Douglas Partners
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REPORT

on

LAND CAPABILITY AND CONTAMINATION ASSESSMENT

ORAN PARK PRECINCT
ORAN PARK AND COBBITTY

Prepared for

GROWTH CENTRES COMMSSION

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EXECUTIVE SUMMARY

This report presents the results of a land capability assessment undertaken on a 1100 ha parcel known as the “Oran Park Precinct”, lying in the suburbs of Oran Park and Cobbitty (henceforth “the site”, refer Drawing 1). The work was commissioned by the Growth Centres Commission (GCC). The site predominantly held by two landowners (The McIntosh Family and the Perich Family). Site usage is largely rural with some rural/residential in independently owned lots with educational usage in some parts of the site (Macarthur Anglican College).

It is understood that the area has been identified by GCC and Camden Council for potential re-zoning and urban development. GCC and Council require that the area be investigated to assess its constraints for urban development with regards to:

- slope instability;
- soil erosion risks;
- soil salinity hazard;
- geotechnical factors; and
- site contamination .

To address these matters, this investigation comprised:

- Site history searches for environmental reporting. Searches were undertaken with historical societies and government agencies to identify potential areas of environmental concern, based on the sites past uses (the searches undertaken are detailed in Section 7).
- Site mapping for slope instability and erosive features. A senior engineering geologist undertook a site walkover and produced maps of current and historic landslips and soil erosion features (refer Section 9.1).
- Electromagnetic surveying for salinity potential. An EM31sonde mounted to an all terrain vehicle traversed the site collecting salinity data for salinity mapping.
- Samples were collected from 155 test pits to ground truth the EM31 data. (This process is further explained in Section 11).
- Excavation of a further 20 test pit locations based on the results of the salinity mapping, targeted across the site to provide further information for the preparation of a preliminary salinity management plan (see Section 12.3.6).

- Soil testing for geotechnical purposes was undertaken from selected test pits. This data allowed the development of preliminary values for geotechnical conditions including footings, pavement design, site preparation (refer Section 12.6).

Based on these investigations, constraint maps were developed, as described below:

- Geotechnical Constraint (refer Drawing 8): This map shows areas of constraint with respect to geotechnical factors such as landslip and erosion. The map details areas of minor constraint which should be managed by sound earthworks practices.

- Salinity Constraint (refer Drawing 17): This map shows areas of constraint with respect to very saline soil conditions and moderately saline soil conditions. Management strategies for both soil types are provided in Section 12.3.6.

- Aggressivity and Sodicity Mapping (refer Drawings 18-21). Soils at the site have been shown to be aggressive and dispersive, with risk areas by depth shown on the maps. Response strategies to these constraints are provided in Section 12.3.6).

- Areas of Environmental Concern (refer Drawing 22): This map shows areas of the site where further site investigation will be required for contamination purposes. It is considered that all sites are likely to be able to be remediated and made suitable for the proposed land use and hence are not likely to present a constraint to development.

Further investigation will be required as conceptual design/planning progresses together with additional work during the construction phase. Specific investigation would include but not necessarily be limited to:

- Detailed environmental investigation (comprising subsurface sampling and laboratory testing) in the nominated areas of environmental concern (AEC), primarily in those areas which lie within the proposed “development footprint”. The purpose of this work would be to quantify the level of contamination (if any) and delineate contaminated areas in order to facilitate the preparation of remediation action plans (RAP).

- Additional hazardous building material assessments should be undertaken on all buildings in the precinct earmarked for demolition.
- Unexploded ordinance resulting from previous military usage has not been addressed in this report and reference should be made to the report prepared by Milsearch Pty Ltd.
- Remediation and validation monitoring of areas subject to an RAP, to render such areas appropriate for the proposed land use, from the contamination viewpoint.
- Additional investigation should be undertaken in development areas which are to be excavated deeper than 3 m or into rock at shallower depth, where direct sampling and testing of salinity has not been carried out. Salinity management strategies herein should be modified or extended following additional investigation by deep test pitting and/or drilling, sampling and testing for soil and water pH, electrical conductivity, TDS, sodicity, sulphates and chlorides.
- Installation of groundwater bores well in advance of construction and monitoring/sampling/analysis before, during and after construction, to assess changes in groundwater quality, electrical conductivity and level as a result of the development. The bores would be strategically located on a catchment basis near creek lines.
- Routine inspections and earthworks monitoring during construction.
- Detailed geotechnical investigations on a stage-by-stage basis for determination of pavement thickness designs and lot classifications.
- Further investigation into the potential for future coal mining and correspondence with the relevant authorities regarding subsidence and any foreseen restrictions on the development.

SUMMARY OF LAND CAPABILITY FOR SITE DEVELOPMENT

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

- Deep-seated hillslope instability (landslip) affects the upper slopes of the two highest sections of the ridge line within the north-western section of the site. This instability is considered to be a major constraint to development (i.e. it would to be economically addressed by normal and possibly even extensive development works including removal of failed materials, site regrading and subsurface drainage - as discussed in Section 12.1). All other areas contain only minor or moderate constraint associated with slumping and soil creep which should be addressed by standard engineering practices for hill side development including site specific investigation and engineering of structures.

- The presence of erosive soils on site should not present significant constraints to development provided they are well managed during earthworks and site preparation stages. Gully erosion already present on site should be remediated during site works as discussed earlier in Section 12.2.
- Development will be constrained by moderately saline soils over a significant portion of the Precinct however very saline soils are generally confined to the riparian corridor of South Creek and should have minor impact on the development if construction does not take place in this creek corridor (See Drawing 17).
- Although mild aggressivity to concrete is widespread in the far north and central section of the Precinct, constraint regions due to moderately aggressive soils are limited in area and can be managed using standard practices, such as those detailed in the Piling Code of Australia (see Drawings 18 – 19).
- Highly sodic soils appear widespread and will require management to reduce dispersion, erosion and to improve drainage (See Drawings 20 – 21).
- Based on the extensive site history review, inspection/field mapping and groundwater, surface water and sediment investigation, the overall potential for contamination at the subject site is considered to be low and limited to the identified areas of environmental concern.

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1. INTRODUCTION

This report presents the results of a land capability assessment undertaken on an 1100 ha parcel known as the “Oran Park Precinct”, lying in the suburbs of Oran Park and Cobbitty (henceforth “the site”, refer Drawing 1). The work was commissioned by the Growth Centres Commission (GCC).

It is understood that the area has been identified by GCC and Camden Council for potential re-zoning and urban development. GCC and Council require that the area be investigated to determine its suitability for urban development with regards to slope instability, soil salinity, the potential for soil contamination and soil erosion risks.

The investigation comprised site history searches, site inspections, non-intrusive and intrusive site investigation followed by laboratory testing of selected samples, engineering analysis and reporting.

Details of all work undertaken and results obtained are given within, together with comments relating to land capability, engineering design and construction practice. Whilst pertinent results of field work, and laboratory test results are included in the text, further details are provided in the following Appendices:

A Drawings
B WorkCover Results
C Electromagnetic Survey - Field and Processing Methods
D Potential Areas of Environmental Concern (PAEC) Identification and Inspection Logs
E Notes from Interviews
F Bore Logs and Construction Notes for Groundwater Wells
G Test Pit Logs
H Laboratory Results for Soil Sample Tests
I Laboratory Results for Groundwater and Surface Water Analysis
J Salinity Results (Table 7a)
K Guide to Home Owners on Foundation Maintenance and Footing Performance (CSIRO Publication)

2. SITE DESCRIPTION

The site is approximately 1100 ha in plan area and is largely held by two landowners. Site usage is largely rural/residential with educational usage in some parts of the site (Macarthur Anglican College).

The site is essential divided into three ownership sectors:

- The Greenfields Development Company Lands (GDC) – Currently used as an agricultural property and also housing Oran Park Raceway. Incorporates the majority of the land to the east of the Northern Road
- McIntosh Land – Cattle farm that incorporates the majority of the land to the west of the Northern Road.
- Various small Landowners – three distinct areas in which individuals hold land including access to Springfield Road, The central northern portion of the site west of the Northern Road and the area in the vicinity of the McArthur Anglican School (MAS)

The site is generally cleared and grass covered. Remnant stands of trees surround creek lines. Low lying areas are vegetated with salt-resistant vegetation, including Bulrushes and Spiny Reeds.

In addition to salt-resistant vegetation, salt scalds and eroded soils were also noted across the site. Many salt scalds show salt efflorescence at the surface.

Topographical relief across the majority of the site is slight with steeper sections in the north western corner of the site.

3. PROPOSED DEVELOPMENT

The site is located within the Camden Local Government Area. Douglas Partners Pty Ltd (DP) understands that this area is to be developed and forms one of the first precincts to be released by the Growth Centres Commission. The site encompasses an area of 536 ha and is proposed to provide approximately 4000 housing lots as well as significant areas of commercial space.

The following sections provide general comment on development constraints relevant to geotechnical factors, soil chemistry and environmental contaminants to assist in the conceptual planning of the site. It is noted that further investigations will need to be undertaken as the conceptual planning and design proceeds.

4. PREVIOUS STUDIES

Previous studies have been undertaken at the site. The following document has been reviewed whilst preparing this report:

- Environmental & Earth Sciences NSW (EES), *Preliminary Environmental Site Investigation and Geotechnical Appraisal of GDC Land Oran Park Precinct*, New South Wales, October 2006 (Project No: 106070).

EES undertook a preliminary environmental site investigation on the western half of the Oran Park Precinct (beyond the Northern Road) as per the NSW EPA Guidelines". EES identified 32 areas of environmental concern (ACEC) that require detailed environmental site investigations (at the western portion of the site), to assess if the site is suitable for the proposed mixed use development. EES recommended that sampling and analysis plans (SAP) be developed for the areas of concern. The relevant findings from the EES report are logged in to the PAEC forms.

5. REGIONAL SOIL LANDSCAPE, GEOLOGY AND HYDROGEOLOGY

5.1 Soil Landscape

Reference to the 1:100 000 Soil Landscapes of the Wollongong – Port Hacking and Penrith Sheets (Refs. 1 and 2) indicates that the site area is mostly included within the Blacktown Soil Landscape but with significant areas included within the Luddenham, Picton, South Creek and Richmond Soil Landscapes.

The Blacktown Soil Landscape is characterised by topography of *"gently undulating rises on Wianamatta Group Shale, with local relief to 30 m and slopes usually less than 5%"*. This is a residual landscape which the mapping indicates comprises up to four soil horizons that range from shallow red-brown hard-setting sandy clay soils on crests and upper slopes, to deep brown to yellow sand and clay soils, overlying grey plastic mottled clay on mid to lower slopes. These soils are typically of low fertility, are moderately reactive and have a generally low wet-bearing strength.

The soils landscape mapping indicates that the Luddenham is mapped in the some hill areas in the central-southern and north-western sections margin of the site. This soil landscape is characterised by *"undulating to rolling low hills on Wianamatta Group Shales, often associated with Minchinbury Sandstone with local relief 50 – 80 m, and slopes 5% – 20%*. The mapping indicates that it is an erosional unit with shallow (<1.0 m) Brown Podsolic Soils and massive earthy clays on crests and ridges, and moderately deep (0.7 – 1.5 m) Red Podsolic Soils on upper slopes.

The Picton Soil Landscape is mapped as being present within ridge crest and west to southwest-facing upper hillslopes within the north-western section of the site. It is characterised by *"steep side slopes characterised by mass movement and terracettes on Wianamatta Group derived colluvial materials with local relief 90 – 300 m and slope gradients of >20%"*. This unit includes shallow to deep (0.5 – 2.0 m) Red Podsolic Soils and Brown Podsolic Soils on upper slopes, Brown Podsolic Soils, Yellow Podsolic Soils and Soloths on lower slopes and benches with Red Earths and Brown Earths on colluvial material. Very deep (>3.0 m) Yellow Podsolic Soils and Soloths are commonly developed on lower slopes and drainage lines.

The South Creek Soil Landscape is mapped as 200 m to 300 m wide zone in the South Creek valley floor and associated major gullies. This soil landscape is characterised by *"flat to gently sloping alluvial plain with occasional terraces or levees providing low relief <10 m and slopes <5%."* The alluvial soils are often very deep layered sediments over bedrock or residual soils. Where pedogenesis has occurred, structured plastic clays or structured loams are characteristic in and adjacent to the drainage lines, and yellow podsolic soils are most common on the terraces.

The Richmond Soil Landscape is developed in the south-western section of the site and is associated with the alluvial flat and adjacent footslopes about Sickles Creek (Cobbity Creek) and its associated tributary gullies. This soil landscape is characterised by *"mostly flat terrace tops, terrace edges and levees providing low relief of up to 10 m."* The alluvial soils are poorly structured orange to red clay loams, clays and sands. Ironstone nodules may be present.

Due to the scale of the published mapping, it is difficult to precisely delineate the various boundaries (see Drawing 4). The instability observed in the higher ridge area at the central-northern section of the site, indicates that the Picton Soil Landscape may be more widely distributed than that shown on the published mapping.

