SINCLAIR KNIGHT MERZ

SKM

St Marys Project
Western Precinct Plan

WATER, SOILS AND INFRASTRUCTURE REPORT

- Final
- May 2009

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Sinclair Knight Merz
ABN 37 001 024 095
100 Christie Street
PO Box 164
St Leonards NSW
Australia 1590
Tel: +61 2 9928 2100
Fax: +61 2 9928 2500
Web: www.skmconsulting.com

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Executive Summary

Sinclair Knight Merz (SKM) has prepared this report for Maryland Development Company (MDC) to provide background information, describe existing and proposed conditions and provide Water, Soil and Infrastructure Management Strategies for the Western Precinct of the site at St Marys. The report addresses the following aspects in relation to the Western Precinct of the site at St Marys:

- Introduction, background and proposed development;
- The existing environment;
- Performance objectives;
- Management strategies for the water cycle and water;
- Management strategies for stormwater trunk drainage system;
- Management strategies for groundwater and salinity; and
- Essential services infrastructure (water, sewer, and electricity);

The proposed stormwater quality management strategy for the Western Precinct is based on the principles of Ecologically Sustainable Development (ESD) and Water Sensitive Urban Design (WSUD). This strategy includes the use of water quality controls such as gross pollutant traps, constructed wetlands and biofiltration basins.

The proposed development involves changes to the local catchments, including an increase in the amount of impervious area. Stormwater quantity would be managed via the use of detention basins. Runoff would be conveyed to the detention basins via an underground pipe network and above-ground overland flow paths. The lots would remain flood-free in events up to and including the 100 year ARI event. Detention of stormwater runoff would ensure that peak flows do not increase in storm events up to and including the 100 year ARI event.

Groundwater and salinity investigations have been carried out on the site in several phases since 1991. An electro-magnetic induction (EMI) survey was undertaken by DLWC in December 1999 and apparent electrical conductivity (ECa) was identified to be generally low in the Western Precinct with the exception of a highly saline anomaly (ECa of 17 dS/m at a depth of 0.6 m) which was detected in an area located along the central valley. This EMI anomaly was investigated further by field testing and the results indicated that salinity in this area was moderately saline rather than highly saline. Although soil salinity is unlikely to pose environmental problems at Western Precinct, we suggest a number of groundwater management measures in the report to reduce infiltration and so keep the water table as low as possible.

Sydney Water and Integral Energy have indicated that they are able to service the Western Precinct with extensions to their existing networks. In brief water would be from existing reservoir at Cranebrook immediately adjacent the site. Sewer would be transferred to existing St Marys Sewage Treatment Plant via pumping stations, rising mains and carriers. Electricity would be from existing zone substation at Cranebrook enabling establishment of a temporary zone substation on the site with ultimately a permanent zone substation on the site.

The Western Precinct lies to the west of South Creek and the site is not at risk of flooding from South Creek in the 1 in 100 year ARI event or the Probable Maximum Flood (PMF).

These measures proposed would achieve SREP30 and EPS requirements and objectives the details are further described in the report.

1. Introduction

1.1 Background

The St Marys Development site was endorsed by the NSW Government for inclusion on the Urban Development Program (UDP) in 1993. The site is owned by St Marys Land Limited and is being jointly developed by ComLand Limited and Lend Lease Development Pty Limited through their joint venture company, Maryland Development Company.

The site is located approximately 45km west of the Sydney CBD, 5km north-east of the Penrith City Centre and 12km west of the Blacktown City Centre. The main western railway line is located approximately 2.5km south of the site. The Great Western Highway is located another 1 km south and the M4 Motorway a further 1.5km south.

The site has an area of 1,545 ha and stretches roughly 7km from west to east and 2km from north to south. It is bounded by Forrester Road and Palmyra Avenue in the east, The Northern Road in the west, Ninth Avenue and Palmyra Avenue in the north and the Dunheved Industrial Area, Dunheved Golf Clun and the suburbs of Cambridge Gardens, Werrington Gardens and Werrington County in the south.

The overall site, which has been rezoned for a variety of uses, comprises 6 development “Precincts”, namely the Western Precinct, Central Precinct, North Dunheved Precinct, South Dunheved Precinct, Ropes Creek Precinct and Eastern Precinct. The boundaries of the precincts within the St Marys site are shown in **Figure 1-1**.

Because the St Marys site straddles the boundary between two local government areas (i.e. Blacktown and Penrith), the State Government decided that a Regional Environmental Plan should be prepared to guide and control future development of the land.

Technical investigations into the environmental values and development capability of the land were commenced in 1994, and State Regional Environmental Plan 30 (SREP30) was subsequently gazetted in January 2001.

SREP 30 is the main statutory planning framework document for the St Marys site. It contains planning principles, objectives and provisions to control development. The overarching aim of SREP 30 is to provide a framework for the sustainable development and management of the St Marys site. The original precinct and zone boundaries of SREP30 were altered by the gazettal of Amendment No 1 in April 2006.

