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Report on
Land Capability, Salinity & Contamination Investigation
Volume 1 - Introduction

Riverstone East Precinct
North West Growth Centre

Prepared for
Mott MacDonald Pty Ltd

Project 73895
Report 73895-2, Volume 1
September 2014

Integrated Practical Solutions

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Document History

Document details

Project No.	73895.00	Document No.	2
Document title	Report on Land Capability, Salinity & Contamination Investigation		
Site address	Riverstone East Precinct, North West Growth Centre		
Report prepared for	Mott MacDonald		
File name	\\Dpsydfp02\Projects\73895 RIVERSTONE EAST & VINEYARD, Land Capability NLE\Docs\REPORTS\RVE\73895_2_RVE_Vol 1_Intro.docx		

Document status and review

Revision	Prepared by	Reviewed by	Date issued
0	N. Edwards / R. Lloyd	P. Gorman / RW Lumsdaine	9 September 2014

Distribution of copies

Revision	Electronic	Paper	Issued to
0	1	0	Mott MacDonald (C. Avis)

The undersigned, on behalf of Douglas Partners Pty Ltd, confirm that this document and all attached drawings, logs and test results have been checked and reviewed for errors, omissions and inaccuracies.

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Executive Summary

1. Introduction

This letter report provides a summary of the available results of the Land Capability, Salinity and Contamination Investigation for the Riverstone East Precinct of the North West Growth Centre (the Precinct). The investigation has been conducted to support the current rezoning process. The rezoning will allow for urban development, including residential and employment related development. Full reporting is currently underway and will be provided in due course.

2. Summary of Land Capability Investigation Geotechnical Results

2.1 Geology

A review of available geology maps for the Precinct (Penrith 1:100 000 Geological Series Sheet 1) indicates that most of the Precinct is underlain by rocks of the Wianamatta Group (Ashfield Shale, Minchinbury Sandstone and Bringelly Shale). Quaternary age sediments are present along a small section of the north-eastern boundary (associated with the south-eastern part of Killarney Chain of Ponds) and also along most of the western boundary of the Precinct which is approximately defined by First Ponds Creek.

In summary, the underlying geology and lateral extent of the formations and associated soils comprise;

- Bringelly Shale (mapping unit Rwb) underlies most of the Precinct, particularly the slightly more elevated ridge areas and extends almost to the northern point of the Precinct. This formation typically comprises shale, carbonaceous claystone and laminite, with very minor coal in parts.
- Ashfield Shale (mapping unit Rwa) underlies much of the mid-slope parts across the northern two thirds of the Precinct, extending to the eastern and western boundaries. The rock of this formation typically comprises shale, laminite and dark grey siltstone, sometimes with a relatively deep, clay soil profile.
- recent sediments (mapping unit Qal) comprise fluvial sediments of sand silt and clay and underlie the western boundary within First Ponds Creek and towards the upper section of Killarney Chain of Ponds.

The Minchinbury Sandstone separates the Ashfield and Bringelly Shale formations and is a thin, typically less than 3 m thick, persistent quartz-lithic sandstone.

2.2 Soil Associations

The Soil Landscape map (Penrith 1:100 000 Sheet) indicates that the Precinct is almost entirely underlain by a single soil landscape group, the Blacktown soil group. The South Creek soil group is also present and is associated with the First Ponds Creek and the upper section of Killarney Chain of Ponds alignments.

The Blacktown (bt) soil group is a residual soil landscape which characterises the mid-slope topography formed on the Wianamatta Group shales. These areas, including the northern part of the Precinct, have local relief to 30 m and slopes usually less than 5%, but up to 10%. There are rounded crests and ridges with gently inclined slopes. The mapping indicates multiple soil horizons that range from shallow red-brown podzolic soils comprising mostly clayey soils on crests and upper slopes, with deep brown to yellow clay soils on mid to lower slopes and in areas of poor drainage. These soils are typically of low fertility, are moderately to highly reactive, highly plastic and generally have a low wet strength.

The South Creek (sc) group occupies the lower flood plains, valley flats and drainage depressions. The soils are fluvial, often very deep layered sediments overlying residual/relict soils or bedrock. The topography is typically flat to gently sloping (slopes of <5%) with the soils comprising brown, red and yellow brown, clays, silty and sandy clays. These soils are typically of low fertility, highly erodible, with some stream bank and gully erosion, and are moderately reactive in some areas.

2.3 Fieldwork Results

Subsurface conditions encountered during the geotechnical investigation confirmed the presence of the mapped soil types and rock formations.

The boreholes, drilled using a geotechnical drilling rig (Bores 41 to 45) for the installation of groundwater monitoring wells, generally on the lower creek line parts of the Precinct, typically encountered clays with some ironstone gravel to the full depth of investigation (5 m to 6 m). The exceptions were Bores 42 and 44, which were located on a minor creek line and the upper end of Killarney Chain of Ponds, respectively and encountered shale below 2.2 m depth.

Groundwater was encountered in the deeper bores (Bores 41, 43 and 45) at 3.5 m to 5.9 m depth whilst Bores 42 and 44 did not encounter groundwater during the drilling and installation of monitoring wells. Subsequent monitoring indicated water levels between 0.44 m and 1.5 m below surface level (on 10 April 2014).

The remaining bores and test pits typically encountered stiff to hard residual clays and silty clays (away from the creek lines) grading into weathered bedrock of shale and siltstone at depths ranging from 0.5 m to about 1.5 m. The soil depths were greater towards the creek lines where alluvial sediments were present and in some mid-slope areas, particularly overlying the Ashfield Shale.

The shallower push tube bores generally did not encounter groundwater, although seepage was noted at some locations. The test pits did not encounter any groundwater (except Pit 72A where seepage was encountered at 1.6 m) and were backfilled on completion, which precluded long term monitoring of groundwater levels.

2.4 Geotechnical Laboratory Results

Geotechnical laboratory test results undertaken on soil samples collected from the Precinct indicated conditions as typically anticipated for the mapped and encountered geology and soil types.

In summary, the soils were generally found to be/have;

- medium to high plasticity (with moderate linear shrinkage),
- medium and high reactivity (i.e. medium and high potential for soil volume change due to variation and seasonal changes of soil moisture content);
- moderate CBR values (4%, 5% and 7%);
- a predisposition to erosion in some areas;
- sodic to highly sodic;
- predominantly non-saline to slightly saline, becoming very saline in places; and
- predominantly non-aggressive to concrete and steel, becoming mildly aggressive to concrete in places.