5.2 Geology

Reference to the Wollongong - Port Hacking and Penrith 1:100 000 Geological Series Sheets (Refs. 3 and 4) indicates that the site is underlain by Bringelly Shale (mapping unit Rwb) of the Wianamatta Group of Triassic age. This formation typically comprises shale, carbonaceous claystone, laminite and some minor coaly bands. Unnamed, fine to medium grained, quartz-lithic sandstone members (mapping unit Rwbs) are mapped within the site area, particularly within the topographically higher hilltop areas at the south-eastern and north-western corners of the site (see Drawings 5 and 6).

The published mapping also indicates the strata is gently deformed by the Camden Syncline which is aligned approximately north-south through the site near the alignment of The Northern Road.

5.3 Hydrogeology

McNally (2005, Ref 5) describes some general features of the hydrogeology of Western Sydney which are relevant to this site. 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. This salt is concentrated by evapo-transpiration and often reaches highest concentrations in the B-horizon of residual soils. In areas of urban development, this can lead to damage to building foundations, lower course brickwork, road surfaces and underground services, where these impact on the saline zone or where the salts are mobilised by changing groundwater levels. Seasonal groundwater level changes of 1 - 2 m can occur in a shallow regolith aquifer or a deeper shale aquifer due to natural influences, however urban development should be carried out with a view to maintaining the natural water balance (between surface infiltration, runoff, lateral throughflow in the regolith, and evapo-transpiration) so that long term rises do not occur in the saline groundwater level.

The former Department of Infrastructure Planning and Natural Resources (DIPNR), on their map entitled "Salinity Potential in Western Sydney 2002" (Ref. 6), infers "moderate salinity potential" over most of the site and "high salinity potential" or "known salt occurrence" in the lower slopes and drainage areas of the north-trending South Creek, the north-westerly trending Cobbity Creek and their tributary gullies.

The DIPNR mapping (see Drawing 7 for approximate boundaries) is based on soil type, surface level and general groundwater considerations but is not in general ground-truthed, hence it is not generally known if actual soil salinities are consistent with the potential salinities of DIPNR.

Groundwater investigations undertaken by DP in the Camden area and previous studies of areas underlain by the Wianamatta Group and Quaternary river alluvium indicate that:

- the shales have a very low intrinsic permeability, hence groundwater flow is likely to be dominated by fracture flow with resultant low yields (typically < 1 L/s) in bores;

- the groundwater in the Wianamatta Group is typically brackish to saline with total dissolved solids (TDS) in the range 4000 – 5000 mg/L (but with cases of TDS up to 31750 mg/L being reported). The dominant ions are typically sodium and chloride and the water being generally unsuitable for livestock or irrigation.

6. SCOPE OF WORKS

From the brief provided by the GCC, DP identified the following scope of works for the site. For clarity, the scope of works undertaken for the assessment was divided up based upon the individual tasks required for the site.

6.1 Stability, Erosion and Salinity

The initial stage of the study comprised the collection and review of background information, predominantly from published data and aerial photographs. Subsequently, field mapping was undertaken by a senior engineering geologist to identify potential unstable areas and to nominate locations for subsurface investigation.

The locations (Mapping Reference Points 17 – 75) of individual features of note were determined using a hand held GPS receiver, thus enabling positioning (to GDA/MGA94 co-ordinate system) of features in relation to digital aerial photographs and basemaps, provided for generation of the drawings within this report.

Subsurface investigation comprised the excavation of 220 test pits across the site with a rubber-tyred backhoe to profile the subsurface strata. The pits incorporated regular soil samples to assist in strata identification and for laboratory testing to determine soil plasticity, erosion potential and salinity potential.

6.2 Soil Salinity

An electromagnetic survey was undertaken as part of the examination of soil salinity potential, enabling rapid continuous measurement of apparent conductivity, to supplement the laboratory electrical conductivity testing of discrete samples taken from test pits.

Apparent conductivity is variously referred to as ground conductivity, terrain conductivity, bulk conductivity or bulk electrical conductivity and is generally designated as σ_a or ECa. Although measurement of apparent conductivities can include contributions from a variety of sources including groundwater, conductive soil and rock minerals and metals, it has been estimated (Baden Williams in Spies and Woodgate, 2004, Ref. 7) that in 75 - 90% of cases in Australia, apparent conductivity anomalies can be explained by the presence of soluble salts. Apparent conductivity can therefore be considered, in the majority of cases, a good indicator of soil salinity.

Most portable instruments measure apparent conductivity in milliSiemens per metre (mS/m) and typical measurement ranges (Table 1) have been suggested as indicative of salinity classes (Chhabra 1996, Ref. 8).

Table 1 – Salinity Classes in Relation to Apparent Conductivity

Class	ECa (mS/m)
Non Saline	<50
Slightly Saline	50 – 100
Moderately Saline	100 – 150
Very Saline	150 – 200
Extremely Saline	>200

The survey was undertaken using a Geonics EM31 ground conductivity meter mounted 1 m above the ground surface from the side of an all terrain vehicle (ATV). The EM31 was operated in the vertical dipole (horizontal coil) mode for a maximum depth of investigation of approximately 6 m. In this configuration, approximately 50% of the system response arises within a depth of 3 m below the coils (i.e. from material at depths of up to 2 m below ground surface). Other EM systems and configurations can be employed for greater near-surface resolution, however a system with a significant response to material within 2 m of surface is considered appropriate given that excavation for proposed urban development is likely to extend to this depth.

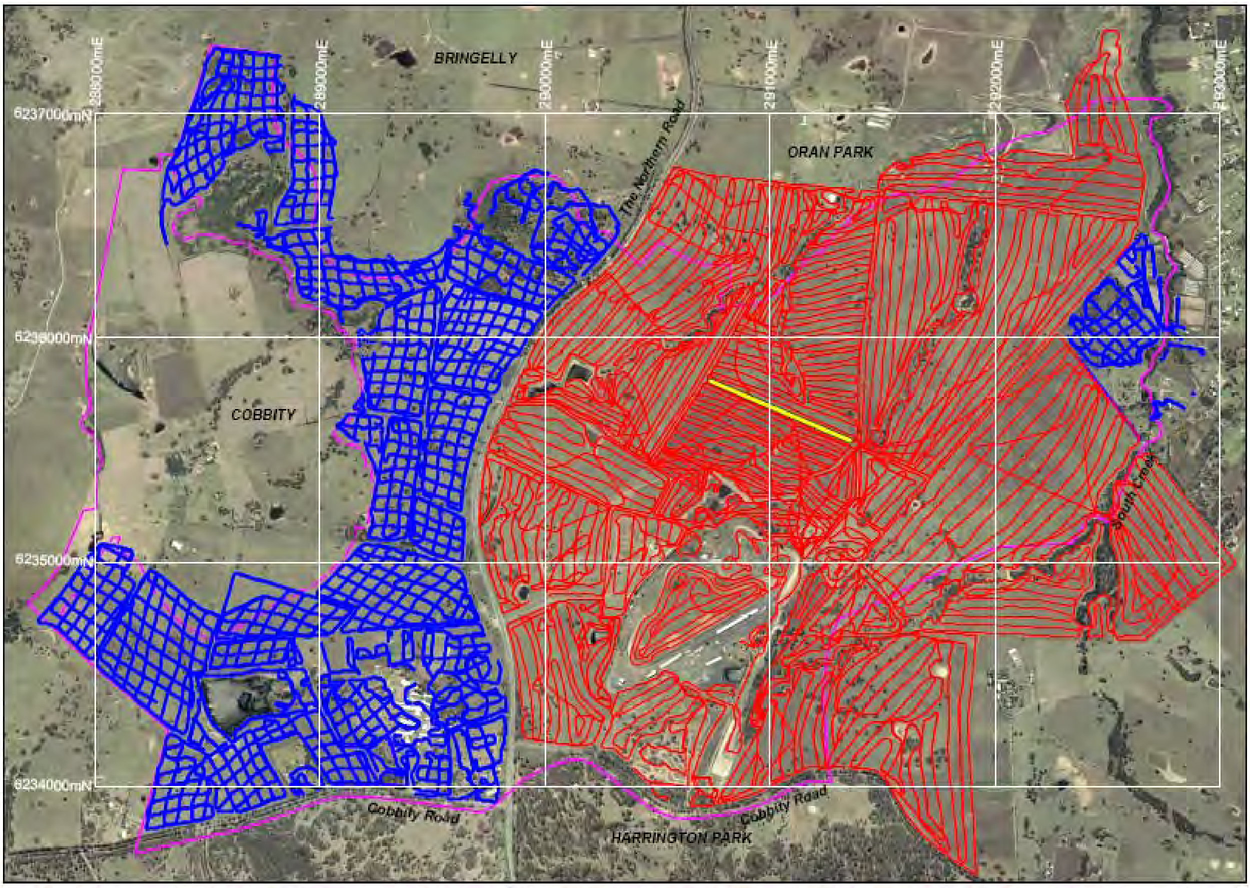
A Trimble AgGPS114 Differential Global Positioning System (DGPS) receiver, antenna and iPAQ hand-held computer were employed to digitally record grid coordinates at 1 second intervals as the ATV was navigated around the survey area. ECa data were acquired at a 1 second repetition rate and logged to a Geonics Polycorder digital data logger, synchronised to the DGPS.

Data were obtained along approximately 132 km of linear traverse (54,500 data points) in all accessible parts of the site, with an average data point spacing of 2.4 m.

The Denbigh property in the west of the Precinct was excluded from the investigation and other development, including a large dam in the southwest of the Precinct and some private property paddocks in the southwest and far east, prevented access to some areas. However, a grid of primary survey lines approximately 100 m apart was achieved in the accessible areas as shown by the ECa measurement points (track of the ATV) in Drawing 14 (Appendix A and thumbnail image below).

Additional raw EM data were provided courtesy of Environmental & Earth Sciences NSW (EES) and Landcom (EES Report 106070 and Addendum, October 2006), covering most of the Oran Park Precinct east of The Northern Road. These survey lines are also shown on Drawing 14.

Further details of field methods, data processing and interpretation are given in Appendix C.



Locations of EM31 Profiles (See Drawing 14, Appendix A)

6.3 Soil Contamination

6.3.1 Potential Sources of Contamination

In order to determine the potential for land contamination to result in environmental constraints in the release area, a Phase 1 Environmental Site Assessment was conducted that included an appraisal of the potential for site contamination that may have resulted from past and present land uses.

Based on the information relating to the proposed development, the Phase 1 assessment included the following scope of works:

- Field mapping by an environmental engineer.

- A search through the NSW EPA Land Information records to confirm that there are no statutory notices current on any parts of the release area under the *Contaminated Land Management Act* (1997).
- A review of historical aerial photography for the area through the Land Information Section of the Department of Lands.
- A review of previous site ownership records including land title records archived at the Land Titles Office, compiled by Clive Lucas Stapleton & Partners, the European Heritage Consultant for the project.
- A search of historical Council and property attributes records pertaining to previous site use and any information relating known areas of flood prone land, or site contamination.
- Interviews with local residents and land owners (where possible) to obtain anecdotal information regarding the potential nature and extent of site filling.
- Installation and development of a groundwater bore into the shallow groundwater system.
- A groundwater and sediment sampling program, one week after the installation of groundwater bores. The groundwater and surface water investigation was used to confirm the results of the preliminary assessment.

At the conclusion of the Phase 1 assessment, a list of all identified Areas of Environmental Concern (AECs) and any associated chemicals of concern was prepared. This formed the basis for recommendations regarding the need for a field-based environmental investigation. The Phase 1 assessment will provide a brief scope of work for each AEC identified in the release area, in such a way that Phase 2 investigations can be accurately costed and proceed with limited delay.

6.4 Soil Management Plan

A preliminary soil management plan was prepared to address management procedures and development criteria. The overall plan includes the preparation of constraint maps that will address problematic areas and provide development criteria which will be suitable for inclusion in future planning documents. These controls will incorporate recommendations for areas that require further testing. A response strategy for potential future problems in relation to soil conditions will also be developed.

6.5 Horizontal and Vertical Control

The coordinates of the field tests and other pertinent features were determined by use of a GPS receiver. This enabled positioning of features in relation to digital aerial photographs and maps, and allowed generation of the drawings within this report. This receiver has an accuracy of ±3m which was considered suitable for the scale of mapping produced.

All field measurements and mapping for this project have been carried out using the Geodetic Datum of Australia 1994 (GDA94) and the Map Grid of Australia 1994 (MGA94), Zone 56. Digital mapping has been carried out in a Geographic Information System (GIS) environment using MapInfo software. All reduced levels are given in relation to Australian Height Datum (AHD) and are interpolated from the contour maps provided.

7. ENVIRONMENTAL HISTORY REVIEW

An extensive site history investigation was undertaken on the property. Every issue pertinent to contamination was logged as a Potential Area of Environmental Concern (PAEC). These PAEC Identification & Inspection Logs described site observations and the potential for contamination and further classified each individual area as an Area of Environmental Concern (AEC), where required. Where no evidence of current or historic contamination was considered to have occurred at a PAEC location, the area was recorded as such.

The following sections detail the methodology of investigations undertaken with results of the investigations discussed in Section 12.3. PAEC Identification & Inspection Logs are contained in Appendix D, which contain detailed information and observations relating to each identified area, and provide the rationale for declaring a site's AEC status.