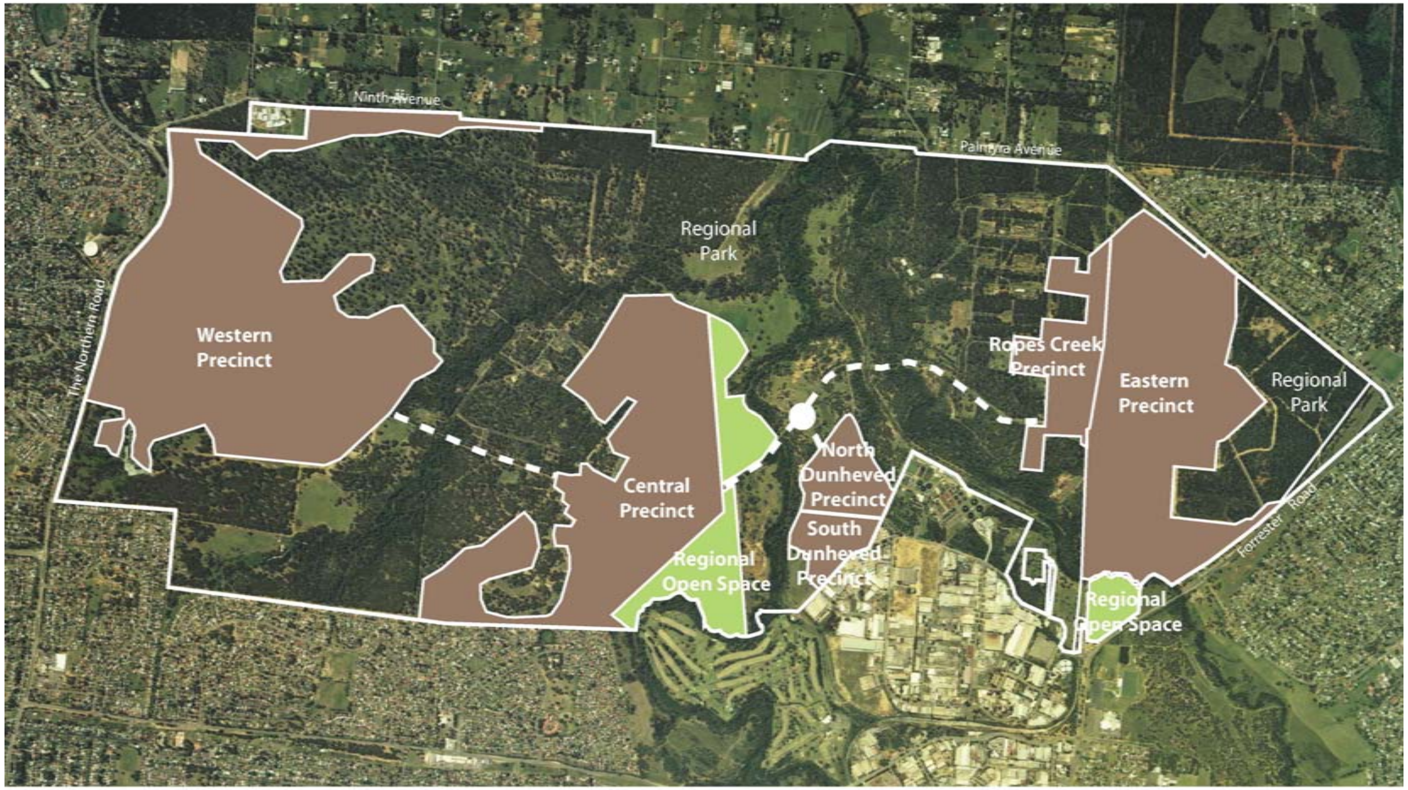
SREP30 is accompanied by the St Marys Employment Planning Strategy (EPS) which identifies the aims for the future use and management of the site and sets out specific performance objectives and strategies to address key planning issues, including: conservation, cultural heritage, water and soils, transport, urban form, energy and waste, human services, employment, and remnant contamination risk.

The St Marys EPS identifies actions to be undertaken by local and State governments, as well as the obligations of developers. A Development Agreement was entered into in December 2002 between the joint venture developer and the NSW Government setting out the developer's and State Government's responsibilities in providing services and Infrastructure. A Development Agreement has also been entered into between Penrith City Council (PCC) and the joint venture developer for the Dunheved Precinct and PCC wide transport contributions and will be updated for other contributions required as a result of the development of the Central and Western Precincts.

SREP30 requires the development control strategies contained within the St Marys EPS to be taken into account in any development proposals for the St Marys site. It also requires that a Precinct Plan be adopted by Council prior to any development taking place. Planning for any Precinct is to address all of the relevant issues in SREP30 and the St Marys EPS, including preparation of management plans for a range of key issues.

On 29 September 2006 the Minister for Planning declared the Western Precinct to be a release area in accordance with the provisions of SREP30.

- **Figure 1-1 Precinct Boundaries**



1.2 Proposed Development

The Western Precinct is bounded by Ninth Avenue and rural residential development in Llandilo to the north, The Ninth Avenue and residential development in Cranebrook to the west, land zoned for Regional Park to the south and east. The Precinct has a total area of approximately 229 ha.

The land within the Precinct is currently zoned part Urban (201 ha) and part Employment (28 ha). Under a draft amendment to SREP30 currently being prepared, the Precinct is zoned entirely Urban, with the existing Employment zone relocated into a consolidated Employment zone in the Central Precinct. Land zoned Urban is intended to accommodate primarily residential uses, with limited non-residential uses such as local retail and commercial uses.

The proposed development of the Western Precinct, as shown in the Framework Plan at **Figure 1-2**, entails:

- A Village Centre zone, comprising a mix of retail, commercial, community, open space and residential uses, in the southern part of the precinct;
- Predominantly residential development in the remainder of the precinct;
- Areas of open space; and
- Construction of roads, including connections to The Northern Road and Ninth Avenue and east to the Central Precinct, and stormwater infrastructure.