2.5 Geotechnical Issues and Constraints

Based on the results of the assessment so far, the following summary points are noted:

- No evidence of significant hillside/slope instability was observed within the Precinct. There were a number of examples of minor creek bank collapse/erosion in the lower areas of the Precinct, however it is considered that such instability does not impose significant constraints on the proposed development.
- The presence of erosive soils on the Precinct should not present significant constraints to development provided they are well managed during earthworks and site preparation stages. Minor sheet and rill erosion was observed with some gully erosion towards the lower creek lines, generally in line with the soil dispersion results (Emerson Class Number).
- Highly sodic and sodic soils appear widespread (refer Salinity Summary Table, attached) and will require management to reduce dispersion, erosion and to improve drainage).
- Some mild aggressivity to concrete was indicated by the test results (refer Salinity Summary Table, attached), however, the indicated aggressivity levels are considered manageable, subject to appropriate design and construction considerations.
- With respect to residential foundation design (to AS 2870 – 2011 "*Residential Slabs and Footings*") the undisturbed subsurface profiles at most locations are typical of Class M (moderately reactive) and Class H (highly reactive) sites. Further delineation between Class H1 and Class H2 sites would need to be made for any subsequent construction certificate issue or prior to linen release. It is noted that disturbed ground, such as existing dam walls, including where existing filling is present (such as at the very northern end of the Precinct where it appears there has been flood mitigation/drainage works and adjoining some areas of Killarney Chain of Ponds), would warrant an alternative classification of Class P (problem site).
- CBR values indicate that appropriate assessment, design and road construction methods will be required. It is anticipated that some poor quality materials and subgrades are likely to be present in some lower lying areas of the Precinct.

3. Summary of Salinity Investigation Results

Disturbed and undisturbed samples of filling, soil and weathered rock were obtained by excavation and using a hydraulic push tube, respectively, to depths of investigation of 3 m or prior refusal. Locations were selected for reasonably representative sampling of the primary geological units and landforms, although the lower slopes were more closely sampled than ridge areas due to the typically higher risks of salinity and aggressivity in these areas. Samples were taken at/near surface and at 0.5 m depth intervals to termination or refusal depth and an initial batch of samples, from locations reaching the greatest depths, were tested in a NATA-accredited laboratory for salinity and related parameters.

Vertical soil salinity profiles and vertical soil aggressivity profiles were constructed from the test results from the initial batch in order to determine if a particular depth zone or zones presented a more significant salinity-related risk to proposed land use or structures. Elevated salinities and aggressivities were indicated in the 1.0 m to 1.5 m depth zone, resulting in testing of a second batch of samples taken predominantly from this zone.

All salinity-related laboratory results are presented in the Summary Table (attached) and these results were analysed in two depth zones by calculation of Bulk pH values and Bulk Electrical Conductivity values (ECe) in two depth zones defined as the:

- Foundation Zone (0 – 1.5 m below ground level (bgl)); and the
- Piling Zone (0 – 3 m bgl).

Drawings S1 to S4, Appendix A, present interpolated and contoured pH and ECe values for these depth zones, highlighting those areas classified as mildly aggressive to concrete and moderately to very saline, where management methods will need to be applied during bulk earthworks and construction. These classifications will require refinement by further sampling and testing to cover areas presently untested due to access restrictions or restrictions due to underground services and when cut/fill designs are available to confirm the likely depths of impact of the development.

4. Summary of Contamination Investigation Results

4.1 Land Uses

The contamination investigation identified that:

- The majority of the Riverstone East Precinct is currently used for rural residential purposes, including low intensity agriculture and minor commercial activities;
- Other land uses include market gardens, poultry sheds, low-risk commercial and a meat rendering works;
- Historical land uses have generally been residential and agricultural, including market gardens and poultry production.

Drawings C1 to C5, Appendix A, provide a visual representation of current and historical land use types.

4.2 Field and Laboratory Results

4.2.1 Observations of Environmental Concern

Land uses, which can be indicative of contamination are summarised in Section 4.1.

Potential issues of environmental concern not related to specific land uses generally include:

- Filling with soil of unknown origin, which could potentially include contaminants. Extensive filling was only observed in the lower reaches of First Ponds Creek, immediately before it exited the Precinct under Windsor Road. The creek alignment in this area had been extensively modified and flood levees and other filling were observed.

  Filling is also present in dam walls, however this usually comprises local cut-and-fill with a lower potential for contamination.

  No other obvious signs of extensive filling were observed, however, filling is also likely to be present along some drainage lines and where cut and fill has occurred, and in localised areas.

  Filling is also likely to be present along some local drainage lines, and where cut and fill has occurred in localised areas.

- Asbestos. Asbestos cement from demolition or degradation of buildings is likely to be present on some properties within the Precinct. No obvious signs of asbestos cement fragments at the ground surface were observed, although some fibre cement buildings are present.

4.2.2 Soil Results

Selected soil samples were tested for a variety of heavy metals to provide data on background levels of metals in soils in the Precinct for use in future assessments.

Preliminary environmental investigation levels have been calculated for selected metals in accordance with NEPC (2013)[1] and these are suitable for initial screening for future investigations.

4.2.3 Groundwater Results

All groundwater analyte concentrations were within the investigation levels[2] with the exception of manganese. This is, however, considered to be naturally occurring and not to present a limitation on residential rezoning or development.

A low concentration of the organochlorine pesticide dieldrin was detected in one sample. This result was within the investigation level but is likely to be indicative of the use and presence of dieldrin in the area near this well (Well 43), which included market garden land use.

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[1] National Environment Protection Council (NEPC) *National Environment Protection (Assessment of Site Contamination) Measure 1999* (as amended 2013)

[2] Australian and New Zealand Environment and Conservation Council (ANZECC) / Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (2000). 95% Level or Protection thresholds for freshwater

4.3 Overall Risks and Constraints

The risk of contamination over the Precinct is generally considered to be low to moderate, although more elevated risk is associated with some commercial properties (i.e. sites where DSI is recommended, refer to Drawing C6, Appendix A). The main constraints for residential redevelopment of the Precinct from contamination issues are expected to be additional costs and time associated with the development process. With the exception of the property discussed below these risks are not considered to be significant enough to prevent rezoning or redevelopment of the Precinct for residential development.

The potential for contamination at the following property is considered to present a significant potential constraint for residential redevelopment:

- The meat rendering works, located at the corner of Windsor and Garfield East Roads (shown on Drawing C7, Appendix A).