7.1 Historical Title Search

A search of land title (for the western half of the site) ownership information held by Land Titles Office in Sydney was compiled by Peter S. Hopley Pty Ltd and covered records dating back to circa 1895. A review of the title deeds search undertaken by EES for the eastern half of the site was conducted during the current investigation. Detailed copies of titles and survey plans were analysed:

- no PAEC were logged during this investigation for the western half of the site;
- PAEC were logged for the eastern half of the site, based on the EES investigation;

7.2 Historical Aerial Photography

Historical aerial photographs from six periods of photography, archived by the Land Information Section of the Department of Land, were inspected and indicated that the site has undergone minor changes in layout since the earliest available aerial photograph dated January 1947. Aerial photographs examined included:

- January 1947 (Run 19, Prints 54 – 151, 54 – 153, 54 – 38, 54 – 40, 54 – 149,)
- 1961 (Run 43, Prints 1043-5093)
- 7 July 1970 (Run 23, Prints 1908 – 5037, 1908-5039)
- 25 October 1978 (Run 22, Prints 2727 – 32, 2727 - 34)
- 8 October 1984 (Run 1, Prints 3410 – 35)
- 4 January 1994 (Run 1, Prints 01-22)

All photographs were scanned at high resolution and geocoded for use in a GIS database. Photos were examined and all PAEC were logged. Aerial photographs examined have been included in Appendix A (Drawings 9 – 13).

7.3 Regulatory Notices Search

A search was conducted through the NSW EPA web site for any Regulatory Notices that may be current on the site under the *Protection of the Environment Operations Act* (1997). The search results indicated the following:

- A notice (Notice no: 010557) for approval of the surrender of a licence (002798) (Industry: Package Treatment Plants) was issued by the EPA to Oran Park Motorsport Pty Ltd, Cobbity Road, Narellan on 8 June 2000.
- A notice (Notice no: 008959) for approval of the surrender of a licence (007363) (Industry: Package Treatment Plants) was issued by the EPA Macarthur Angilican Church, Cobbity on 13 December 1999.

The relevant NSW EPA search documents are attached in Appendix E**.**

A search was conducted through the NSW EPA web site for any Regulatory Notices that may be current on the site under the *Contaminated Land Management Act* (1997). No Notices or Orders to investigate or remediate have been issued for the site under the *Contaminated Land Management Act* (1997).

7.4 Council Records Review and s149 Planning Certificates

Council Records were inspected on site at Camden Council. Records were available for the site dating back to c.1998. Earlier information was not available. The records indicated complaints regarding unauthorised use of land as a truck and storage depot, irrigation of land from septic tank. These PAEC were logged.

Property attribute prints obtained from the Camden Council for the site were reviewed. The attributes indicated DA approvals for Oran ark Motor Racing Circuit and a backfill of a dam. These PAEC were logged.

7.5 WorkCover Authority Search

The WorkCover Authority was requested to undertake a search of their database for Licenses to Keep Dangerous Goods for the McIntosh Land. The Authority searched the Stored Chemical Information Database and the microfiche records for information and found no records relating to the property

Full details of the WorkCover Authority database search can be found in Appendix E.

A letter of authorisation to proceed (a WorkCover requirement) was not provided by GDC within the timeframe of this assessment, and as such the investigation was not undertaken, this should be undertaken as part of subsequent environmental investigations at the site.

7.6 Interviews

Anecdotal evidence was compiled from informal interviews conducted with the current site owners. Interviews were carried out in a format of 20 prescribed questions; additional questions and anecdotal evidence were also noted. The following people were interviewed:

- Mr Ian McIntosh – Owner/Manager of Denbigh;
- Mr Mark Perich – Owner/ Manager of Oran Park (interviewed previously by EES);

Completed Standard Interview Sheets are provided in Appendix E for review. All PAEC resulting from the interview process were logged.

7.7 Geotechnical Test Pit Logs

As part of the land capability study, 220 test pits were excavated across the site for geotechnical purposes. The logs for these test pits were examined and areas of filling were identified and logged as PAEC.

7.8 Fly Tipping Investigation

An investigation into the extent of fly tipping ie: uncontrolled dumping of filling or rubbish was conducted by field inspection of the roads surrounding the site. This was further supplemented by interviews with property managers and review of aerial photography. All areas of PAEC were investigated and logged.

7.9 Cattle Tick Dip Site Investigation

Considering the site's previous and current rural use, an investigation into the location of Cattle Tick Dip Sites was undertaken. Review of various relevant guidelines produced by the Department of Agriculture (now Department of Primary Industries) was undertaken and contact with the Cattle Tick Dip Site Management Committee (DIPMAC) was made. Advice from DIPMAC indicated that a register of dip sites in NSW did not include any sites south of Taree. Further to this, DIPMAC noted that as ticks were not generally a problem in the Sydney region, farmers tended to spray cattle as opposed to using the more difficult process of dipping. Only farms within the Northern Tick Quarantine Area (near the Queensland Border) were required to dip cattle.

This information was supported by various past and present workers on the site who had not used dips on the site and did not believe that it would be likely that they had ever been used. In light of this information, no PAEC resulted from this investigation.

7.10 Site History

The report by Godden McKay Logan regarding site history was not available during the preparation of this draft report. A review of the Cultural Heritage consultants report will be made prior to finalisation. All relevant PAEC identified will be logged.

7.11 Site Inspections

Numerous site inspections were undertaken during the course of the investigation. The majority were informal, to gain familiarity with the site, or related to tasks such as the groundwater monitoring well installation and monitoring. Each visit to site was used as an opportunity to inspect the site for PAEC, and all resultant findings were recorded on PAEC identification logs (see Appendix D).

A formalised visit on 21-23 February 2007, was undertaken with the intent of visiting all logged areas of PAEC which required site inspection. During this visit all sites were visited, photos were taken and site inspection logs recorded. Details are provided in the PAEC Identification Logs in Appendix D. Site photos are included in Appendix B.

8. GROUNDWATER AND SURFACE WATER INVESTIGATION

8.1 Monitoring Well Installation and Sampling

Seven groundwater bores were installed at selected locations to establish an understanding of groundwater quality across the site and to use the results as an indication of overall catchment contaminant levels.

The monitoring well locations were selected on a catchment basis using GIS interpretation of the topographic data. The bores were placed at the exit points of the major catchments at the site (see Drawing 3).

The monitoring wells were installed using a trailer mounted GEMCO 210B drill rig drilling with solid flight augers. The wells were constructed of Class 18 UPVC casing and machine slotted screen sections with screw joints. The bores were backfilled with sand and sealed with bentonite plugs 0.5 – 1 m above the screened section. Bore logs and monitoring well construction details are included in Appendix F.

The monitoring wells were sampled seven days after installation. Due to the low hydraulic conductivity of the soil units, the wells were purged until dry using disposable bailers and allowed to recover before a sample was taken. Samples were preserved in appropriate laboratory provided sampling media. Samples to be analysed for metals were filtered using a 0.45-micron filter before preservation in a nitric acid preserved bottle. Samples were cooled on ice prior to dispatch to the laboratory under *Chain-of-Custody* conditions.

8.2 Surface water Sampling Locations

No surface water was flowing off site at the time of the investigation. The only surface water currently on site is in dams located across the site. Five dams across the properties were selected for sampling based upon their size and size of the catchment they intercept. Sampling locations are shown on Drawing 3.

Samples were preserved in appropriate laboratory provided sampling media. Water samples to be analysed for metals were filtered using a 0.45-micron filter before preservation using nitric acid. Samples were cooled on ice prior to dispatch to the laboratory under *Chain-of-Custody* conditions.

9. FIELD WORK RESULTS

9.1 Geotechnical Site Observations

The principal geotechnical observations made during the inspections of the site are summarised below and are further detailed on Drawings 4 – 7.

- gully erosion locally entrenches the colluvial, residual or alluvial soils within the bases of creek lines (see Drawing 4). Erosion depths ranged from <0.3 m to approximately 2.5 m.
- there are only isolated, very minor rock outcrops and these are mostly associated with an unnamed sandstone member (or members) exposed mostly in the headcarps of landslides at the edges of ridges in the north-western section of the site. There are also isolated gully floor exposures of shale and siltstone (Mapping Reference Point 65 and 67). Bedrock

exposures of interbedded shale, siltstone and fine grained sandstone are, however, present at shallow depth (typically at depths in the range 0.5 m to 1 m) within road cuttings of The Northern Road, access tracks, the Oran Park Raceway track and dam excavations (Drawings 5 and 6).

- possible soil creep, shallow slumping and extensive, deep seated landslide activity were noted in gully head or steeper slope locations below a resistance un-named sandstone member (or members) within the north-western corner of the site (see Drawing 5). The surface profile (e.g. only partially degraded debris toes) at the landslide features suggests that at least some of the instability dates from historical time, possibly related to the initial clearing of the area for pasture. The landslide affected areas are characterised by sandstone exposed in the headscarp and numerous sandstone blocks included in the debris. Terracing on steeper slopes indicates on-going soil creep within the debris.
- salt efflorescence is present within the banks and bases of the erosion gullies developed along a South Creek tributary gully and also about the margins of dams (at Mapping Reference Points 63, 69 and 70). Salt tolerant vegetation (Casuarina and Melaleuca species) is also present along the course of South Creek, Cobbity Creek and the tributary erosion gullies (see Drawing 7).
- bare soil patches (Mapping Reference Points 74 and 75) were associated with salt efflorescence.
- areas of possible surface ponding, seepage or waterlogging, with consequent salinity risks, were noted in the vicinity of farm dams and a drainage canal constructed adjacent to the channel of South Creek within the eastern section of the site.

9.2 Subsurface Investigation

Details of the subsurface conditions encountered in the test pits are given in the test pit logs included as Appendix G. The logs should be read in conjunction with the accompanying notes that define classifications methods and descriptive terms.

Relatively uniform conditions were encountered underlying most of the site with the residual soils a result of weathering of the underlying Bringelly Shale. Sandstone was encountered in the more elevated parts of the site which confirmed the geological mapping. Whilst some variability in the overall stratigraphy was encountered in the 175 test pits excavated on the site, the general succession of strata can be broadly summarised as follows:

TOPSOIL: brown silty clay/clayey silt to depths of 0.1 – 0.3 m.

CLAY: stiff to hard (but predominantly very stiff to hard) clay, silty clay and gravelly silty clay to depths of 1.2 m to in excess of 3 m (limit of investigation).

BEDROCK: variably extremely low to medium strength shale (112 test pits) and highly weathered extremely low to low strength sandstone (19 test pits). Rock was not encountered in 42 of the 175 test pits excavated on the site to the 3.3 m limit of investigation.

Slightly variable conditions were encountered in Pit 68 where topsoil directly overlies the weathered shale and in Pits 30, 57 and 95 where filling/silty clay, cobbles and some rubble were encountered to depths of 0.2 – 0.5 m.

Free groundwater was only encountered in Pit 204 during excavation at a depth of 2.9 m. Groundwater was not encountered in the remaining pits which were backfilled immediately following logging and sampling, thus precluding longer term monitoring of groundwater levels.

9.3 Groundwater Surface water and Sediment Investigation

Electrical conductivity and pH were measured in the field during monitoring of surface and groundwater. Depth to groundwater was also recorded from the surface. The following table provides the results of field work (refer Drawing 2 for sample locations):

Table 2 – Groundwater and Surface Water Investigation

Location	Sample	Type	Depth (BGL)	pH	EC μS/cm
GW1	-	GW	Submerged	-	-
GW2	40740/GW1	GW	1.65 m	7.2	15,000
GW3	40740/GW5	GW	0.8 m	6.7	23,000
GW4	40740/GW7	GW	1.0 m	6.9	26,000
GW5	40740/GW11	GW	2.0 m	7.0	25,000
GW6	40740/GW10	GW	1.7 m	7.1	23,000
SW1	40740/1	SW	-	7.0	1,300
SW2	40740/3	SW	-	7.3	380
SW3	40740/4	SW	-	6.7	470
SW4	40740/6	SW	-	9.5	1,300
SW5	40740/13	SW	-	8.1	100
SW6	40740/8	SW	-	7.9	90
SW7	40740/9	SW	-	7.1	690
SW8	40740/12	SW	-	8.3	420
SW9	40740/2	SW	-	6.8	150

GW – Groundwater SW – Surface water

10. LABORATORY TESTING

10.1 Soil Samples

Selected samples from the pits were tested in the laboratory for measurement of field moisture content. Atterberg limits, linear shrinkage from the liquid limit condition and Emerson Class Number.

The detailed test report sheets are given in Appendix G and indicate that the soils tested are dry of the plastic limit which can be considered as being an approximation of the equilibrium moisture content of the soil. The plasticity of the soils tested ranged from low plasticity (cK) with a liquid limit of 32% to high plasticity (CH) with a liquid limit of 64%. As such, the clays would be susceptible to shrinkage and swelling movements with changes in soil moisture content. The results of the Emerson crumb tests indicate that six of the twenty samples tested were dispersive (ECN values of 1 and 2) with the remainder being non-dispersive (ECN of 4).

The mechanical testing data is summarised in Table 3. Discussion of the results and implications for the proposed development are given in Section 12.5.