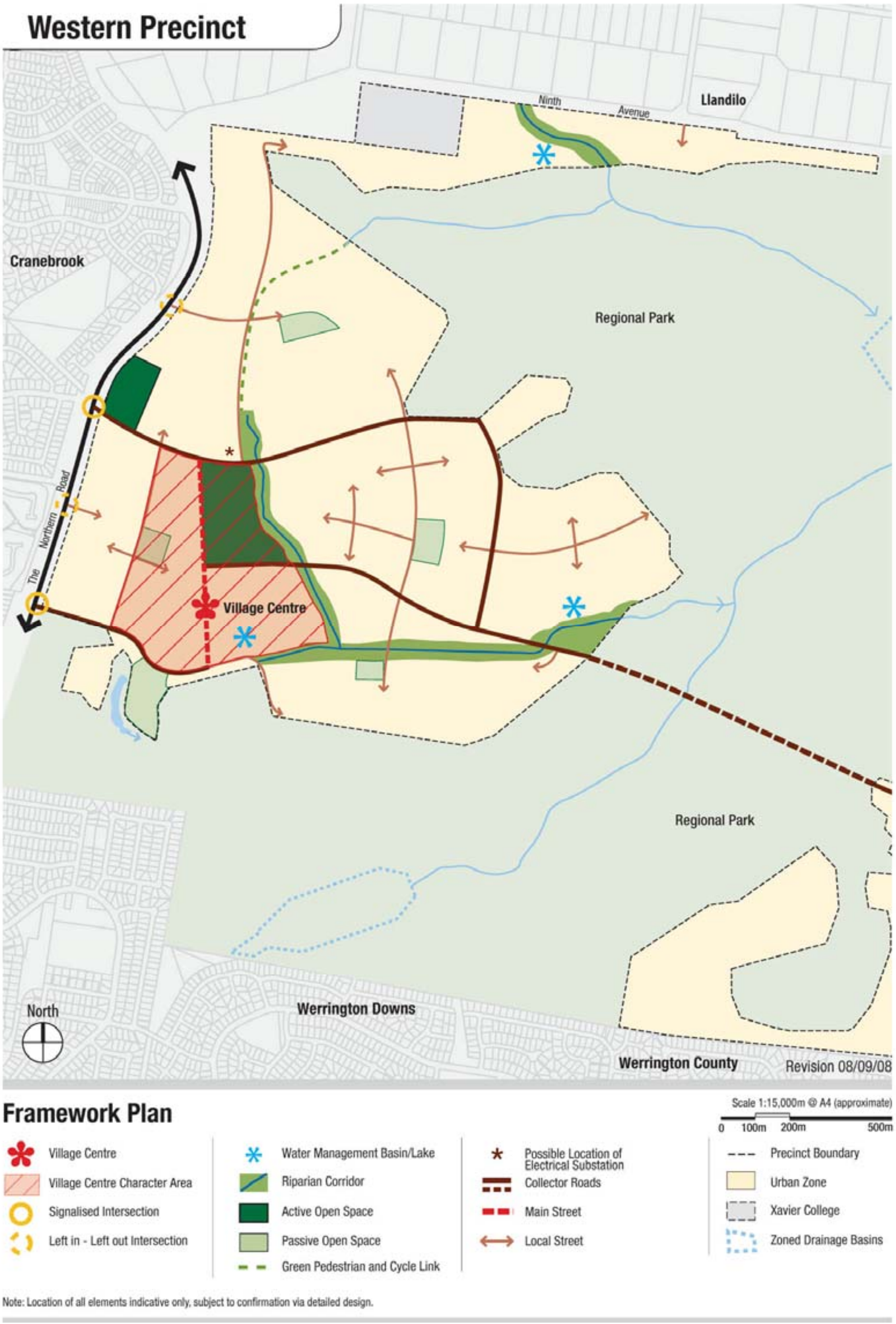
1.3 Purpose of this Report

This report has been prepared in accordance with the requirements of SREP30 and the EPS. It supports the draft Precinct Plan for Western Precinct and has been prepared to assist in determining the proposals for, and the planning principles, strategies and development controls that will guide the future development of all land within the Precinct in an integrated manner.

While the focus of the report is on the Western Precinct, the investigations carried out have taken into account the following:

- Relationship of the future development within the Precinct to the adjoining Regional Park; and,
- Future integration with the balance of the site and the existing surrounding neighbourhoods.

- **Figure 1-2 Framework Plan**



2. Existing Environment

2.1 Topography

The Western Precinct occupies approximately 229 hectares of the St Marys development site. The land surface is planar, rising generally north and westwards to the site boundary. Elevations vary from 40mAHD to 60mAHD within the Precinct area. The southern and northern catchments of the Precinct drain eastwards to a tributary of South Creek.

2.2 Soils

Based on the Penrith 1:100,000 soil landscapes map (Bannerman and Hazelton, 1990) the two soil units within the site area include the Luddenham (lu) and South Creek (sc) soil landscapes (SLs). The first is predominant within the southern and western third portion of the site, while the South Creek SL covers the remainder. A more detailed description is provided in section 5 of this report.

2.3 Groundwater & Salinity

Two groundwater-bearing systems are present within the St Marys site. These are referred here as the shallow and deep aquifers, but regolith (soil) and fractured shale bedrock aquifers would be more accurate titles. Neither would normally be regarded as true aquifers because of their low permeability, limited storage capacity, inhomogeneity and indefinite boundaries. A more detailed description is provided in section 5 of this report.

2.4 Hydrology Runoff Quantity

There are two drainage lines in which runoff leaves the Western Precinct. The majority of the Precinct drains in a south east direction towards an unnamed tributary of South Creek, while the northern strip of the Precinct (adjacent to the site boundary) drains east to join the unnamed tributary further downstream. The unnamed tributary flows in a north east direction to join South Creek, approximately 500m upstream of the northern site boundary.

A RAFTS model was set up to predict existing peak flows from the site for a range of storm events. Details and results of the RAFTS model are included in **Appendix A**. Runoff quantities were determined at key locations points where runoff leaves the Western Precinct.