  It is noted that this property was not accessible for inspection, and a preliminary site investigation would be required to determine the contamination potential at the property. Contaminants of concern are, however, expected to include petroleum compounds, pesticides, heavy metals, polychlorinated biphenyls and asbestos as well as water pollutants (nutrients, biological oxygen demand, salts, suspended solids, faecal matter and bacteria). Potential presence of animal fats and wastes (including buried carcases) and diseases are also of concern and could be present a risk to human health and the environment and/ or unacceptable aesthetic concerns.

  It is recommended that a Detailed Site Investigation (DSI) is undertaken for this site, and that the contaminated land assessment and management process be subject to a Site Audit.

  It is understood that the meat rendering works has been rezoned for public recreation. The potential for contamination is not expected to prevent the site being used for open space subject to appropriate investigation and remediation and/ or management of any identified contaminants. It is further understood that areas in the north and west of the property are being considered for urban uses. It is advised that there could be sub-areas where significant contamination may constrain residential development in the short to medium term (several years or more), particularly if significant groundwater contamination is present. It is recommended that a DSI be undertaken prior to finalising plans for urban uses at the property, with the results of the DSI considered in determining appropriate land uses.

4.4 Recommendations for Minimum Investigation

Drawing C6 provides a visual representation of the recommended categories for further contamination investigation to be undertaken on each property prior to redevelopment. The <u>minimum initial investigation</u> scope for each category is detailed below. Additional investigation and/ or remediation and/ or management are expected to be required for some properties depending on the recommendations of the initial investigation, or to meet Council specific requirements.

Category 1 – Site Inspection

- Detailed site inspection for signs of concern;
- Hazardous Building Materials Survey of any buildings built during or before 2003;
- Implementation of the recommendations from the above; and
- Unexpected Finds Protocol (see below).

Category 2 – PSI

- Preliminary Site Investigation, including a detailed review of site history;
- Hazardous Building Materials Survey of any buildings built during or before 2003;
- Implementation of the recommendations from the above; and
- Unexpected Finds Protocol (see below).

Category 3 – PSI with Limited Sampling

- Preliminary Site Investigation with limited sampling aimed at targeting any areas of potential chemical use and filling;
- Hazardous Building Materials Survey of any buildings built during or before 2003;
- Implementation of the recommendations from the above; and
- Unexpected Finds Protocol (see below).

Category 4 – DSI

- Preliminary and Detailed Site Investigation, including detailed site history review, and intrusive sampling, analysis and reporting in accordance with NSW EPA guidelines;
- Hazardous Building Materials Survey of any buildings built during or before 2003;
- Implementation of the recommendations from the above; and
- Unexpected Finds Protocol (see below).

Category 5 – DSI and Site Audit

- Preliminary and Detailed Site Investigation, including detailed site history review, and intrusive sampling, analysis and reporting in accordance with NSW EPA guidelines;
- Contaminated Land Site Audit by a NSW EPA accredited Site Auditor;
- Hazardous Building Materials Survey of any buildings built during or before 2003;
- Implementation of the recommendations from the above; and
- Unexpected Finds Protocol (see below).

An Unexpected Finds Protocol should be included in all site management plans for redevelopment works setting out the steps to be taken to ensure that any signs of potential environmental concern are appropriately identified and managed.

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Volume 6

Volume 1 – Methodology and Field Results
Report on Land Capability, Salinity and Contamination Investigation
Riverstone East Precinct, North West Growth Centre

1. Introduction

This report was prepared for Mott MacDonald and provides the results of the Land Capability, Salinity and Contamination Investigation for the Riverstone East Precinct of the North West Growth Centre (the Precinct). The investigation has been conducted to support the current rezoning process. The rezoning will allow for urban development, including residential and employment related development. Details of the work undertaken and the results obtained are presented in this report, which is provided in three volumes, as follows:

- Volume 1 – Executive Summary, Background, Methodology and Fieldwork Results
- Volume 2 – Geotechnical and Salinity Results, Recommendations and Preliminary Soil, Water and Salinity Management Plans
- Volume 3 – Contamination Investigation Results and Recommendations

2. Study Area

The Riverstone East Precinct:

- Is located at the eastern, central portion of the North West Growth Centre, wholly within the Blacktown Local Government Area (LGA);
- Comprises 656 ha in total;
- Lies north east in orientation; it is located east of First Ponds Creek and West of Windsor Road;
- Is generally currently zoned General Rural under the Blacktown Local Environmental Plan 1988 with certain land at the northern end of the Precinct zoned for residential purposes.

The Riverstone East Precinct includes part of the suburbs of Riverstone, Rouse Hill and Schofields. The land is subdivided into approximately 200 Lots held by a variety of owners.

The location and boundary of the Precinct are shown in Figure 1.1, below.