Table 3 – Results of Laboratory Testing (Physical Properties)

Pit No.	Depth (m)	FMC (%)	PL (%)	LL (%)	PI (%)	LS (%)	ECN	Material
1	0.5	18.7					4	Silty Clay
3	0.5	13.4					4	Silty Clay
4	1.0	9.1	13	33	20	9.5	2	Silty Clay
9	0.5	15.1					4	Silty Clay
20	1.0	8.7					4	Silty Clay
26	1.0	11.1					1	Silty Clay
33	1.0	8.3					4	Silty Clay
56	0.5	8.7					4	Silty Clay
62	0.5	14.4					4	Silty Clay
74	1.0	18.9					2	Silty Clay
92	1.0	14.2	22	63	41	150	4	Silty Clay
94	0.4	18.3					4	Silty Clay
105	1.0	14.2					2	Silty Clay
132	0.5	14.0	18	51	33	13.5	4	Silty Clay
134	1.0	12.1					4	Silty Clay
148	0.5	12.4					4	Silty Clay
157	0.5	25.1					4	Silty Clay
211	1.0	10.7	15	32	17	6.5	2	Silty Clay
215	1.0	1.0					1	Silty Clay
219	0.5	18.0	21	64	43	15.5	4	Silty Clay

Where FMC = Field moisture content; PL = Plastic limit
LL = Liquid limit; PI = Plasticity index
LS = Linear shrinkage; ECN = Emerson Class No.

10.2 Groundwater and Surface Water Samples

Groundwater (GW) and surface water (SW) samples collected from the site were analysed at the laboratory for a wide range of common chemical contaminants including:

- 8 heavy metals;
- polycyclic aromatic hydrocarbons;
- Total Recoverable hydrocarbons;
- Benzene Toluene, Ethylbenzene and Xylene;
- Polychlorinated Biphenyls; and
- OC and OP pesticides.

All analytes returned results below the practical quantitation limit of the laboratory, except for heavy metals which are summarised together with relevant guideline criteria in the table below. Details of the other test results are included in Appendix I.

Table 4 – Analytical Results for Heavy Metals in Water (Results in µg/L)

Location & Type	Sample	As	Cd	Cr*	Cu	Pb	Hg	Ni	Zn
2/GW	40740/GW1	<1	0.1	<5	<5	<5	<1	<5	**34**
3/GW	40740/GW5	<1	**0.9**	<5	**6.3**	<1	<0.1	32	**130**
4/GW	40740/GW7	<1	**0.5**	<5	**5.7**	<1	<0.1	7.8	**68**
5/GW	40740/GW11	<1	**0.7**	<5	**28**	1.5	<0.1	9.8	**66**
6/GW	40740/GW10	<1	**0.8**	<5	**7.5**	3.1	<0.1	**12**	**150**
1/SW	40740/1	<1	<0.1	<5	<5	<1	<0.1	<5	**9.1**
2/SW	40740/3	1.7	<0.1	<1	**1.6**	<1	<0.1	1.1	5.9
3/SW	40740/4	2.0	<0.1	<1	**3.5**	<1	<0.1	2.9	**23**
4/SW	40740/6	<1	<0.1	<5	<5	<1	<0.1	<5	**8.9**
5/SW	40740/13	1.3	<0.1	1.6	**3.7**	1.1	<0.1	1.8	**14**
6/SW	40740/8	2.0	<0.1	9.1	**13**	**7.5**	<0.1	5.6	**39**
7/SW	40740/9	12	<0.1	3.2	**5.7**	**5.4**	<0.1	5.1	**34**
8/SW	40740/12	2.6	<0.1	3.2	**7.0**	2.1	<0.1	3.5	**18**
9/SW	40740/2	1	<0.1	<1	**2.1**	<1	<0.1	1.2	6.3
Guideline 1		**24**	**0.2**	**7.7**	**1.4**	**3.4**	**0.6**	**11**	**8.0**

Guideline 1 ANZECC 2000 Guidelines Trigger Values for freshwater with 95% level of protection.
Shaded Indicates an exceedence of the guideline value
* Assumed to be Cr(III), as Cr(VI) is unstable in most natural environments. (Marine Water guideline used in the absence of Freshwater Criteria)

Table 5 – Analytical Results for Heavy Metals in Sediments (Results in mg/kg)

ID	As	Cd	Cr*	Cu	Pb	Hg	Ni	Zn
40740/1a	4.7	<1.0	13	13	15	<0.1	7.3	19
40740/2a	7.8	<1.0	20	18	24	<0.1	10	37
40740/3a	11	<1.0	22	21	26	<0.1	11	43
40740/4a	8.7	<1.0	18	29	25	<0.1	15	70
40740/6a	13	<1.0	19	39	20	<0.1	13	62
40740/8a	6.4	<1.0	17	34	31	<0.1	14	69
40740/9a	5.5	<1.0	14	23	18	<0.1	9.6	48
40740/12a	4.5	<1.0	12	9.2	13	<0.1	4.7	12
40740/13a	4.7	<1.0	12	29	20	<0.1	11	67
Guideline 1	0.2 - 20	0.04 - 2	0.5 - 100	1 - 100	<2 - 200	0.001 - 0.1	2 - 60	2 - 180

Note: 1 Lowest range of background level criteria and SILs
shaded Exceeds Guideline Criteria

All analytes returned results below the practical quantitation limit of the laboratory, except for heavy metals which are summarised together with relevant guideline criteria in the table below. Details of the other test results are included in Appendix I.

11. SALINITY DATA

11.1 Analysis and Presentation

Soil salinity is often assessed with respect to electrical conductivity of a 1:5 soil:water extract (EC 1:5). This value can be converted to ECe (electrical conductivity of a saturated extract) by multiplication by a factor dependent of soil texture ranging from 6 for shale to 17 for sand. Richards (1954, Ref. 9) and Hazelton and Murphy (1992, Ref. 10) classify soil salinity on the basis of ECe, and describe the implications of the salinity classes on agriculture as follows:

Table 6 – Soil Salinity Classification

Class	ECe (dS/m)	Implication
Non Saline	<2	Salinity effects mostly negligible
Slightly Saline	2 – 4	Yields of sensitive crops affected
Moderately Saline	4 – 8	Yields of many crops affected
Very Saline	8 – 16	Only tolerant crops yield satisfactorily
Highly Saline	>16	Only a few very tolerant crops yield satisfactorily

Salinity measurements on 218 samples from 176 test pits throughout the Oran Park Precinct are distributed throughout the salinity classes as shown in detail in Table 7a (Appendix J) and statistically in Table 7 below.

Table 7 – Distribution of Test Pit Sample Salinities

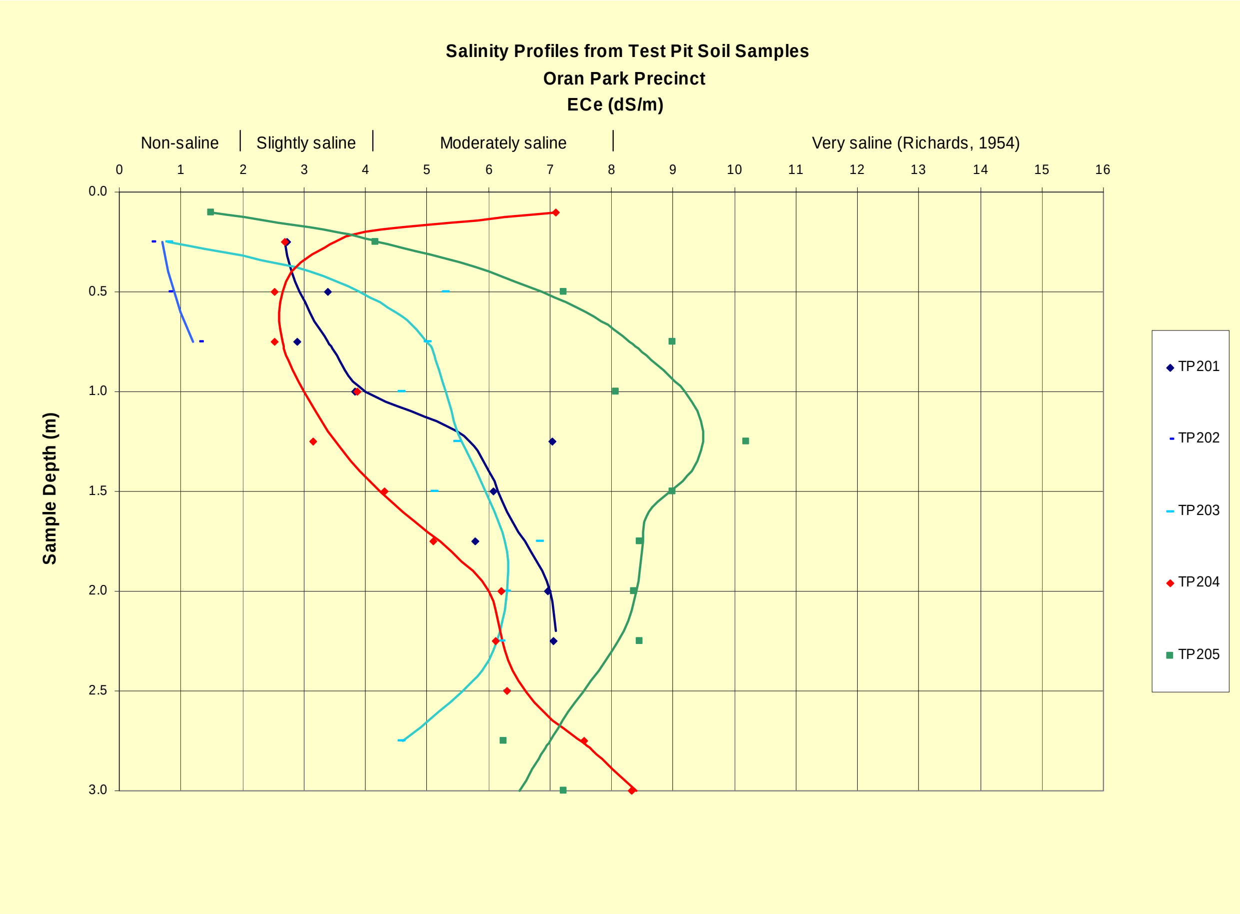
Class	ECe (dS/m)	% of Measurements
Non Saline	<2	23
Slightly Saline	2 – 4	27
Moderately Saline	4 – 8	41
Very Saline	8 – 16	8
Highly Saline	>16	1

The implication of these results, to the extent that the 176 test pit samples are representative of the study area, is that non-saline to very saline conditions can be expected throughout the study area, with only minor occurrences of highly saline conditions. These results are derived from salinity measurements in soils to depths of up to 3 m but with 49% of samples obtained at a depth of 1.5 m, for reasons described below.

At five test pits (selected as “control test pits” from EM profiling results to cover the full range of apparent conductivities), soil samples were taken at a depth of 0.1 m then at 0.25 m depth intervals to a maximum of 3 m or to rock level, enabling the construction of vertical soil salinity profiles (Figure 1 below).

From these profiles it is inferred that in a number of areas, salinities reach maxima in the 1 m to 2 m depth zone. In one tested location (Test Pit 204), maxima occur near surface (discharge type profile) and again close to rock level. In order to assess the most saline soil horizon, follow-up test pits were sampled for salinity tests at depths of 1.3 m to 1.7 m (104 tests), with checks at 0.5 m and 1.0 m (69 tests). In addition, salinity test results from depths of approximately 1.5 m were selected for correlation with EM results (below), since the horizon of maximum salinity (around 1.5 m) was inferred to have produced the bulk of the EM response.

Figure 1 – Vertical Soil Salinity Profiles



11.2 Salinity Data from Electromagnetic Measurements

On completion of EM31 profiling, field data were corrected for the measured conductivity response of the ATV and were filtered with a moving average operator to reduce the noise induced by irregular ATV motion (changes in height of the coils above the ground conductor). A bulk shift was applied to all DP data prior to merging with EES data, on the basis of a check profile recorded in the centre of the Precinct. Details of these corrections and subsequent processing steps are presented in Appendix C.

The histogram (Figure 2) and Table 8 below show that of the 54,500 corrected and filtered apparent conductivity measurements over the study area, 92% fall in the non-saline to slightly saline classes of Chhabra (1996, Ref 8), with <8% in the moderately saline class and <1% in the very to extremely saline classes. This represents an apparent shift towards lower salinity classes by comparison with the classifications from test pit sample salinities alone (Table 7 above), as a result of the difference in classification schemes. This highlights the need for "calibration" of the conductivity data to conform with the classification scheme of Richards (1954, Ref. 9), currently accepted by authorities such as DIPNR for use in urban salinity management.