2.5 Hydrology Runoff Quality

The Western Precinct has been previously cleared and is currently fenced off to keep macro fauna (kangaroos and emus) within the site. The assessment of any potential impact on stormwater quality as a result of the proposed development needs to review existing water quality conditions and predict developed conditions (with water quality controls). In order to estimate the existing runoff pollutant loads and determine the effectiveness of the proposed stormwater treatment train, a water quality model was set up to estimate pollutant loads for existing and proposed (with controls) conditions. Details and results of the MUSIC water quality model are given in **Appendix B.**

2.6 Flooding

The Western Precinct lies to the west of South Creek and the site is not at risk of flooding from South Creek in the 1 in 100 year ARI event. The Probable Maximum Flood (PMF), the regional flooding in the Hawkesbury-Nepean River system does not impact on the Western Precinct which is demonstrated on the SREP30 Structure Plan.

2.7 Services

The existing infrastructure in and around the Western Precinct has been identified. The trunk components such as water reservoirs, sewage treatment plants and zone substations exist in close proximity to site. Other services such as communications and gas also exist in the area.

3. Performance Objectives

The performance objectives for water, soils and infrastructure components are detailed in the SREP30 and the EPS. The objectives are summarised in this section along with an overview of the proposed management strategies are outlined in **Table 3-1**. Sections of the report are referenced to identify where more information can be found.

- **Table 3-1 Performance Objectives**

SREP 30 Clause Number / EPS Clause No	**Requirement**	**Where Addressed**
Content of draft precinct plans		
10.2.e	A draft precinct plan is to include proposals for, and information about, the following, for the land to which it applies: drainage systems and flooding issues, including an assessment of the risk of flooding and damage likely to result	N/A
10.2.n	A draft precinct plan is to include proposals for, and information about, the following, for the land to which it applies: any other major infrastructure, such as above or below ground trunk electrical systems, trunk sewerage or water supply lines	Services Infrastructure
Conservation		
24.4 / 4.3.4	Infrastructure is to be designed and located to minimise potential adverse impacts on the conservation values of land.	Services Infrastructure
EPS 4.4.11	Litter and pollution control measures designed to limit the entry of waste material into the creeks will be regularly maintained and monitored.	Catchment Management Strategy

SREP 30 Clause Number / EPS Clause No	**Requirement**	**Where Addressed**
Watercycle		
28.1 / 6.3.1	During and following construction, impacts upon water quality are to be minimised, through the utilisation of effective erosion and sediment control measures in accordance with industry standards.	Catchment Management Strategy
28.2 / 6.3.2	The use of the land to which this plan applies is to incorporate stormwater management measures that ensure there is no net adverse impact upon the water quality (nutrients & suspended solids) in South Creek and Hawkesbury-Nepean catchments.	Catchment Management Strategy
28.3 / 6.3.3	Water usage on and the importation of potable water onto the land to which this plan applies are to be minimised.	Catchment Management Strategy
28.4 /6.3.4	Development is to be designed and carried out so as to ensure that there is no significant increase in the water table level and that adverse salinity impacts will not result.	Soils, Groundwater & Salinity
28.5 / 6.3.5	There is to be only minimal impact upon flood levels upstream or downstream of the land to which this plan applies as a consequence of its development.	N/A
28.6 / 6.3.6	Drainage lines are to be constructed and vegetated so that they approximate as natural a state as possible. Where it is necessary to modify existing drainage lines to accommodate increased stormwater runoff from urban areas, this should be done in a manner which maximises the conservation of indigenous flora in and around the drainage lines.	Catchment Management Strategy
28.7 / 6.3.7	Development is to be carried out in a manner that minimises flood risk to both people and property.	N/A
28.8 / 6.3.8	Changes in local flow regimes due to development are to be minimised for rainfall events up to the 50 percent AEP rainfall event.	Catchment Management Strategy
28.9 / 6.3.9	Gross pollutants are to be collected at, or as close as possible to, their source or at all stormwater outlets, or at both of those places, so that there is no increase in sediment/litter entering creeks as a result of development.	Catchment Management Strategy

SREP 30 Clause Number / EPS Clause No	**Requirement**	**Where Addressed**
Soils		
29 / 6.3.10	The development is to have regard to soil constraints to ensure that the risk of adverse environmental and economic impacts is minimised.	Soils, Groundwater & Salinity
Land below the PMF level		
49.5	Road systems on land which would be affected by the PMF are to be designed to facilitate safe evacuation during flood events.	N/A
Services		
60	Development must not be carried out on any land to which this plan applies until arrangements have been made for the supply of water, sewerage drainage and underground power that are satisfactory to the consent authority.	Services Infrastructure
EPS - Water & Soils		
6.4.3	There will be no formed trunk drainage channels on land zoned for the regional park.	Catchment Management Strategy
6.4.4	Water and drainage infrastructure through the regional park will be confined to existing established easements agreed with the National Parks Wildlife Service prior to transfer of the land with the exception of those drainage basins identified in the structure plan.	Catchment Management Strategy
6.4.5	A series of combined wetland/detention basins and wetlands will be provided on the site generally in locations outlined in the structure plan. The total wetland area on the site will be between 2% and 4.8% of the development catchment area.	Catchment Management Strategy
6.4.6	Additional investigations will be undertaken at the precinct plan stage to identify the exact boundaries and development capacity of the identified soil types.	Soils, Groundwater & Salinity
6.4.7	A precinct plan will include sufficient information on infrastructure design and management measures to demonstrate that water usage will be managed within the constraints of the Sydney Water Corporation service criteria and obligations.	Catchment Management Strategy