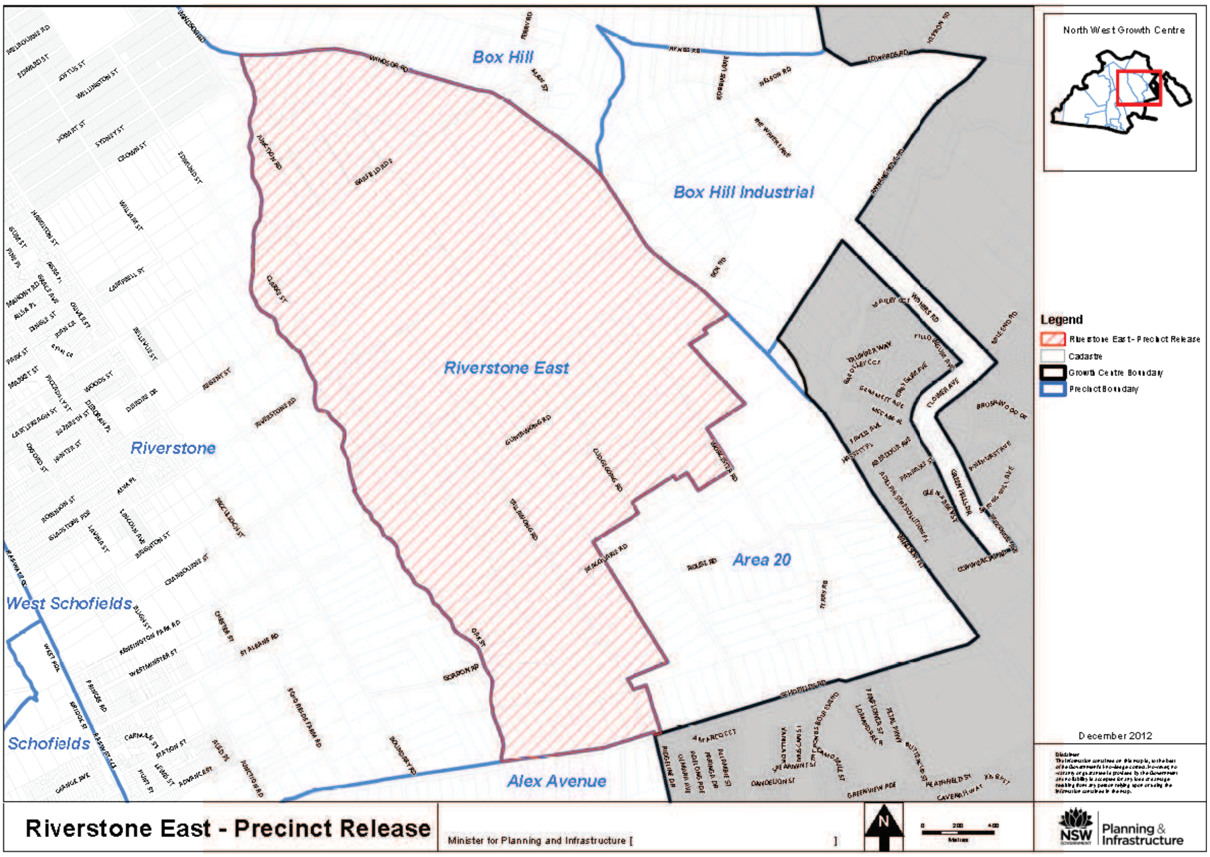

Figure 1.1 – Location and Boundary

3. Proposed Development

The Riverstone East Precinct is proposed to be rezoned for residential and ancillary land uses. The NSW Department of Planning and Environment preliminary estimates indicate this 656 hectare precinct could accommodate up to 5,300 dwellings for 15,000 residents.

4. Scope of Works

The scope of works was as follows:

- Review of regional mapping for topography, geology and soils;
- Review of groundwater bores registered with the NSW Office of Water;
- Review of Council mapping for zoning;
- A search through the NSW EPA published records under the *Contaminated Land Management Act* (1997) and *Protection of the Environment Operations Act* (1997);
- Review of sites listed as potentially impacted by unexploded ordnance;

- A review of historical aerial photography for the area available through the Land Information Section of the Department of Planning (from years 1947, 1961, 1970, 1982, 1991, 2002, 2014). Digitised and geo-referencing the photography to allow preparation of drawings and extraction of geographic co-ordinates;
- Discussions with Council personnel, local residents and land owners (where possible) regarding local current and historical land use including of any large commercial operations and other information relevant to contamination potential (e.g. filling, spills, pesticide use, creek re-alignments);
- Research in the local studies sections of the Council libraries regarding history of the area and current and historic land use as necessary to follow up on other sources of information;
- Field mapping by an experienced environmental scientist and geologist based on drive over/ walkover of accessible areas;
- Drilling of 16 boreholes using push tube or auger methods. Logging of observed subsurface conditions and collection of soil samples at regular intervals. Preparation of logs of each sample location;
- Extending five of the test boreholes using auger methods to depths of approximately 6 m, and construction of groundwater piezometers (monitoring wells) in each bore;
- Excavation of six test pits using a backhoe. Logging of observed subsurface conditions and collection of soil samples at regular intervals. Preparation of logs of each sample location;
- Conducting Dynamic Cone Penetrometer (DCP) test at selected borehole location;
- Analysis of samples at a NATA accredited laboratory for:
  - soil texture (65 tests);
  - Electrical conductivity (EC1:5, 65 tests);
  - pH (65 tests);
  - Exchangeable sodium potential (ESP, 10 tests);
  - Emerson Crumb Number (ECN - dispersibility, 6 tests);
  - Chlorides and sulphates (10 tests);
  - Moisture content, plasticity, linear shrinkage (6 tests);
  - Californian Bearing Ratio (3 tests);
  - Shrink-swell Index (6 tests);
  - Metals (17 total metals including priority heavy metals As, Cd, Cr, Cu, Pb, Hg, Ni, Zn and Fe, Mn, B, Ba, Be, Co, Mo, Se, Sn) (10 tests);
  - Cation Exchange Capacity (CEC) (10 tests);
  - Clay content (2 tests).
- Development of groundwater monitoring wells by removal of 3 well volumes of water (or until dry).
- Undertake groundwater sampling approximately one week after the installation of groundwater monitoring wells. Record field measurements (including pH, EC, dissolved oxygen, REDOX);
- Field measurements of EC and pH from surface water at various accessible locations;
- Analyse of groundwater samples at a NATA accredited laboratory for:
  - Metals (17 total metals including priority heavy metals As, Cd, Cr, Cu, Pb, Hg, Ni, Zn and Fe, Mn, B, Ba, Be, Co, Mo, Se, Sn); (4 samples);
  - Total recoverable hydrocarbons (TRH) (4 samples);

  - Monocyclic Aromatic Hydrocarbons (Benzene, Toluene, Ethyl benzene and Xylene – BTEX) (4 samples);
  - Organochlorine and organophosphorous pesticides (OCP and OPP) (trace level, 4 samples);
  - Hardness (4 samples);
  - Polycyclic aromatic hydrocarbons (PAH) (4 samples);
  - Polychlorinated biphenyls (PCB) (trace level, 2 samples); and
  - Volatile organic compounds (VOC) (2 sample).
- Calculation of ECe from soil texture and EC values;
- Calculation of preliminary EILs from heavy metal, EC, pH and clay content values;
- Plotting the results as vertical soil salinity and pH profiles versus depth. Based on these results the most saline and aggressive horizon or depth zone will be identified;
- Assessment of the above to identify areas of environmental concern (AECs) and previous land uses. An assessment of each land parcel using a risk approach with respect to its contamination potential, and provision of comments regarding the need for further investigation and any potential limitations for the proposed rezoning or landuse;
- Provision of a salinity, aggressivity and contamination hazard maps;
- Provision of a preliminary salinity management plan;
- Provision of comments on objectives and criteria for controlling erosion and sedimentation; and
- Provision of this report.

5. Regional Topography, Geology, Soils and Water

5.1 Topography and Surface Water

The Precinct is located on a ridge between First Ponds Creek, which forms the south western Precinct boundary, and Second Ponds Creek, located to the south east of the Precinct. The upper reaches of Killarney Chain of Ponds and various tributaries of First Ponds Creek are located within the Precinct, and small valleys are associated with this drainage lines.