Figure 2 – Distribution of Apparent Conductivities from EM 31 Profiling

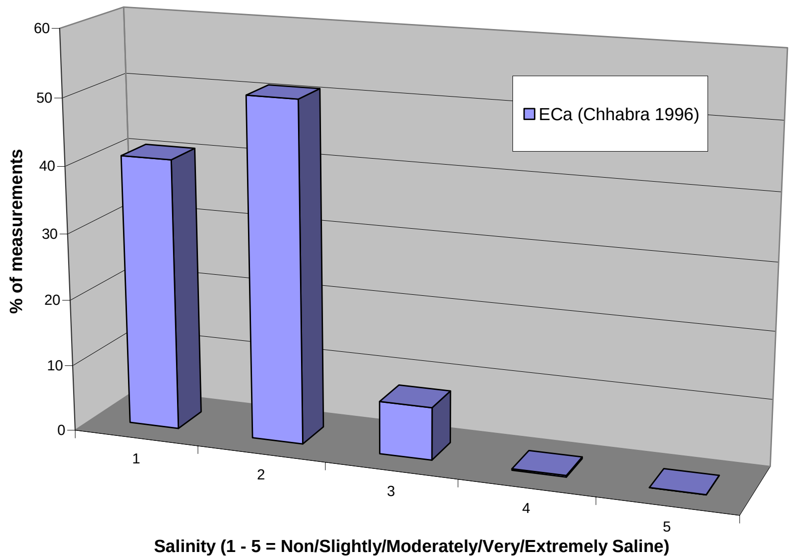
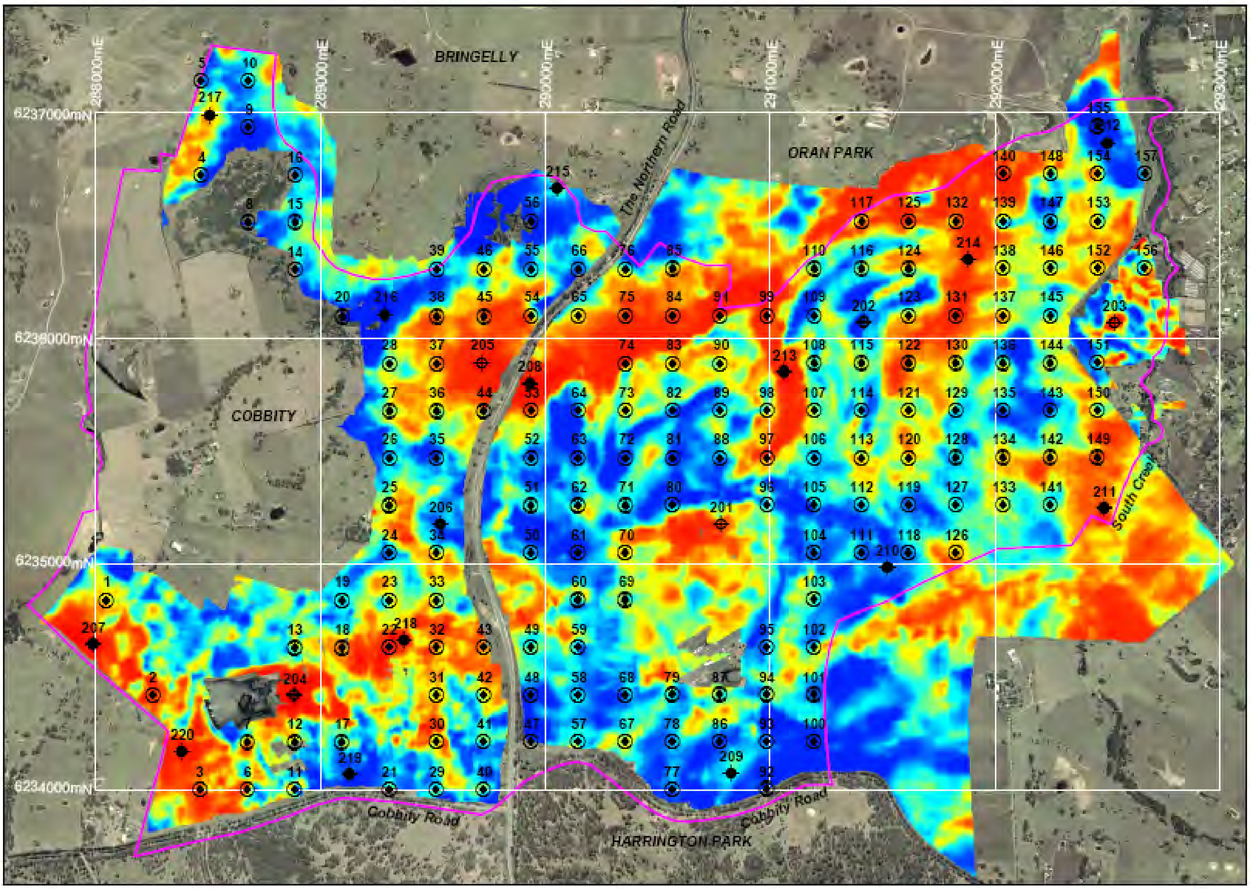


Table 8 – Distribution of Apparent Conductivities from EM 31 Profiling

ECa Range (mS/m)	<50	50 – 100	100 – 150	150 – 200	> 200
Salinity Class (Chhabra 1996)	Non-saline	Slightly saline	Moderately saline	Very saline	Extremely saline
%ECa data	40.8	51.0	7.9	0.3	0.0

Apparent conductivity data were added to the GIS database for interpolation onto a regular grid throughout the area surveyed. Drawing 15 (Appendix A and thumbnail image below) presents the apparent conductivity image with a continuous colour spectral scale in mS/m. Areas of most interest are those coloured bright red. Using the classifications of Chhabra (1996, Ref 8), these colours may indicate moderately saline to extremely saline ground conditions.



Apparent Conductivity (see Drawing 15, Appendix A)

To achieve a consistent classification from both test pit samples and EM profiling data, a form of calibration of the latter was carried out as described in Appendix C. A line-of-best-fit to an ECe/ECa scattergram provided a factor of 6.4 by which to multiply apparent conductivities (in dS/m) to estimate ECe values throughout the EM31 data set. The histogram (Figure 3) and Table 9 below show that of the re-scaled data points, 60% fall in the non-saline to slightly saline classes of Richards (1954, Ref. 9), 38% fall in the moderately saline class and 2% fall in the very saline class.

Figure 3 – Distribution of Apparent Salinities

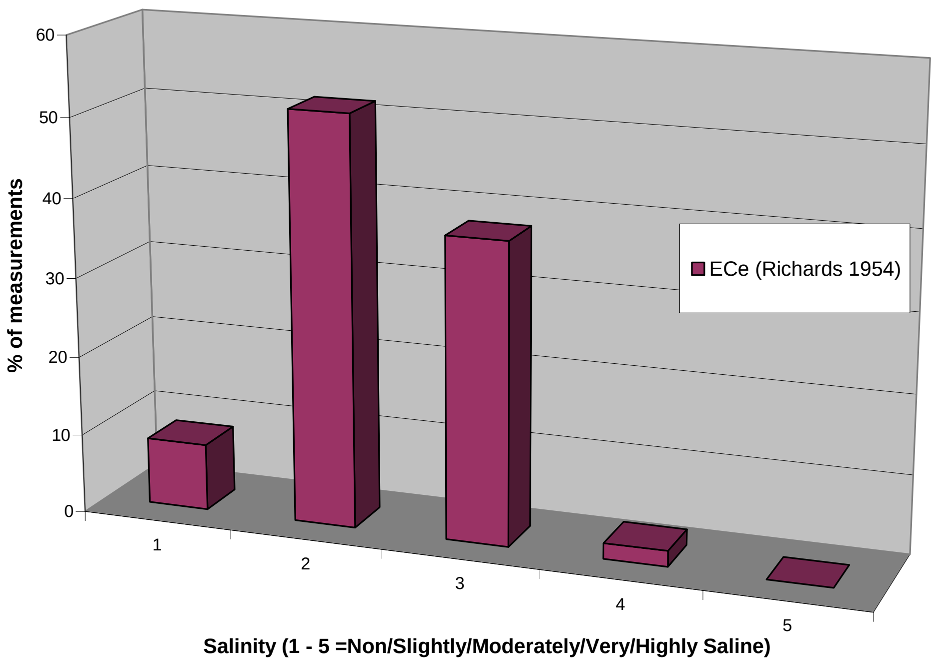


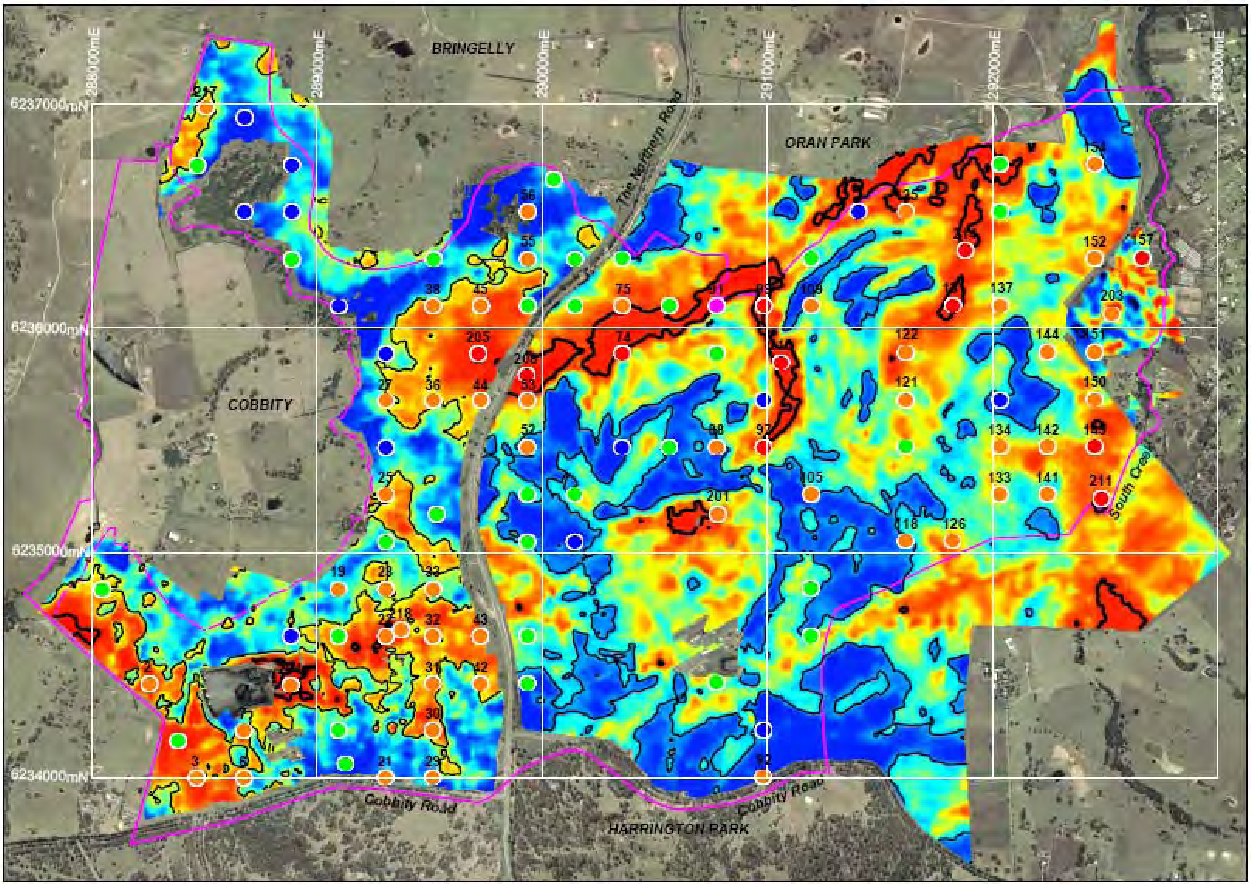
Table 9 – Distribution of Apparent Salinities

ECe Range (mS/m)	<2	2 – 4	4 – 8	8 – 16	> 16
Salinity Class (Richards 1954)	Non-saline	Slightly saline	Moderately saline	Very saline	Highly saline
%ECe data	8.4	51.7	37.9	2.0	0.0

The scale factor was applied to all EM data for presentation as an apparent salinity image (Drawing 16 Appendix A and thumbnail image below) with a continuous colour spectral scale in dS/m, based on the Richards classification scheme.

Contours were added to the image in Drawing 16, corresponding to the 4 dS/m and 8 dS/m boundaries of the salinity classes of Richards, providing a direct subdivision of the study area into non-saline and slightly saline classes (<4 dS/m), moderately saline class (4 – 8 dS/m) and very saline class (>8 dS/m). No highly saline areas were inferred.

Areas inferred to be moderately saline or very saline generally occur along the South Creek drainage system (especially in an unnamed drainage line traversing the northern portion of the GDC land) but extend into low lying drainage areas and around the large dam at the head of Cobbitty Creek in the south of the McIntosh Land.



Apparent Salinity (see Drawing 16, Appendix A)

12. DISCUSSION

12.1 Slope Instability

Thick residual soil profiles of the Blacktown, Luddenham and Picton Soil Landscapes can be prone to slope instability due to erosion or seepage triggered slumping and soil creep, particularly on steep south-facing slopes underlain by shale. The high clay content of these soils results in poor drainage, and therefore reduced cohesion during periods of high rainfall or where natural drainage has been disturbed by development. Instability due to slumping is typically associated with thick soils and slopes in excess of 118 - 20º (or greater than a 20% gradient - Ref. 7).

Deep-seated hillslope instability (landslip) affects the upper slopes of the two highest sections of the ridge line within the north-western section of the site. This instability is considered to be a major constraint to development (i.e. it would to be economically addressed by normal and possibly even extensive development works including removal of failed materials, site regrading and subsurface drainage).