SREP 30 Clause Number / EPS Clause No	Requirement	Where Addressed
EPS - Water & Soils		
6.4.8	A watercycle management strategy will be prepared for each release area and submitted with each precinct plan. The strategy will identify the detailed actions, measure and design principles that will be implemented to meet the performance objectives relating to watercycle management. The strategy will: a. include infrastructure design and management measures which will minimise potable water usage on the site; details will include: - incorporating best practice measure for the reuse of stormwater for irrigating open space areas - reducing demand on potable water - minimising adverse impacts on local groundwater regimes b. incorporate measure in the infrastructure design, which ensure that changes in local flow regimes which result from the proposed development are minimised c. identify arrangements for the ongoing maintenance and monitoring of the watercycle management system d. ensure constructed trunk drainage channels are designed to convey the 100 year average recurrence interval (ARI) e. identify the relationship between staging of development within the precinct and the timing of provision of stormwater management measures.	Catchment Management Strategy
EPS - Water & Soils		
6.4.9	An electromagnetic induction (EM) survey of the site will be undertaken and submitted with the first precinct plan. The survey of all land will identify areas of high recharge as well as zones of concentration of salts in discharge areas.	Soils, Groundwater & Salinity

SREP 30 Clause Number / EPS Clause No	**Requirement**	**Where Addressed**
EPS - Water & Soils		
6.4.10	A groundwater management strategy will be prepared for each release area having regard to the findings of the EM survey, and be submitted with each precinct plan. The strategy will deal with: ▪ planning infrastructure such as subdivision layout and the location of dwellings, roads, wetlands and stormwater detention basins ▪ the cumulative impacts of development ▪ measures to be incorporated into the development to ensure the appropriate management of groundwater resources, such as: a) adopting small garden/lawn areas to reduce irrigation requirements b) planting low water requirements plants c) using mulching cover – this shall not occur in drainage lines d) including low flow watering facilities to avoid over watering by residents e) introducing and implementing a tree planting program (especially in high recharge areas); plant species should be native, deep-rooted, large growing species, which will assist in retention of the groundwater at existing levels f) retaining existing native tree cover wherever possible g) not permitting drainage basins, infiltration pits or tanks to disperse surface water h) promoting the use of drought resistant grasses within the development area.	Soils, Groundwater & Salinity
6.4.11	A flood evacuation plan must be prepared for each precinct and will be consistent with the regional flood evacuation plan prepared by the State Emergency Service. The plan will be submitted with the draft precinct plan. The plan will: a) demonstrate that continuously graded evacuation routes above the PMF for South Creek and the Hawkesbury-Nepean River are provided b) provide for progressive evacuations of developed areas within the site c) identify temporary evacuation centres on high ground.	N/A

SREP 30 Clause Number / EPS Clause No	Requirement	Where Addressed
EPS - Water & Soils		
6.4.12	The information available on flooding and evacuation will be consistent with the education program in place for all lands similarly affected in the local government area.	N/A
6.4.13	Precinct plans will incorporate the following trunk drainage system requirements: a) stormwater control facilities will be implemented on the site designed to prevent adverse impact on water quality as a result of development b) the stormwater management system for the site will be designed in accordance with the following requirements, unless alternative designs or specifications can meet the performance objectives outlined in section 6.3 above: i) wetlands and detention basins will be designed to prevent thermal stratification; applicants will consider this objective in statements of environmental effects which accompany applications for such facilities j) wetlands will be lined with an appropriate material to guard against water infiltration to the groundwater system k) wetlands will be regularly cleared of noxious weeds l) detention basins/wetlands will include native macrophytes and wetland species which will assist in erosion and sediment control and promote biodiversity m) basins will meet the relevant Dam Safety Committee requirements n) all basins and surrounding landscapes will be designed to allow machinery to undertake scheduled maintenance work every 1.5 years or less; the design of basins and surrounding landscapes will facilitate access for machinery to undertake less frequent maintenance.	Catchment Management Strategy
6.4.14	On land subject to the PMF, precinct plans will ensure that services such as power, potable water, sewerage and drainage are located to minimise disruption during floods and will consider the need for flood proofing (consistent with the *NSW Floodplain Development Manual* or its successor) to guarantee supply.	Services Infrastructure

SREP 30 Clause Number / EPS Clause No	**Requirement**	**Where Addressed**
EPS - Water & Soils		
6.4.15	The sewer system infrastructure for the site will: a) be designed to utilise best practice connections and construction techniques to result in a better 'sealed' or low infiltration system b) ensure pressure tests are carried out to ensure systems integrity c) ensure house connections are to be cut and welded as the system is built d) implement other best practice measures as appropriate at the time of development e) ensure that pumping station designs eliminate dry weather overflows and mitigate odour generation.	Services Infrastructure
6.4.17	All trunk drainage infrastructure will provide appropriate safety measures to the consent authority's satisfaction.	Catchment Management Strategy
6.4.18	All trunk drainage infrastructures will be designed to reduce constraints on the flow of floodwaters, especially in relation to events above 1 percent AEP.	Catchment Management Strategy
6.4.19	Measures will be incorporated into infrastructure design to minimise demand for potable water. These will include: 1) specifying low water demand fixtures in all dwellings and other buildings where appropriate 2) limiting maximum pressure by managing system zonings (pressure zoning) having regard to critical water supply needs such as pressure for fire fighting 3) including above ground rainwater tanks for dwellings on lots greater than 400m^2 4) using stormwater for irrigating open space areas 5) incorporating other best practice measures at the time of development.	Catchment Management Strategy

4. Catchment Management Strategy

The objectives of the total catchment management strategy are to:

- Ensure peak flow rates do not increase for all storms up to the 100 year ARI event;
- Maximise source controls for runoff quantity and quality;
- Achieve a no net increase in the annual pollutant load exported from the site;
- To achieve efficient use of water and minimise demand for potable water;

The relevant measures listed below could be adopted for the Western Precinct. The performance of the proposed water quantity and quality controls was assessed and the results demonstrate that the proposed total catchment management plan meets the required objectives.