The creeks all flow generally to the north (northern east to north west) eventually discharging into the Hawkesbury River or one of its tributaries.

Various large dams and surface water storage are present in the Precinct.

The area is understood to be prone to flooding.

5.2 Geology

A review of available geology maps for the Precinct (Penrith 1:100 000 Geological Series Sheet 1) indicates that most of the Precinct is underlain by rocks of the Wianamatta Group (Ashfield Shale, Minchinbury Sandstone and Bringelly Shale). Quaternary age sediments are present along a small section of the north-eastern boundary (associated with the south-eastern upper reaches of Killarney Chain of Ponds) and also along most of the western boundary of the Precinct which is approximately defined by First Ponds Creek.

The approximate geological boundaries, as shown on the geology map are shown on Drawing G1, Appendix A.

In summary, the underlying geology and lateral extent of the formations and associated soils comprise;

- Bringelly Shale (mapping unit Rwb) underlies most of the Precinct, particularly the slightly more elevated ridge areas and extends almost to the northern point of the Precinct. This formation typically comprises shale, carbonaceous claystone and laminite, with very minor coal in parts.
- Ashfield Shale (mapping unit Rwa) underlies much of the mid-slope parts across the northern two thirds of the Precinct, extending to the eastern and western boundaries. The rock of this formation typically comprises shale, laminite and dark grey siltstone, sometimes with a relatively deep, clay soil profile.
- recent, Quaternary age sediments (mapping unit Qal) comprise fluvial sediments of sand, silt and clay and underlie the western boundary within First Ponds Creek and towards the upper section of Killarney Chain of Ponds.

The Minchinbury Sandstone separates the Ashfield and Bringelly Shale formations and is a thin, typically less than 3 m thick, persistent quartz-lithic sandstone.

5.3 Soil Landscapes

The Soil Landscape map (Penrith 1:100 000 Sheet) indicates that the Precinct is almost entirely underlain by a single soil landscape group, the Blacktown soil group. The South Creek soil group is also present and is associated with the First Ponds Creek and the upper section of Killarney Chain of Ponds alignments. The approximate soil landscape boundaries, as on the soil landscape maps, are shown on Drawing G2, Appendix A.

The Blacktown (bt) soil group is a residual soil landscape which characterises the mid-slope topography formed on the Wianamatta Group shales. These areas, including the northern part of the Precinct, have local relief to 30 m and slopes usually less than 5%, but up to 10%. There are rounded crests and ridges with gently inclined slopes. The mapping indicates multiple soil horizons that range from shallow red-brown podzolic soils comprising mostly clayey soils on crests and upper slopes, with deep brown to yellow clay soils on mid to lower slopes and in areas of poor drainage. These soils are typically of low fertility, are moderately to highly reactive, highly plastic and generally have a low wet strength.

The South Creek (sc) group occupies the lower flood plains, valley flats and drainage depressions. The soils are fluvial, often very deep layered sediments overlying residual/relict soils or bedrock. The topography is typically flat to gently sloping (slopes of <5%) with the soils comprising brown, red and yellow brown, clays, silty and sandy clays. These soils are typically of low fertility, highly erodible, with some stream bank and gully erosion, and are moderately reactive in some areas.

5.4 Salinity

Reference to the Map of Salinity Potential in Western Sydney, indicates that the Site is predominantly located in an area of *"Moderate salinity potential"* where *"saline areas may occur .... which have not yet been identified or may occur if risk factors change adversely"*. Soils along the drainage lines are generally in an area of *"High salinity potential"* where *"conditions are similar to areas of known salinity"* with some areas of mapped "*Known salinity"* where *"there is a known occurrence of saline soil".* These classifications are based on the landform and geology and it is noted that due to the resolution at the scale of the mapping, it is not possible to delineate the zone boundaries with precision.

Several references[3] describe some general features of the hydrogeology of western Sydney which are relevant to areas of the site which are underlain by shale. The shale terrain of much of western Sydney is known for saline groundwater, resulting either from the release of connate salt in shales of marine origin or from the accumulation of windblown sea salt. Seasonal groundwater level changes of 1.0 m to 2.0 m can occur in a shallow regolith aquifer or a deeper shale aquifer due to natural influences.

The unweathered shale rock unit is effectively impermeable and the few bores drilled into the unweathered shales in the Sydney area are generally dry or yielding small flows of saline groundwater, typically with total dissolved salts (TDS) contents of 10,000 mg/L to 30,000 mg/L (Old, 1942; McNally, 2004).

5.5 Hydrogeology and Groundwater Bore Database

Groundwater in the Precinct is expected to flow generally to the north, towards the Hawkesbury River and to include a shallow aquifer in the quaternary sediments with a deeper regional aquifer present in the underlying bedrock.

The NSW Government website NR Atlas was reviewed with respect to groundwater vulnerability and groundwater bores registered with the NSW Office of Water (NOW).

The mapping shows (Figure 1.2, below) that in general the groundwater aquifer is highly vulnerable near First Ponds Creek, and generally of low vulnerability away from creek line with the exception of some localised areas of moderate vulnerability. The vulnerability level indicates the level of risk of aquifers to contamination and relates to physical characteristics of the location, such as the depth to the water table and soil type. The mapping indicates that groundwater in the sediments along First Ponds Creek in the Precinct has an elevated level of risk to impact from potentially contaminating activities.

A number of groundwater bores are registered in and near the Precinct as shown on Figure 1.3, below. Many of the bores did not information available regarding their use or construction. Of the bores with information, uses included irrigation, domestic stock and monitoring bores. The reviewed bores included shallower bores (less than 15 m depth) and deeper bores (greater than 100 m depth).

[3] Including McNally, G. 2005. *Investigation of urban salinity – case studies from western Sydney*. UrbanSalt 2005 Conference Paper, Parramatta

These results are indicative that groundwater is used as a resource in the region, including within the Precinct.