Observed or inferred surficial soil creep and possible shallow ancient slumping of residual soils is also noted in over-steepened gully head or steeper ridge slope locations below the mapped or interpreted un-named sandstone member within the north-western section of the site (see Drawing 6). It is considered that potential soil creep or shallow slump instability is likely to impose only minor to moderate constraints (i.e. able to be addressed by good engineering practices for hillside development including site specific investigation and engineering of structures).

An assessment of the areas of geotechnical constraints is shown in Drawing 8. The landslide, soil creep and erosion features impose constraints on site development and include:

- restriction of residential and infrastructure development in both the current landslide affected areas and bordering areas characterised by equivalent topography and stratigraphy. For initial planning purposes, the restricted use area should include a downslope buffer at least 50 m in excess of the greatest identified runout distance of existing debris flow deposits.
- restriction of soil creep areas adjacent to landslides from development unless site specific investigation is able to ensure that appropriate engineering works (e.g. retaining walls and drainage measures) can provide acceptable levels of risk for the development.
- restriction of development adjacent to creek and gully banks, where erosion and/or soil creep may be present, unless appropriate engineering works (e.g. recontouring or bank support) can be put in place to provide acceptable levels of risk for the development.
- imposition of a program of revegetation of the landslide and soil creep affected areas.

Other than erosion-triggered slumping of a material (probably a few cubic metres at any event) from the low height banks of the gullies within the site, there does not appear to be a significant risk of stream bank instability. It is considered that stream bank instability impose only minor constraints (i.e. able to be addressed by good engineering practices) on the proposed site development.

12.2 Erosion Potential

Soils of the Blacktown, Luddenham and Picton Soil Landscapes are typically of moderate erodibility (K values of 0.02 – 0.04). The more sodic or saline soils of the Blacktown soil landscape can have high erodibility and the erosion hazard for this landscape is estimated as moderate to very high (Refs. 1 and 2). Similarly, the erodibility of the soils of the South Creek Soil Landscape is classed as high and the erosion hazard is potentially very high to extreme, while the Richmond Soil Landscape is classed as having moderate to high erosion hazard for concentrated flows.

It is considered that the erosion hazard within the areas proposed for development would be within usually accepted limits which could be managed by good engineering and land management practices which will also be required to address flood hazard and localised waterlogging limitations of soils along the course of South Creek. These hazards are considered to impose only minor constraints to development.

It is anticipated that the treatment of the existing gullies as part of an overall site development would include:

- filling using select materials (i.e. non – dispersive or erodible) placed under controlled conditions;
- provision of temporary surface cover (e.g. pegged matting) during the period of valley floor revegetation;
- channel lining in sections of rapid change in gully floor grade;
- piping of flow where appropriate;
- the re-establishment of a zone of tree cover along gully banks.

12.3 Soil Salinity, Aggressivity and Sodicity

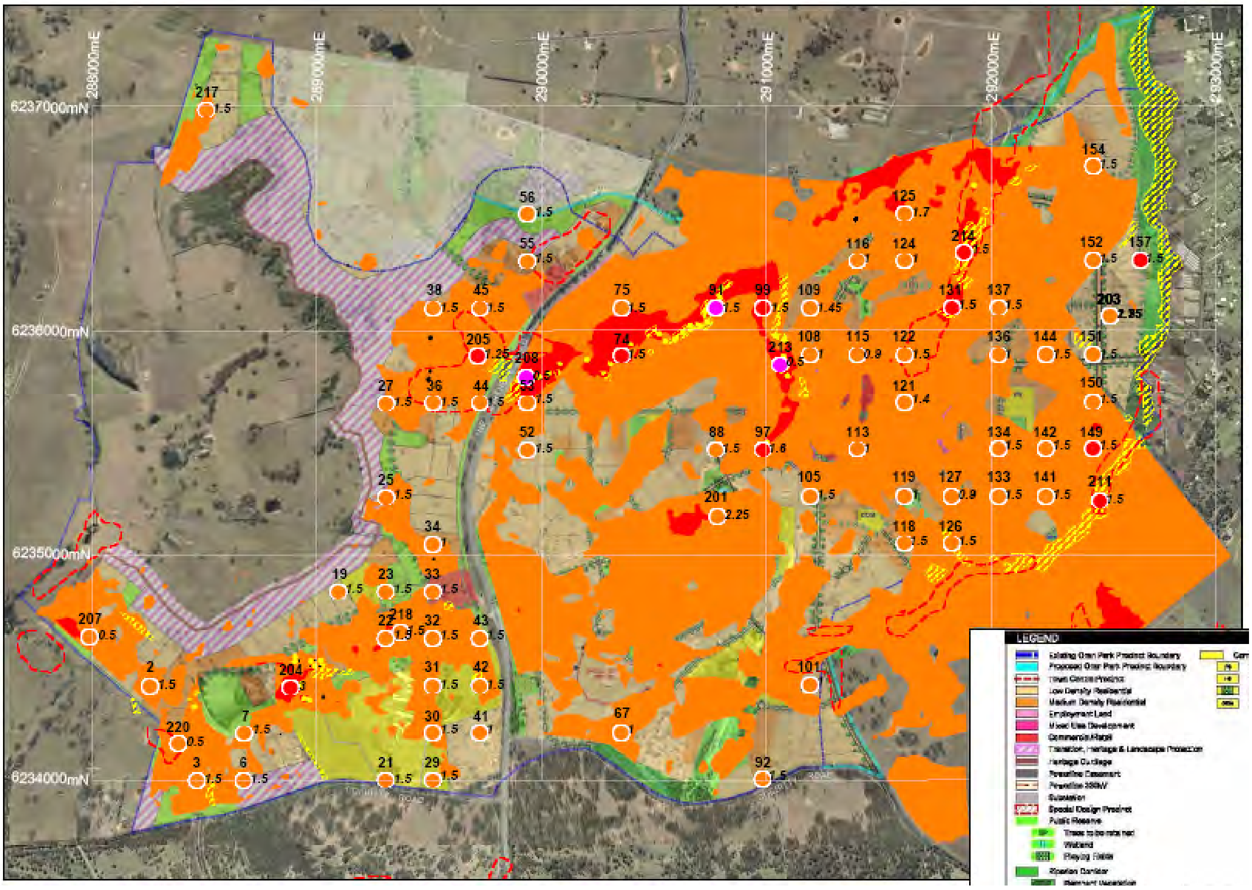
12.3.1 Assessment of Salinity Constraints

Three methods of assessment of soil salinity were employed to ground-truth the salinity potential map of DIPNR (2003, Ref. 6):

- Visible indicators of salinity mapped during a geological inspection;
- ECe estimates derived from 218 laboratory tests of soil samples from 176 test pits; and
- ECa (apparent conductivity) data obtained at 54,500 measurement stations.

No single method of assessment is sufficient due to spatial sampling and other limitations, however a joint assessment can provide a practical means of defining areas where there is a risk that urban development will be affected by soil salinity, or will adversely affect the salinity of the environment.

To better assess the constraints that saline soils may place on the proposed development, a number of mappable features were overlain on the aerial photograph of the site to produce a Salinity Constraints map (Drawing 17 Appendix A and thumbnail image below).



Salinity Constraints (see Appendix A, Drawing 17).

These features included:

- the Indicative Layout Plan (ILP) dated 6 February 2007;
- zones of "known salt" i.e. surface salt observed or inferred from airphoto interpretation (DIPNR 2003, Ref. 6);
- locations of salinity indicators observed by DP;
- locations of test pits where salinity estimates (ECe) from samples at any sample depth, exceeded 4 dS/m (i.e. moderately to highly saline soil anywhere within the soil profile);
- constraint regions based on 4 dS/m and 8 dS/m ECe contours. The ECe values (termed apparent salinities herein) were derived, as detailed in Appendix C, by correlation of apparent conductivities (ECa) from EM profiling, with ECe estimates from laboratory testing of soil samples. Correlation was carried out with samples from a depth of 1.5 m, since soil at this general depth was considered (from vertical salinity profiles) to be contributing most of the EM31 response.

For a conservative approach in some areas, the constraint regions were inferred to extend across minor saddles in the calculated ECe contours. Similarly, a number of test pits indicating moderate salinity (at some depth within the soil profile), lie outside the main constraint region but are shown with a "local" constraint region of unknown extent.

Drawing 4 is characterised by widespread moderately saline soils but shows a reasonable correspondence between the known salt zones (DIPNR 2003, Ref. 6) along the northern tributaries to South Creek and the very saline constraint regions inferred from the DP and EES investigations. That is, in this area ground truthing has generally confirmed the salinity potential indicated by DIPNR. Where the southeast Precinct boundary follows the drainage system, salt-tolerant vegetation and very saline soil in Test Pits 149 and 211 are consistent with the DIPNR known salt zones, although re-gridded EES data indicates a broad area of only moderate salinity.

It is assumed that the development (represented by the ILP dated 6 February 2007) will not impact on the riparian corridors of South Creek and its tributaries and that the very saline and highly saline soils identified in the riparian corridors will not be exposed, hence will not impact on the development. However, moderately to highly saline soils have been identified outside the corridors and parts of the proposed development may be constrained as indicated below. Where locations are given in relation to test pits, see Table 7a (Appendix J) for coordinates.

12.3.2 Possible Development Constraints due to Soil Salinity

Development may be constrained by the need to apply various levels of salinity management, as indicated below:

- Apply management strategies for highly saline soil at shallow depth (0.5 m) within the substation area adjacent to The Northern Road (Test Pit 208), within the medium density residential lot at the west of the town centre (Test Pit 213) and at locations of salt efflorescence shown on Drawing 17.
- Apply management strategies for very saline soil at depths of the order of 1.5 m
  - Around Test Pit 107 (within the southwestern low density residential area and adjacent park land)
  - Within southwestern low density residential lots and adjacent park land near Test Pit 204;
  - Locally within a medium density residential lot at Test Pit 205, west of the northern section of The Northern Road;
  - Within parts of the employment area adjacent to The Northern Road and within medium density residential lots and park lands flanking the riparian corridor between Test Pits 208 and 99;
  - Within park land, wetlands and low density residential lots southwest of Test Pit 201;
  - Within park land, medium density residential lots and mixed use development areas at the west of the town centre;
  - Within low density and high density residential lots and wetlands east and northeast of Test Pit 125 along the northern Precinct boundary; and
  - Locally within low density residential lots around Test Pits 157 and 149 on the eastern Precinct boundary.
- Apply management strategies for moderately saline soil at depths of the order of 1.5 m, throughout much of the remaining parts of the Precinct, except for most of the heritage and

conservation zone around Denbigh homestead and much of the community area adjacent to Cobbity Road.

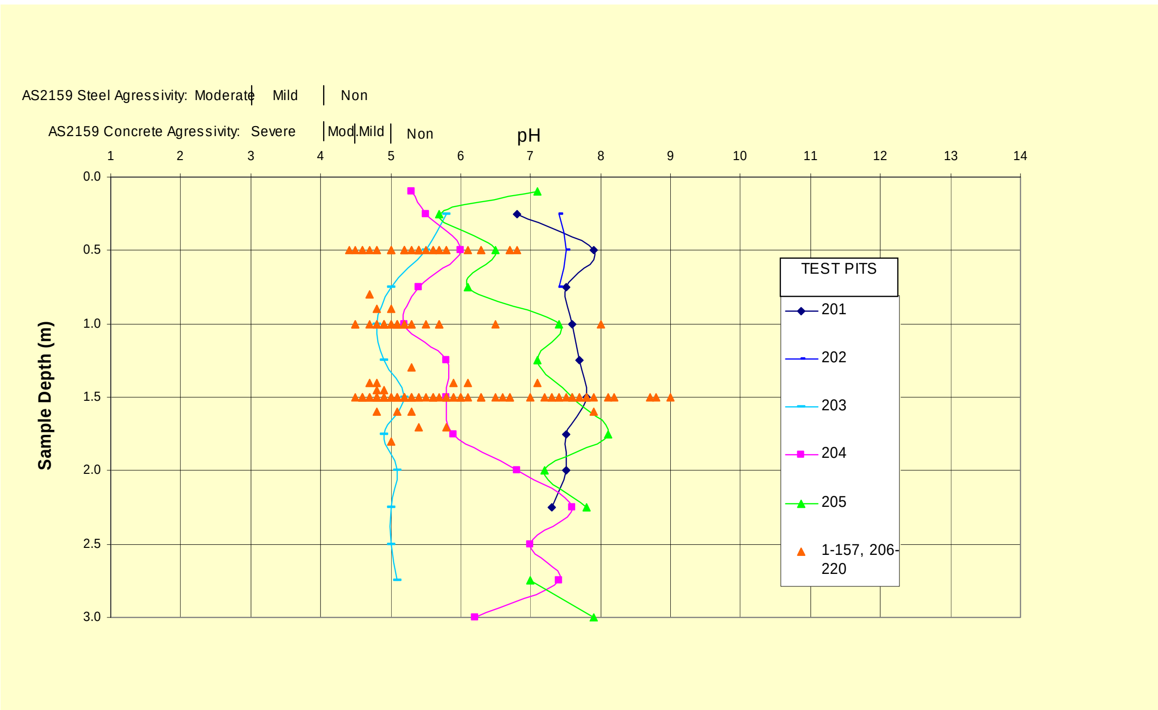
12.3.3 Assessment of Aggressivity Constraints

The aggressivity of the soil to concrete and steel was assessed primarily by measurement of the pH of 202 soil samples from 176 test pits, for classification of the soils according to the criteria of Australian Standard AS2159. Samples were taken at 0.25 m depth intervals from Test Pits 201 to 205 (control test pits) and primarily from depths of 1.5 m, 1 m and 0.5 m at other test pits. From 20 of the 176 test pits, 35 soil samples were also tested for chloride and sulphate concentrations, as a complementary check on aggressivity.