The objectives would be achieved by employing current water management practice which could incorporate the following water quality and quantity controls in the development:

- Rainwater tanks on residential lots for private irrigation reuse;
- Recycled water (treated effluent) for toilet flushing, irrigation in public and private spaces use and other suitable activities such as washing cars;
- Water saving fixtures within the buildings;
- Bioretention vegetated areas in open space areas;
- Gross pollutant traps;
- Constructed stormwater wetlands or dry infiltration bioretention basins; and
- Detention storage intergrated into the wetlands or dry infiltration basin areas.

4.1 Background to Watercycle Management for the Project

In 1998, a Watercycle Management Report was prepared by SKM, "*ADI St Marys Watercycle and Soil Management Study, Final Study Report*, August 1998". The 1998 Study informed SREP30 and was published prior to the Federal Government (Australian Heritage Commission) announcement of lands at St Marys being listed on the Register of the National Estate (RNE). This resulted in a reduction of around 33% of the developable area within Precincts zoned under the original gazettal of SREP30. The SREP30 required amendment to reflect the RNE listing and the subsequent State Deed.

In 2005, SKM reviewed the previous assessment to identify the required number, size and location of stormwater management ponds within the Regional Park in accordance with the revised proposed SREP30 Land Use Plan to meet the water objectives. A history of pond sizes and what is currently proposed is shown in **Table 4-1**.

- **Table 4-1 Stormwater Management Pond History and Proposed for the Western and Central Precincts**

Stormwater Management Pond ID	1998 Study (Basis of SREP 30) Wetlands Land Take (ha) [1]	SREP 30 Amendment (2005) Drainage Zones within Regional Park Land Take (ha)	Current Precinct Plan [2] Minimum Land Take (ha)
A1	2.2		2.5
A2	3.7		2.8
B	6	8	8
C1	3.4		2
C2	2.8	4.5	4.5
C3	1.4		0
D	0.6		2
E	1.4		1
F	0.6		0
G	0.7		0
H	1.6		0
I	4	7.4	7.4
EX1	2.6		0
Total	**31**	**19.9**	**30.2**

1- These 1998 Study landtake estimates are for water quality and detention requirements. These areas do not include benching or pathway areas.

2- For this Precinct Plan assessment, it has been assumed that the actual stormwater management wetland surface area is approximately 75% of the land take.

Many similarities can be drawn between the previous (1998) work and the assessment detailed in this Precinct Plan. The primary function of the wetland/detention basins remains as peak flow mitigation and water quality control. The basins within the Regional Park may need to be online basins as they are fixed zoned areas. The approximate locations of the proposed basins are shown in **Figure 4-1.**

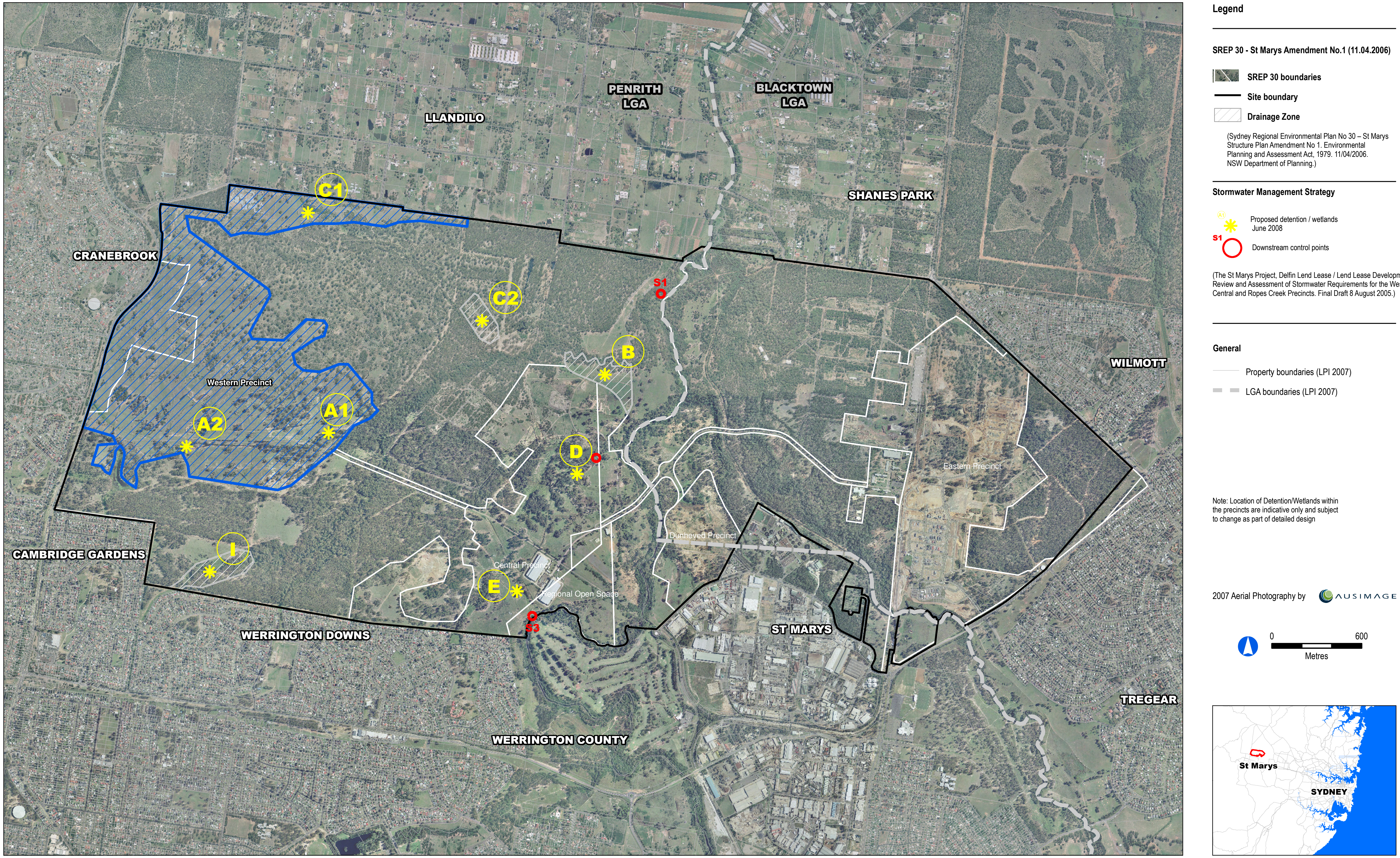
Following recent consultation with Penrith City Council it was agreed that a similar approach to the this watercycle management would be taken whereby;