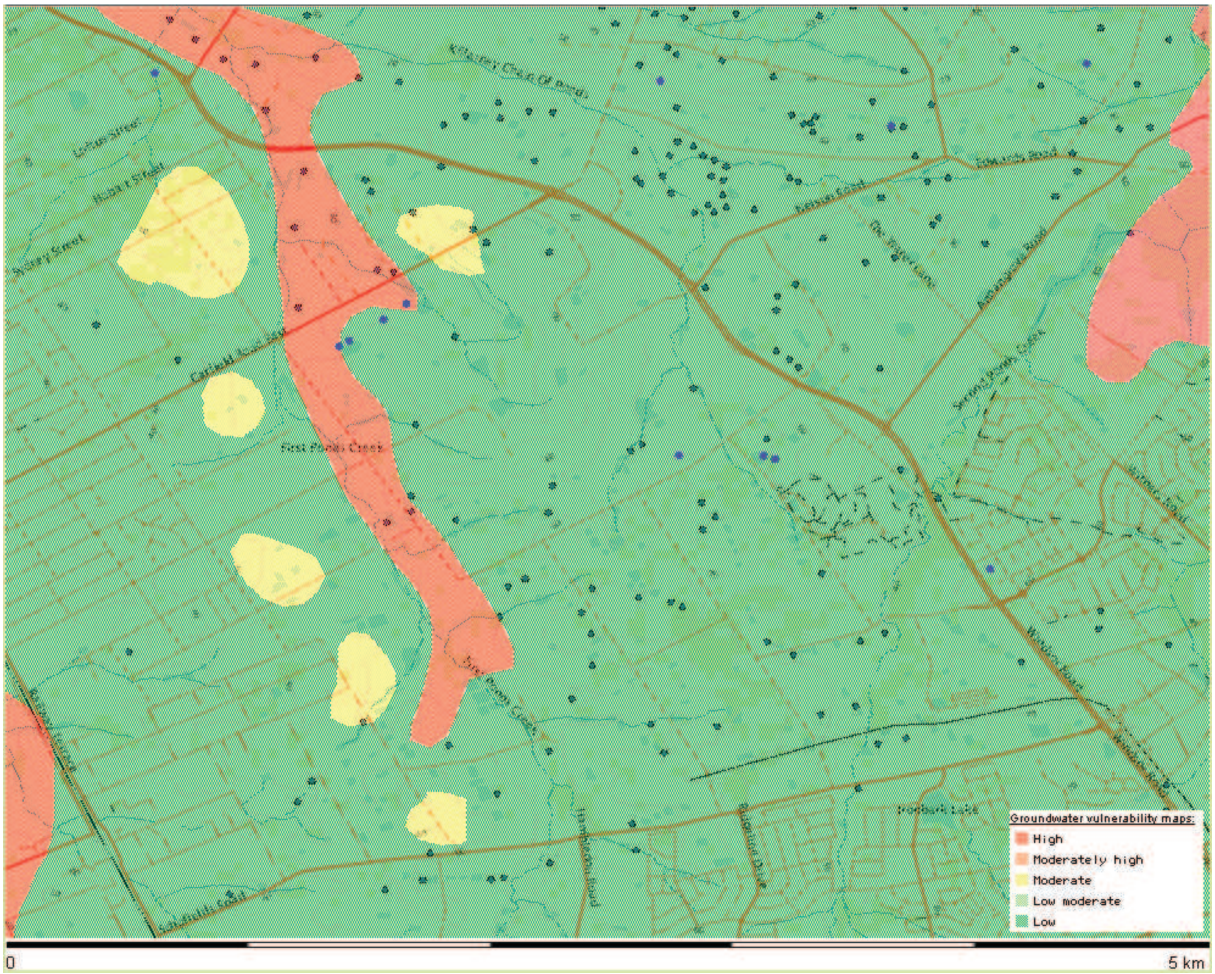

Figure 1.2 – Groundwater Vulnerability[4]

[4] Map created with the NSW Natural Resource Atlas – www.nratlas.nsw.gov.au <date>. Copyright © 2014 New South Wales Government. Map has been compiled from various sources and may contain errors or omissions. No representation is made as to its accuracy or suitability

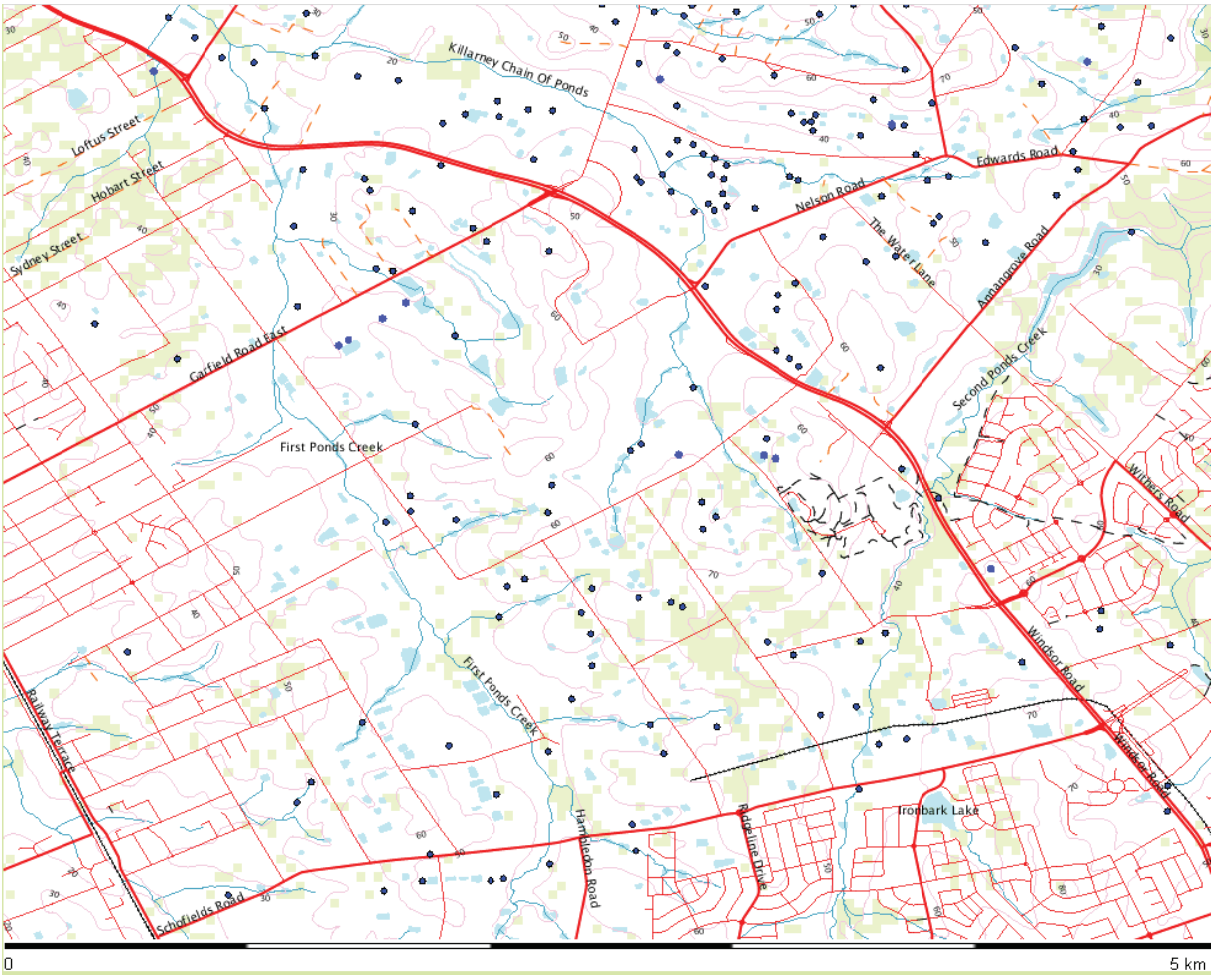

Figure 1.3 – Groundwater Bores Registered with NOW (blue dots represent groundwater wells)

