future management of the capping layer will be undertaken through an EMP.

Following successful validation of the remediation program, the site will be suitable for the proposed use. There will be ongoing constraints on the recreational site that will be outlined in the EMP that will ensure the maintenance of the capping layer. On the basis of existing information, site use on the residential site will be unrestricted.

16 LIMITATIONS

This report has been prepared for Stockland Wallarah Peninsula Pty Limited in accordance with an agreement with RCA dated 12 February 2008. The services performed by RCA have been conducted in a manner consistent with that generally exercised by members of its profession and consulting practice.

This report has been prepared for the sole use of Stockland Wallarah Peninsula Pty Limited. The report may not contain sufficient information for purposes of other uses or for parties other than Stockland Wallarah Peninsula Pty Limited. This report shall only be presented in full and may not be used to support objectives other than those stated in the report without written permission from RCA.

The information in this report is considered accurate at the date of issue with regard to the current conditions of the site. Conditions can vary across any site that cannot be explicitly defined by investigation.

Environmental conditions including contaminant concentrations can change in a limited period of time. This should be considered if the report is used following a significant period of time after the date of issue.

Yours faithfully
RCA AUSTRALIA

Fiona Robinson
Principal Environmental Engineer

REFERENCES

[1] Sinclair Knight Merz, Former Swansea South Tip Site, Geotechnical and Contamination Report, Final April 2003.

[2] RCA Australia, Environmental Site Assessment, Phase 1 Investigation, Wallarah Peninsula Northern Precinct (South), July 2007.

[3] http://www.m.gov.au

[4] NSWEPA, Sampling Design Guidelines, September 1995.

[5] NSWEPA, Solid Waste Landfill Guidelines, 1996.

[6] NEPM, National Environment Protection (Assessment of Site Contamination) Measure, 1999.

[7] NSWEPA, Guidelines for Assessing Service Station Sites, December 1994.

[8] DECC, Guidelines for Assessment and Management of Groundwater, 2007.

[9] NHMRC and NMMC, Australian Drinking Water Guidelines, 2004.

[10] ANZECC, Australian and New Zealand Guidelines for Fresh and Marine Water Quality, October 2000.

[11] Ministry of Housing, Spatial Planning and Environment, Environmental Quality Objectives in the Netherlands, 1994.

[12] NSWEPA, Guidelines for the NSW Site Auditor Scheme, June 1998.

[13] NSWDECC, Waste Classification Guidelines, April 2008.

[14] NSWEPA, Guidelines for Consultants Reporting on Contaminated Sites, November.

GLOSSARY

95%UCL_{ave}	A statistical calculation – 95% Upper Confidence Limit of the mean concentration.
AHD	Australian Height Datum (m), based on a mean sea level.
Aliphatic	Straight chain formation of carbon atoms.
ANZECC	Australian and New Zealand Environmental Conservation Council.
Aromatic	Ring formation of carbon atoms.
Bioremediation	The process by which living organisms act to degrade or transform hazardous organic contaminants.
EMP	Environmental Management Plan.
HIL 'A'	Standard Residential Health Based Investigation Level, pg 9 Schedule B1, *National Environment Protection (Assessment of Site Contamination) Measure.*
HIL 'D'	Residential with minimal opportunities for soil access Health Based Investigation Level, pg 9 Schedule B1, *National Environment Protection (Assessment of Site Contamination) Measure.*
HIL 'E'	Parks, recreational open space and playing fields Health Based Investigation Level, pg 9 Schedule B1, *National Environment Protection (Assessment of Site Contamination) Measure.*
HIL 'F'	Commercial/industrial Health Based Investigation Levels, pg 9 Schedule B1 *National Environment Protection (Assessment of Site Contamination) Measure.*
Hotspot	A sample, or location, where contaminant concentrations exceed 250% of the appropriate guideline.
In-Situ	In place, without excavation.
Interlaboratory	Prefix inter – as meaning between. A sample sent to two different laboratories for comparative analysis.
Intralaboratory	Prefix intra – as meaning within. A sample sent twice to the sample laboratory for comparative analysis.
kg	kilogram, 1000 gram.
Leachate	Fluid that has passed through a soil stratum, possibly collects contaminants.

LEP	Local Environment Plan. A planning tool for the Local Government.
µg	microgram, 1/1000 milligram.
mg	milligram, 1/1000 gram.
NEPC	National Environment Protection Council.
NEPM	National Environment Protection Measure.
NHMRC	National Health and Medical Research Council.
Phytotoxicity	Poisonous, or inhibiting, to plant growth.
PID	Photoionisation Detector. Measures volatile gases in air or emanating from soil or water.
PPE	Personal Protective Equipment.
PQL	Practical Quantitation Limit.
QA	Quality Assurance.
QC	Quality Control.
RPD	Relative Percentage Difference.

Chemical Compounds

BTEX	Benzene, Toluene, Ethylbenzene, Xylene.
Hardness	Content of metallic ions (eg, calcium and magnesium).. The hardness of the water impacts on the way metals behave.
OCPs	Organochlorine Pesticides.
PAH	Polycyclic Aromatic Hydrocarbons. Multi-ring compounds found in fuels, oils and creosote. These are also common combustion products.
PCBs	Poly Chlorinated Biphenyls.
Phenols	Carbolic Acid (C_6H_5OH). Phenols and substituted phenols are used as anti-microbial agents in high concentrations.
TPH	Total Petroleum Hydrocarbons.