- Water quality is assessed for Central and Western Precincts together at a discharge point situated at South Creek;
- Water quantity is assessed for the Western and Central Precincts separately.

Volumes and areas required for detention and water quality purposes are based upon currently available information for input to the respective models. The basin volumes will be refined during detailed design as models are further developed to include the internal piping system, more sub catchment areas and parameters and maybe reduce as a result. During the detailed design stage, the use of onsite detention (OSD) and open space areas for detention may also be explored. Open space areas (for example grassed recreational areas) located in close proximity to creek lines can be utilised to detain floodwater temporarily, thus further reducing the detention volumes required to meet the objectives.

The assessment assumes no detention is currently provided by Basin “I”. The available footprint for Basin “I” has been predetermined and constraints exist with regards to inlet, outlet and potential storage available at this location. During the detailed design stage the detention volume available at Basin “I” will be determined. The inclusion of a detention volume at Basin “I” would further reduce the required detention volumes at the other basin locations within the Western Precinct.

The location of the proposed basins is provided in **Figure 4-1**. The locations of the basins within the Precinct are indicative only thus allowing basin distribution and arrangements to remain flexible at this stage and more or less basins maybe required which would be determined at the detailed design stage.



Legend

SREP 30 - St Marys Amendment No.1 (11.04.2006)

▨ SREP 30 boundaries

— Site boundary

▨ Drainage Zone

(Sydney Regional Environmental Plan No 30 – St Marys Structure Plan Amendment No 1. Environmental Planning and Assessment Act, 1979. 11/04/2006. NSW Department of Planning.)

Stormwater Management Strategy

✳ Proposed detention / wetlands June 2008

S1 ○ Downstream control points

(The St Marys Project, Delfin Lend Lease / Lend Lease Developments. Review and Assessment of Stormwater Requirements for the Western, Central and Ropes Creek Precincts. Final Draft 8 August 2005.)

General

— Property boundaries (LPI 2007)

- - LGA boundaries (LPI 2007)

Note: Location of Detention/Wetlands within the precincts are indicative only and subject to change as part of detailed design

2007 Aerial Photography by AUSIMAGE

0 600 Metres

SKM SINCLAIR KNIGHT MERZ

Figure 4.1 Proposed Basin Locations Western & Central Precincts

St Marys Development Project - Western Precinct

GDA 94 MGA Zone 56

June 18, 2008
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4.2 Stormwater Quantity Management

To achieve the management objectives specified by SREP30 and EPS, detention basins have been proposed for the St Marys site to convey stormwater runoff from the proposed development to downstream discharge points on South Creek. Detention basins within the Precinct will be constructed off line with a low flow bypass to ensure that the peak flow following development does not exceed the peak flow under existing conditions.

A hydrological model (XP-RAFTS) was set up to assess the required detention volume of each basin for 2 yr to 100 year ARI events with details provided in **Appendix A**. The required volume of detention for each basin is shown in **Table 4-2**.

Overview

The objectives of the stormwater trunk drainage system are to:

Safely convey runoff through the proposed development;

Integrate with the road and lot layout; and

Integrate with the water cycle management system such that runoff quality and quantity are controlled efficiently.

Water Quantity Management Objectives

Watercycle management objectives are outlined in two documents SREP30 and EPS, both prepared by the then Department of Urban Affairs and Planning. The following objectives refer to the management of stormwater quantity.

Changes in local flow regimes due to the development are to be minimised for rainfall events up to the 50% AEP rainfall event; i.e. from 2 yr to 100yr Average Recurrence Interval (ARI events).

Proposed Drainage System

The following components would make up the drainage system:

- Pit and pipe system able to carry flows up to the 10 year ARI storm;
- Overland flow paths able to carry flows up to the 100 year ARI storm;
- Open channels able to carry flows up to the 100 year ARI storm; and
- Combined detention/wetland basins able to provide the necessary quality and quantity controls, while also coping safely with the 100 year ARI flow.

Proposed Detention

Four detention basins are proposed for the Western Precinct for peak flow mitigation for 2 year to 100 year ARI storm events. Three basins (A1, A2 and C1) are located within the Western Precinct, whilst the remaining basin (C2) is situated outside the Precinct boundary in the Regional Park as shown on **Figure 4-1**. Required detention volumes to mitigate peak flows have been derived using a hydrology model and are reported in **Table 4-2.**

- **Table 4-2 Proposed Water Quality Detention Basin Volumes Western Precinct**

Detention Basin	Detention Depth (m)	*Water Surface Area (ha)	Detention Volume Required (ML)
A1	2.4	2.5	54
A2	2.5	2.8	65
C1	1.4	2	26
C2	1.3	4.5	45

*Surface area of water in detention basin at maximum detention depth

The volumes for the Western Precinct would be refined at the design stage by further modelling and detailing of the outlet controls for the basins.