Laboratory results and classifications are presented in Table 7a (Appendix J) and indicate non-aggressivity to steel at all tested locations and depths.

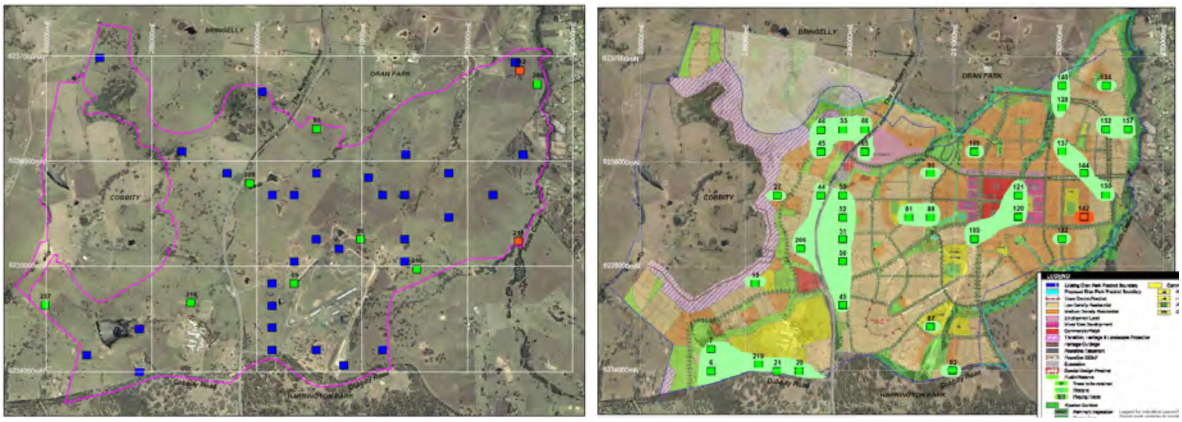
Aggressivity to concrete varied from non-aggressive to moderately aggressive as indicated by the pH profiles and scattergram of Figure 4.

Figure 4 – pH Profiles, Oran Park Precinct



Drawings 18 and 19 (Appendix A and thumbnail images below) show the lateral distributions of aggressivity to concrete at depths of 0.5 m and 1.5 m respectively. At depths of 0.5 m, non-aggressive soils predominate but mildly aggressive soils are present throughout the Precinct. The latter are sparsely distributed and no constraint zones could be defined. One moderately aggressive result was obtained within the Precinct boundaries, from Test Pit 212 in a low density residential area in the far northeast of the Precinct.

At a depth of 1.5 m, locations of mildly aggressive soils are more closely grouped and approximate boundaries of mildly aggressive constraint zones are indicated on Drawing 19. Moderately aggressive soil was indicated at one location (Test Pit 142) in a medium density residential area in the east of the Precinct.



L & R: Aggressivity to concrete at 0.5m and 1.5 m depths (See Drawings 18 & 19, Appendix A)

12.3.4 Possible Development Constraints due to Soil Aggressivity

Salinity management plans should include strategies for management of the often-associated property of aggressivity to concrete. From Drawings 18 and 19, it is inferred that development may be constrained by the need to apply strategies to combat aggressivity, as indicated below:

- Apply management strategies for moderate aggressivity to concrete at depths of the order of 0.5 m

- Locally around Test Pit 212 in the low density residential area in the far northeast of the Precinct.

- Apply management strategies for moderate aggressivity to concrete at depths of the order of 1.5 m
  - Locally around Test Pit 142, within a medium density residential lot in the east of the Precinct.
- Apply management strategies for mild aggressivity to concrete at depths of the order of 1.5 m
  - Within eight zones and local to eight test pits as indicated on Drawing 19, covering a range of land use areas.

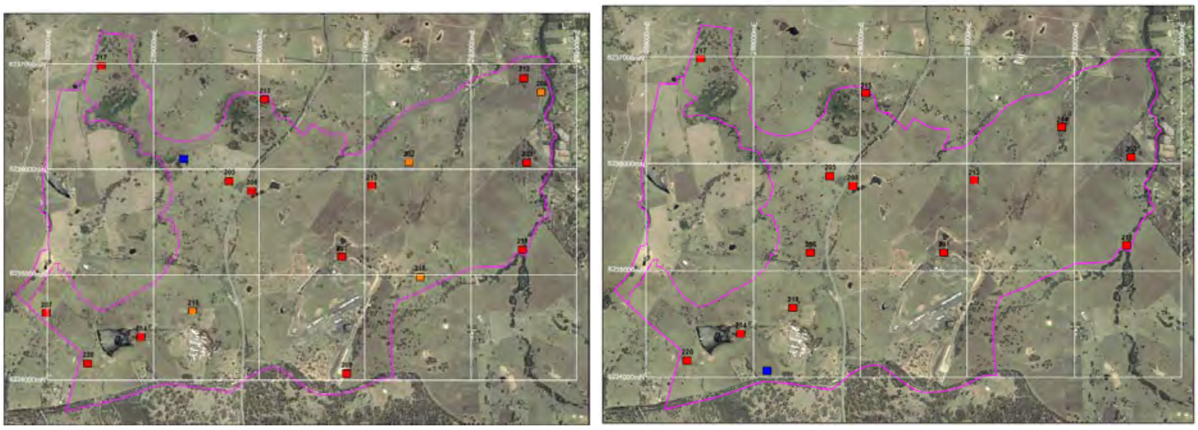
It should be noted that the soils within the lower slopes around the northern tributaries to South Creek are characterised by very saline soil but are inferred to be non-aggressive or only mildly aggressive to concrete, possibly due to lithological differences in the vicinity of the tributaries.

12.3.5 Assessment of Sodicity Constraints

The sodicity of the soil (proportion of exchangeable sodium cations as a percentage of total exchangeable cations) can be elevated due to salt content and can affect properties such as dispersion, erodibility and permeability. Sodicity was assessed by measurement of the exchangeable sodium capacity and total cation exchange capacity of 35 soil samples from 20 test pits, for classification of the soil as non-sodic (<5% sodicity), sodic (5-15% sodicity) or highly sodic (>15% sodicity). Samples were taken from a depth of 0.5 m in 18 test pits, from a depth of 1.5 m to 1.6 m in 13 test pits and from a depth of 1.0 m in 2 test pits.

Laboratory results and classifications are presented in Table 7a (Appendix J) and indicate highly sodic conditions at all depths in most tested locations. At Test Pits 202, 206, 210 and 218, sodic conditions were indicated at a depth of 0.5 m and in Test Pits 216 and 219 non-sodic soils were indicated.

Drawings 20 and 21 (Appendix A and thumbnail images below) show the lateral distributions of sodicity at depths of 0.5 m and 1.5 m respectively. The relatively small number and sparse distribution of test pits from which sodicity measurements were made, prevents the interpretation of detailed sodicity constraint zones. However on the basis of these measurements, it is considered likely that sodic to highly sodic conditions exist throughout the Precinct and that salinity management plans should include strategies for management of this associated property.



L & R: Sodicity at 0.5m and 1.5m depths (See Drawings 20 and 21, Appendix A)

12.3.6 Salinity, Aggressivity and Sodicity Management Strategies

Development must be planned to mitigate against the effects of any potential salinisation that could occur and efforts should be made to prevent or restrict changes to the water balance that will result in rises in groundwater levels, bringing more saline water closer to the ground surface.

Efforts need to be directed at all levels of the development process including site design, vegetation, landscaping, building and infrastructure construction.

The following strategies are based on the assumptions that development will proceed in general according to the ILP dated 6 February 2007 and that earthworks will in general be confined to the depths of investigation of the test pits employed for direct soil sampling and laboratory testing (i.e. up to 3 m). Zones of deeper excavation may require modifications to the management strategies, based on further sampling and testing to the maximum depth of excavation.

In general, the following strategies are directed at:

- maintaining the natural water balance;
- maintaining good drainage;
- avoiding disturbance or exposure of sensitive soils;
- retaining or increasing appropriate native vegetation in strategic areas;
- implementing building controls and engineering responses where appropriate.

Site Design, Vegetation and Landscaping

Planning of the development of the site requires careful management with a view to controlling drainage and infiltration of both surface waters and groundwater to prevent rises in groundwater levels and minimise the potential for erosion.

Precautionary measures to reduce the potential for salinity problems include:

- Avoiding water collecting in low lying areas, along shallow creeks, floodways, in ponds, depressions, or behind fill embankments or near trenches on the uphill sides of roads. This can lead to water logging of the soils, evaporative concentration of salts, and eventual breakdown in soil structure resulting in accelerated erosion.
- Roads and the shoulder areas should also be designed to be well drained, particularly with regard to drainage of surface water. There should not be excessive concentrations of runoff or ponding that would lead to waterlogging of the pavement or additional recharge to the groundwater. Road shoulders should be included in the sealing program should rural construction methods be used.
- Surface drains should generally be provided along the top of all batters to reduce the potential for concentrated flows of water down slopes possibly causing scour. Well-graded subsoil drainage should be provided at the base of all slopes where there are road pavements below the slope to reduce the risk of waterlogging.
- With regard to regrading within the development footprint, a minimum surface slope of 1V:40H is suggested in order to improve surface drainage and reduce ponding and waterlogging, which can lead to evaporation and salinisation. Consideration should also be

given to regrading of natural slopes outside the development footprint within salinity risk zones, where this will improve overall drainage without creating additional erosion hazards.

- Where possible materials and waters used in the construction of roads and fill embankments should be selected to contain minimal or no salt. This may be difficult for cuts and fills in lower areas where saline soils are exposed in cut or excavated then placed as filling. Under these circumstances where salinisation could be a problem, a capping layer of either topsoil or sandy materials should be placed to reduce capillary rise, act as a drainage layer and also reduce the potential for dispersive behaviour in any sodic soils.
- Where a capping layer of topsoil, sandy material or crushed rock cannot be placed to reduce the potential for dispersive behaviour of the sodic to highly sodic soils, consideration should be given to mixing of gypsum into filling and placement on exposed slopes to improve soil structure and reduce the potential for scour.
- Salt tolerant grasses and trees should be considered if re-planting close to creeks and in areas of moderate and greater salinity to reduce soil erosion and maintain the existing evapotranspiration and groundwater levels. Reference should be made to an experienced landscape planner or agronomist.

Building and Infrastructure Construction

The extent of measures adopted during construction, in particular the concrete, masonry and steel requirements, should depend on the particular level of salinity or aggressivity at the actual site. In general, for the construction of buildings or infrastructure (buried services) on moderately or more saline sites, the following guidelines are suggested:

- To manage soil from specific building sites or services alignments within the moderate salinity constraint regions or moderate aggressivity constraint regions of Drawings 17 and 19 (Appendix A), use of a bedding layer of sand (say 100 mm minimum) followed by a membrane of thick plastic is recommended under concrete slabs to act as a moisture barrier and drainage layer to restrict capillary rise under the slab.
- Higher than normal strength concrete (say 32MPa) or sulphate resistant cement may need to be considered in very saline constraint regions in order to reduce the risk of reinforcement corrosion in concrete slabs. A minimum of 65 mm of concrete cover on slab reinforcement, proper compaction and curing of concrete are also suggested to produce a dense low permeability concrete.

- As an alternative to slab-on-ground construction, suspended slab or pier and beam construction should be considered, particularly on sloping sites as this will minimise exposure to saline or aggressive soils and reduce the potential cut and fill on site which could alter subsurface flows.
- Other measures that can be considered to improve the durability of concrete in saline environments include reducing the water to cement ratio (hence increasing strength), minimising cracks and joints in plumbing on or near the concrete, reducing turbulence of any water flowing over the concrete.
- It is essentially that in all masonry buildings a brick damp course be properly installed so that it cannot be bridged either internally or externally. This will prevent moisture moving into brickwork and up the wall.
- There are various exposure classifications and durability ratings for the wide range of masonry available. Reference should be made to the supplier in choosing suitable bricks of at least exposure quality. Water proofing agents can also be added to mortar to further restrict potential water movement.
- In areas of elevated salinity, bricks that are not susceptible to damage from salt water should be used. These are generally less permeable, do not contain salts during their construction, and have good internal strength so that they can withstand any stress imposed on them by any salt encrustation.
- Consideration could be given to use of infrastructure service lines deeper than say 1.2 m, to promote subsurface drainage by incorporating slotted drainage pipes fitting into the stormwater pits in lower areas where pipe invert levels are within about 1 m of existing groundwater levels.
- Service connections and stormwater runoffs should be checked to avoid leaking pipes which may affect off site areas further down slope and increase groundwater recharge resulting in increases in groundwater levels.
- Within very saline constraint regions, consideration should be given to use of higher grade (more resistant) materials in all underground service lines.