6. Methodology

6.1 Rationale

The purpose of the soil testing was to provide information on the soil types and likely salinity and geotechnical characteristics and limitations over the site. Test locations were selected based on the review of background information and the field mapping to target various landforms, geology and soils types to verify expected site conditions based on published mapping and surface features. Locations were modified to take into account access availability and underground services. Presence of underground services in the road corridor was a significant limitation in placement of test locations. Access to locations was also limited in some instances by localised flooding during fieldwork.

Selected samples would be subjected to laboratory testing based on providing a coverage of the various geological and topographical units, and targeting depths of concern.

Given the large area, number of lots and landholders in the Precincts, the investigation aimed to assess broad scale issues which may impact the suitability of areas within the Precinct for rezoning. Localised/ lower risk issues may not be identified in all cases.

Given the purpose of the investigation, testing of soil for contamination was not considered to be an efficient method of investigation. Five groundwater monitoring wells were placed along drainage lines at the site to identify potential broad scale contamination.

6.2 Assessment Datum

The coordinates of the field tests and other pertinent features were determined by use of a portable dGPS receiver, which indicated a typical accuracy of about 1 m, however, this accuracy can be effected by tree cover and weather. Horizontal positioning was referenced to the Map Grid of Australia 1994 (MGA94), Zone 56 datum. Vertical positioning was referenced to reduced levels relative to AHD, with levels at test locations recorded to the nearest 0.5 m, as derived from survey contours on provided 1 m contour maps.

6.3 Field Work

6.3.1 Site Inspection

Site inspections were undertaken by an experienced engineering geologist and environmental scientist.

The inspections focused on issues relevant to the assessment including, but not limited to, topography and landform, land use, signs of slippage and erosion, indicators of filling.

6.3.2 Service Location and WHS

Prior to undertaking the intrusive investigations, DP conducted a Dial-Before-You-Dig search for buried services and undertook on-site services scanning at each test location using an electromagnetic scanner.

DP's standard Work Health and Safety procedures were followed for all works, including preparation and implementation of Safe Work Method Statements.

6.3.3 Soil Sampling

Test Pit Excavation and Soil Recovery

- Test pits were excavated using a backhoe to a nominal depth of 2 m or into the top of bedrock (if encountered above 2 m); and
- Soil for sampling was recovered directly from the excavator bucket and placed into plastic bags for transport to the laboratory;

Drill Rig and Soil Recovery

- Five boreholes were drilled to a nominal depth of 6 m using a conventional auger drilling rig;
- Eleven boreholes were drilled to nominal depths of 2 to 3 m, or prior refusal, using a push tube drilling rig;
- Soil for sampling was recovered directly from the augers or push tube and placed into plastic bags for transport to the laboratory.

A log of materials encountered, other observations and samples collected would be prepared for each location.

6.3.4 DCP Tests

The dynamic cone penetrometer (DCP) test comprises driving a 16 mm diameter steel rod, tipped with a 20 mm diameter cone, into the soil using a 9 kg hammer dropping through a standard distance of 510 mm. The number of blows required to drive the rod each 150 mm is recorded and used to estimate the consistency of the soils. Testing was carried out at a number of borehole locations and the results were incorporated onto the Borehole log sheets.

6.3.5 Well Construction and Groundwater

Groundwater monitoring wells were installed in the five 6 m deep boreholes, and details of their construction is provided on the borehole logs.

The groundwater investigation targeted the shallow (perched) aquifer. The wells were installed using acid washed PVC casing and with screens over the expected full depth of the water column. Bentonite seals were used in the construction to prevent surface water entering the well. A lockable road box was used to finish each well.

Wells were developed at least one week prior to sampling by removal of a minimum of three borehole volumes of water.

Groundwater samples were collected by an environmental engineer/ scientist using low flow sampling techniques, following stabilisation of field parameters collected during well micropurging to ensure that representative samples are collected.

6.3.6 Surface Water

EC and pH readings were collected from five sample locations as shown on Drawing 1, Appendix A.

The readings were collected in the field using a calibrated meter.

6.4 Laboratory Analysis

Laboratory analysis was conducted by NATA accredited laboratories. Details of the methodologies are provided in the laboratory reports in Appendix F.

Samples were selected for analysis to provide site coverage over the range of materials and conditions encountered.

6.5 Interpretation of Results

The results were interpreted in accordance with relevant Australian Standards and guidance as detailed below.

Geotechnical

- Standards Australia 2011, AS 2870 – 2011 *Residential Slabs and Footings*.
- Standards Australia 1996, AS 1726 – 1993 *Geotechnical Site Investigations.*

Salinity

- Standards Australia 2009, AS 2159 – 2009 *Piling Design and Installation*.
- Standards Australia 1996, AS 2870 – 1996 *Residential Slabs and Footings*.
- Standards Australia 1996, AS 3798 – 2007 Guidelines on Earthworks for Commercial and Residential Developments.
- Standards Australia 2000, AS 1547 – 2000 *On-Site Domestic Waste Water Management*.
- Standards Australia 2009 (and subsequent amendments), AS 3600 – 2009 *Concrete Structures*.
- Cement, Concrete and Aggregates, Australia 2005, Guide to Residential Slabs and Footings in a Saline Environment, Introduction to Urban Salinity.
- Department of Natural Resources (DNR) 2002, *Broad Scale Resources for Urban Salinity Assessment Sydney* (now managed by DPI).
- DNR 2002, *Indicators of Urban Salinity* (now managed by DPI).
- DNR 2002, Site Investigations for Urban Salinity (now managed by DPI).
- DNR 2003, *Building in a Saline Environment* (now managed by DPI).
- DNR 2003, *Roads and Salinity* (now managed by DPI).
- DNR 2004, *Urban Salinity Processes* (now managed by DPI).
- DNR 2004, *Waterwise Parks and Gardens* (now managed by DPI).
- (Rebecca Nicholson for) WSROC, DNR and natural Heritage Trust (amended January 2004) *Western Sydney Salinity Code of Practice*.