12.4 Soil Contamination Potential

12.4.1 Potential Areas of Environmental Concern

Thirty-two areas were identified in the course of site history investigations as Potential Areas of Environmental Concern (PAEC) (logs in Appendix D give locations). Each PAEC was logged on a PAEC Identification & Inspection Log. These logs are included for reference in Appendix D. The logs contain detailed information regarding the investigations and analysis undertaken for the assessment. Table 10 below lists the identified PAEC which includes an "outcome" as not all nominated PAEC became AEC.

Table 10 – Identified Potential Areas of Environmental Concern

PAEC #	Description	Identified from	Inspection Type	Outcome
1	Unauthorised use as truck and storage depot	Council Records	Walkover	AEC
2	Irrigation of land from septic tank water	Council Records		Not AEC
3	Oran Park Raceway (4 USTs, oil storage area, grease traps, hydrocarbon staining and filling)	EES Investigation (EES 01) Aerials		AEC
4	Fill mound and pit area for 4WD	EES Investigation (EES 02) Aerials		AEC
5	Military camp (rifle range, fuel pump and facilities constructed of asbestos)	EES Investigation (EES 03) Anecdotal		AEC
6	Leppington Pastoral (used as dairy and an unidentified area was used for dumping dead cow carcasses)	EES Investigation		AEC
7	Old dairy (old dairy demolished, gully used for dumping waste), Dam	EES Investigation (EES 32 (AEC 17)) Aerials		AEC
8	Unidentified disturbance	EES Investigation (EES 33 (AEC 18))		AEC
9	House/ sheds removed	EES Investigation (EES 34 (AEC 19)) Aerials		AEC
10	House/ sheds	EES Investigation (EES 35) Aerials		AEC
11	Houses/ sheds removed	EES Investigation (EES 36 (AEC 20)) Aerials		AEC
12	Infilled Dam	EES Investigation (EES 37 (AEC 21))		AEC
13	Residential building removed	EES Investigation (EES 38 (AEC 22))		AEC
14	Residential building (possibly asbestos) removed	EES Investigation (EES 39 (AEC 23))		AEC
15	Residential building removed	EES Investigation (EES 40 (AEC 24))		AEC
16	Residential building removed	EES Investigation (EES 44 (AEC 27))		AEC
17	Unidentified disturbance	EES Investigation (EES 45 (AEC 28)) Aerials		AEC
18	Unknown disturbance	EES Investigation (EES 46)		AEC
19	Unidentified disturbance (possible market gardens or cropping area)	EES Investigation (EES 47 (AEC 29))		AEC
20	Backfilled dam	Property Attribute	Interview	Not AEC
21	Disturbed area	Aerials	Walkover	Not AEC

22	Dam	Aerials		Not AEC
23	Dam	Aerials		Not AEC
24	Dam	Aerials		Not AEC
25	Dam	Aerials		Not AEC
26	Dam	Aerials		Not AEC
27	Dam	Aerials		Not AEC
28	Dam	Aerials		Not AEC
29	Dam	Aerials		Not AEC
30	Structures	Aerials	Walkover	AEC
31	Collage Campus	Aerials		Not AEC
32	Earthmoving and structures	Aerials		Not AEC
33	Cleared area	Aerials	Walkover	Not AEC
34	Dam	Aerials		Not AEC
35	Dam	Aerials		Not AEC
36	Dam	Aerials		Not AEC
37	Dam	Aerials		Not AEC
38	Dam	Aerials		Not AEC
39	Dam	Aerials		Not AEC
40	Suspected ex-military camp	Aerials		Not AEC
41	Unidentified disturbance (earthworks/ demolished shed)	Aerials	Walkover	AEC
42	Ground disturbance	Aerials		Not AEC
43	Ground disturbance	Aerials	Walkover/ interview	Not AEC
44	Ground disturbance	Aerials		Not AEC
45	Unidentified disturbed area	Aerials	Walkover	Not AEC
46	Ground disturbance	Aerials	Walkover	Not AEC
47	College Campus – agriculture area	Aerials		Not AEC
48	Evidence of cultivation	Aerials	Walkover / interview	Not AEC
49	Evidence of cultivation	Aerials	Walkover / Aerial	Not AEC
50	Evidence of cultivation	Aerials	Walkover / Aerial	Not AEC
51	Building material / demolition waste and possible evaporation basin	GeoEnviro Report		Not AEC
52	Possible market garden	Aerial	Walkover	AEC
53	Asbestos pipe system	Geotechnical		AEC
54	Asbestos pipe system	Geotechnical		AEC
55	Fragments of asbestos	Geotechnical		AEC
56	Fragments of asbestos	Geotechnical		AEC
57	Filled creek line	Inspection		AEC
58	Fragments of asbestos	Geotechnical		AEC

12.4.2 Areas of Environmental Concern (AEC)

The site history and inspection indicated that the site had mainly been used for agricultural and rural/residential purposes. Following investigation of each PAEC and on the basis of these findings, the identified areas of environmental concern (AEC) are summarised in Table 11 together with an assessment of the potential contamination associated with each AEC. The location of each of the AEC is shown on Drawing 13, Appendix A.

Table 11 – Summary of Identified Areas of Environmental Concern

AEC#	PAEC #	Description	Property	Contaminants	Level of Assessment
1	1	Unauthorised use as truck and storage depot	20 Curtis Lane	Heavy metals, TRH, BTEX, OCP, OPP, PCB, PAH, Asb	
2	3	Raceway	Oran Park	Heavy metals, TRH, BTEX, PAH	
3	4	Unknown fill in 4WD Area	Oran Park	Heavy metals, TRH, BTEX, OCP, OPP, PCB, PAH, Asb	
4	5, 40	Military Camp Area	Oran Park and McIntosh	Heavy metals, TRH, BTEX, OCP, OPP, PCB, PAH, Asb, and further investigation by Milsearch	
5	6	Animal burial area	Oran Park	Heavy metals, TRH, BTEX, OCP, OPP, PCB, PAH, Asb	
6	7	Old Dairy: Demolished building and uncontrolled filling	Oran Park	Heavy metals, TRH, BTEX, OCP, OPP, PCB, PAH, Asb	
7	8	Demolished dwelling	Oran Park	Lead, OC OP Asb	
8	9	Demolished dwelling	Oran Park	Lead and Asbestos	
9	10	Structures	Oran Park	Lead in paint and Asbestos	Hazardous Materials
10	11	Demolished dwelling	Oran Park	Lead, OC OP Asb	
11	12	Unknown fill	Oran Park	Heavy metals, TRH, BTEX, OCP, OPP, PCB, PAH, Asb	
12	13	Demolished dwelling	Oran Park	Lead, OC OP Asb	
13	14	Demolished dwelling	Oran Park	Lead, OC OP Asb	
14	15	Demolished dwelling	Oran Park	Lead, OC OP Asb	
15	16	Demolished dwelling	Oran Park	Lead, OC OP Asb	
16	17	Unknown ground disturbance	Oran Park	Heavy metals, TRH, BTEX, OCP, OPP, PCB, PAH, Asb	
17	18	Unknown ground disturbance	Oran Park	Heavy metals, TRH, BTEX, OCP, OPP, PCB, PAH, Asb	
18	19	Possible market garden	Oran Park	Heavy metals, TRH, BTEX, OCP, OPP, PAH,	
19	30	Various structures	McIntosh	Lead in paint and Asbestos	Hazardous Materials
20	41	Demolished building	Oran Park	Lead, OC OP Asb	
21	52	Possible market garden	189 Springhill Road	Heavy metals, TRH, BTEX, OCP, OPP, PAH	
22	53	Asbestos Pipe System	McIntosh Land	Asb	Asbestos Clearance
23	54	Asbestos Pipe System	Oran Park	Asb	Asbestos Clearance

AEC#	PAEC #	Description	Property	Contaminants	Level of Assessment
24	55	Asbestos found at surface Nr pit 47 & 57	Oran Park	Asb	Asbestos Clearance
25	56	Asbestos found at surface Nr pit 73 & 88	Oran Park	Asb	Asbestos Clearance
26	57	Building Rubble in creek line	Oran Park	Asb	Asbestos Clearance
27	58	Asbestos found at surface near pit 146	Oran Park	Asb	Asbestos Clearance

Notes:
Heavy metals = As, Cd, Cr, Cu, Pb, Hg, Ni, Zn
BTEX = Benzene, Toluene, Ethylbenzene, Xylene
OCP = Organochlorine pesticides
PCB = Polycyclic Biphenyls
TRH = Total Recoverable Hydrocarbons
PAH = Polycyclic aromatic hydrocarbons
OPP = Organophosphorus pesticides
Asb = Asbestos

There is no record of a military investigation being undertaken for the development at the MAS. Consideration should be given to this and it should be noted that investigation of military activities were beyond the scope of this assessment. These were being undertaken by the military researcher, Milsearch.

12.5 Geotechnical Considerations

Development of the site, geotechnically, should be relatively straightforward with comments on site preparation, earthworks, foundations, likely lot classifications, maintenance, drainage and preliminary pavement thickness designs given in the following sections.

The investigation completed to date has also indicated localised areas that will require attention, such as removal of existing fill both on the general site and within localised gullies (refer Drawing 3) together with likely extensive stripping requirements within the existing golf course. Remedial works required for redevelopment of the existing dam located near the southern (lower) limit of the existing golf course will depend on whether or not the dam is to be retained or possibly reduced in size.

12.5.1 Site Classification

Classification of residential lots within the site should comply with the requirements of AS 2870 – 1996 *"Residential Slabs and Footings"* (Ref. 11). Based on the limited work for the current investigation, the subsurface profiles at most locations are as would be expected for Class M (moderately reactive) and Class H (highly reactive) sites. Some Class P areas may result due to relatively deep uncontrolled filling placed on the site or in the event that waterlogging and saturation of low-lying areas occurs. Additional testing will be required at the appropriate time for validation purposes.

12.5.2 Footings

All footing systems for residential type structures should be designed and constructed in accordance with AS 2870 – 1996 (Ref. 11) for the appropriate classification. Whilst conventional high level footing systems would be appropriate for M or H sites, suitable foundation systems for Class P lots could include (depending on the depth of suitable founding stratum and the presence of groundwater) backhoe excavated blockdowns, pier and beam, screw piles or possibly driven timber piles and mini piles founding on the underlying stiff clays or weathered rock.

Footings for all other structures should be based on the results of specific geotechnical investigations. As a guide, preliminary design could be based on maximum allowable bearing pressures of 150 kPa for stiff to very stiff clays and 800 kPa for highly weathered rock.

12.5.3 Site Preparation and Earthworks

Site preparation necessary for development (which would include building and road pavement construction) should allow for the removal of topsoils and other deleterious materials such as existing filling and all topsoils. Whilst excavation within clays and extremely weathered rock would be relatively straightforward, removal of the stronger rock (ie: below test pit refusal depths) would require ripping.

In areas that require filling, the stripped surfaces should be proof rolled in the presence of a geotechnical engineer. Any areas exhibiting significant deflections under proof rolling should be appropriately treated by over-excavation and replacement with low plasticity filling placed in near horizontal layers no thicker than 250 mm compacted thickness. Each layer should be compacted to a minimum dry density ratio of 98% relative to standard compaction with placement moisture contents maintained within 2% of standard optimum. The upper 0.5 m in areas of pavement construction should achieve a minimum dry density ratio of 100% relative to standard compaction.

All formed batters (in both cut and fill) should be constructed no steeper than 3:1 (horizontal:vertical) and appropriately vegetated to reduce the effects of erosion. The construction of toe and spoon drains is recommended as a means of controlling surface flows.

To validate site classifications, sufficient field inspections and in-situ testing of future earthworks should be undertaken in order to satisfy the requirements of a Level 1 inspection and testing service as defined in AS 3798 – 1996 (Ref. 12).

If embankments are proposed for use as water quality control ponds then the results of testing completed to date indicates that the site soils would be suitable for reuse as embankment materials. Subject to the detailed design, detention basins (ie: short term storage only) could be dimensioned with maximum batter slopes of 4:1 (H:V) with allowance made for accommodating the results of erosion (such as topsoiling and turfing) should soils with an ECN of less than 4 be proposed for use. Subject to design permeability requirements, the use of lines on both the embankments and within parts of the reservoir area may also be necessary.

All placement of filling must be undertaken under Level 1 control.

12.5.4 Site Maintenance and Drainage

The site should be maintained in accordance with the CSIRO publication *"Guide to Home Owners on Foundation Maintenance and Footing Performance"*, a copy of which is included in Appendix K. Whilst it must be accepted that minor cracking in most structures is inevitable, the guide describes suggested site maintenance practices aimed at minimising foundation movement to keep cracking within acceptable limits.

Surface drainage must be installed and maintained at the site particularly during the construction phase of the project. All collected stormwater, groundwater and roof runoff should be discharged into the stormwater disposal system.

12.5.5 Pavements

Whilst detailed design of pavements will obviously be undertaken at the development/ construction stage, Table 12 summarises a range of pavement thickness designs. These designs are based on the procedures given in APRG – SR 21 (Ref. 13) (Aust Roads Pavement Research Group) for a range of traffic loadings and subgrade CBR (California Bearing Ratio) values and are provided to give an indication of the range of pavement thickness that can be