Contamination

- National Environment Protection Council (NEPC) *National Environment Protection (Assessment of Site Contamination) Measure 1999 (as amended 2013).*
- State Environmental Planning Policy No. 55–Remediation of Land (1998) under the *Environmental Planning and Assessment Act* (NSW) 1979 (SEPP55).

7. Field Work Results

7.1 Site Observations

Field observations are provided in the discussion sections for geotechnical, salinity and contamination issues respectively.

7.2 Subsurface Conditions – Soils and Bedrock

Subsurface conditions encountered during the geotechnical investigation confirmed the presence of the mapped soil types and rock formations.

The boreholes, drilled using a geotechnical drilling rig (Bores 41 to 45) for the installation of groundwater monitoring wells, generally on the lower creek line parts of the Precinct, typically encountered clays with some ironstone gravel to the full depth of investigation (5 m to 6 m). The exceptions were Bores 42 and 44, which were located on a minor creek line and the upper end of Killarney Chain of Ponds, respectively and encountered shale below 2.2 m depth.

The remaining bores and test pits typically encountered stiff to hard residual clays and silty clays (away from the creek lines) grading into weathered bedrock of shale and siltstone at depths ranging from 0.5 m to about 1.5 m. The soil depths were greater towards the creek lines where alluvial sediments were present and in some mid-slope areas, particularly overlying the Ashfield Shale.

7.3 Groundwater and Surface Water Field Parameters

Groundwater was encountered during drilling in the deeper bores (Bores 41, 43 and 45) at 3.5 m to 5.9 m depth whilst Bores 42 and 44 did not encounter groundwater during the drilling and installation of monitoring wells. Subsequent monitoring indicated water levels between 0.44 m and 1.74 m below surface level (on 10/4/2014) with the recorded data presented in Table 1.1 below. These boreholes generally targeted the creek lines, where groundwater is expected to be shallowest.

The shallower push tube bores generally did not encounter groundwater, although seepage was noted at some locations. The test pits did not encounter any groundwater (except Pit 72A where seepage was encountered at 1.6 m) and were backfilled on completion, which precluded long term monitoring of groundwater levels.

Table 1.1: Summary of Groundwater Levels/Depth Measurements

Borehole	Surface Level	Groundwater Level 10/04/2014	
	m AHD	m bgl	m AHD
41	24.6	Well destroyed prior to sampling	
42	31.8	0.44	31.36
43	29.7	0.8	28.9
44	47.3	1.74	45.56
45	36.3	0.55	35.75

Field parameters for the surface and groundwater are provided in Tables 1.2 and 1.3 below. Groundwater field sheets are provided in Appendix C. Sample locations for where the surface water samples were collected are as shown on Drawing 1, Appendix A

Table 1.2: Summary of Monitoring Results for Groundwater (undertaken 10/04/2014)

Borehole	Temperature	DO	EC	pH	Redox	Salinity
	°C	mg/L	µS/cm	pH units	mV	ppt
41	Well destroyed prior to sampling					
42	20.8	1.13	23,621	6.55	106.7	14.53
43	21.8	2.12	7,234	7.12	100.1	-
44	22.4	2.32	3,307	7.61	174	1.73
45	21.8	1.03	4,114	7.32	108	2.19

Table 1.3: Summary of Monitoring Results for Surface Water (undertaken 7/05/2014)

Parameter	Temperature	pH	EC	Salinity	DO		ORP	Comments
Units	°C	pH units	µS/cm	ppt	%	mg/L	mV	
Garfield Rd East (SW1)	14.7	7.1	6,760	4.68	135.3	13.24	130.2	Not moving, very shallow
Riverstone Rd (SW2)	14.1	9.1	2,800	1.86	92.4	9.31	128.6	Not moving. Water entering creek from small pipes crossing creek
Gordon Rd (SW3)	13.9	8.5	20,050	15.53	73.9	6.6	129	Not moving
Guntawong Rd (SW4)	14	8.9	422	0.26	723.2	2.36	87	not moving

8. References

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9. Limitations

Douglas Partners (DP) has prepared this report for this project at Riverstone East Precinct, North West Growth Centre in accordance with DP's proposal SYD140003, dated 21 January 2014 and acceptance received from Mr Chris Avis of Mott MacDonald dated 20 March 2014. The work was carried out under DP's Conditions of Engagement. This report is provided for the exclusive use of Mott MacDonald and NSW Government Department of Planning and Infrastructure (DP&I) for this project only and for the purposes as described in the report. It should not be used by or relied upon for other projects or purposes on the same or other site or by a third party. Any party so relying upon this report beyond its exclusive use and purpose as stated above, and without the express written consent of DP, does so entirely at its own risk and without recourse to DP for any loss or damage. In preparing this report DP has necessarily relied upon information provided by the client and/or their agents.

The results provided in the report are indicative of the sub-surface conditions on the site only at the specific sampling locations, and then only to the depths investigated and at the time the work was carried out. Sub-surface conditions can change abruptly due to variable geological processes and also as a result of human influences. Such changes may occur after DP's field testing has been completed.

DP's advice is based upon the conditions encountered during this investigation. The accuracy of the advice provided by DP in this report may be affected by undetected variations in ground conditions across the site between and beyond the sampling locations as well as site accessibility.

This report must be read in conjunction with all of the attached and should be kept in its entirety without separation of individual pages or sections. DP cannot be held responsible for interpretations or conclusions made by others unless they are supported by an expressed statement, interpretation, outcome or conclusion stated in this report.

This report, or sections from this report, should not be used as part of a specification for a project, without review and agreement by DP. This is because this report has been written as advice and opinion rather than instructions for construction.

The contents of this report do not constitute formal design components such as are required, by the Health and Safety Legislation and Regulations, to be included in a Safety Report specifying the hazards likely to be encountered during construction and the controls required to mitigate risk. This design process requires risk assessment to be undertaken, with such assessment being dependent upon factors relating to likelihood of occurrence and consequences of damage to property and to life. This, in turn, requires project data and analysis presently beyond the knowledge and project role respectively of DP.

Douglas Partners Pty Ltd