Hydraulics

Channel top widths will be defined for the trunk drainage system during further consultation with the Department of Water and Energy (DWE) regarding their requirements of channel makeup and riparian offsets under the Water Management Act, 2000. It is anticipated that the top widths will vary from 10m in the upstream catchments to 30m further downstream towards South Creek.

Classification of Watercourses

The Water Management Act, 2000 states a requirement to identify “rivers” within the development site. Following a site inspection undertaken with the Department of Water and Energy (DWE), the “rivers” for the Western Precinct as shown on **Figure 4.2** were identified. It was agreed with DWE that the “rivers” will be refined during further consultation with DWE.

Maintenance of Water Quantity Controls

Proposed detention basins/wetlands will be maintained by MDC for an initial three year period following construction. After this time, Penrith City Council will be responsible for the ongoing maintenance of the basins.

Figure 4.2 Identified "Rivers" within the Western Precinct

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4.3 Stormwater Quality Management

Overview

The water cycle management strategy for the Central Precinct development will be based on design principle to meet the stormwater management objectives described in the following documents:

- *SREP No 30, 2001; and*
- *St Marys Environmental Planning Strategy, 2000.*

The adopted strategy will also consider additional state and local government documents listed below:

- *Penrith City Council ,Water Conservation and Water Action Plan – Water Way -— Sustainable Penrith series*
- *Penrith City Council, Sustainability Blue Print for Urban Release Areas, June 2005 – Sustainable Penrith series.*
- *Penrith City Council, Erosion and Sediment Control DCP, December 2006- section 2.4*
- *South Creek Stormwater Management Plan, 1999-2000, Stormwater Trust*
- *Department of Environment & Climate Change (DECC), Managing Urban Stormwater, Environmental Targets, Draft October 2007.*
- *Penrith City Council, Stormwater Quality Control Draft Policy*
- *Landcom, Soils and Construction, 2004*
- ANZECC Guidelines for Fresh and Marine Water Quality, 2000

Water Quality Management Objectives

The water quality objective for the St Marys Project is to ensure that there is no net adverse impact upon the water quality in South Creek, as stated in the SREP30. There will be no increase in the annual pollutant loads in the developed case compared to the existing case. This objective will be applied to all runoff into South Creek entering the creek along the St Marys site from the west. This includes runoff from the Western Precinct, the Central Precinct and any existing urbanised areas located further upstream of this catchment.

To meet this objective, a water quality assessment has been undertaken for the Western and Central Precincts. These models were combined into one assessment to represent runoff from all catchments entering South Creek from the west. A series of stormwater management wetlands have been identified across the Western Precinct, Central Precinct and areas in the Regional Park.

The MUSIC water quality model (eWater CRC, Version 3.01) has been used in the water quality assessment. The water quality modelling details are given in **Appendix B**.

The proposed water quality measures on site are not limited to wetlands. The additional controls are described in the following section. For water quality modelling purpose, only wetlands were included in the assessment. This would result in relatively conservative sizing for the proposed wetlands.

Proposed Water Management System

A number of stormwater management controls would be integrated into the overall drainage concept to manage stormwater quality and quantity where appropriate and to achieve the required objectives. The elements of the water management strategy are based on a hierarchy of stormwater management controls and create a stormwater treatment train. These controls could include:

Source controls

- At the residential lots, rainwater tanks maybe used to capture roofwater for reuse. If recycled water is available, then rainwater tanks may be used depending on the demands on the lot.
- Bioretention systems will be provided where possible depending on the topography and gradients on site. These will be local neighbourhood type small open space areas that will act as large dry infiltration basin and will provide the start of treatment of stormwater runoff higher up in the sub-catchments. The treated runoff will be captured and conveyed in the drainage piping system and will not infiltrate into the natural soils.

Conveyance controls

- Stormwater that enters the piping system, would then pass through a gross pollutant trap (GPT) located immediately upstream of a larger dry infiltration basin or a wetland. The GPTs would remove coarse sediment, litter and debris that are generated on the roads.
- Dry infiltration basins or wetlands will be provided to supplement the treatment of stormwater provided by the source controls and GPTs. Runoff from a dry infiltration basin would be collected by perforated pipes located in the base of the infiltration system and discharged as polished stormwater into the downstream waterways, or if a wetland is proposed instead of a dry infiltration basin, then it would offer a similar treatment of polishing the runoff.

Natural Systems Controls

In addition to the above water quality controls, natural system controls will also be adopted where possible. Natural system controls involve the management of areas within the catchment and creek systems that will remain unchanged. The use of natural system controls does not necessarily involve specific structural control measures, but rather a general planning approach. Natural systems controls recognises that natural waterways, floodplains and native vegetation perform essential hydrological and ecological functions that cannot easily be replicated by constructed stormwater control measures.

Therefore essential elements of the natural system will be retained in the development, and where degraded they will be rehabilitated and may include:

- Open space areas located near natural drainage lines;
- Existing native vegetation maintained where possible; and
- Revegetation with native species to batters and open space areas will assist in reducing stormwater pollutant loads, and therefore assist in improving the long term water quality.

Size of Proposed Water Quality Controls

The land take requirements of the proposed stormwater wetlands in the Western and Central Precincts (Western Precinct basins are highlighted in bold) that would meet the water quality objectives for South Creek are shown in **Table 4-3.**

- **Table 4-3 Proposed Water Quality Stormwater Management Wetland Sizes for the Western and Central Precincts**

Stormwater management wetland ID	Minimum* land take (ha) for water quality purposes only
A1	**1**
A2	**1.8**
B	8
C1	**1**
C2	4.5
D	2
I	7.4

***** Refer to Table 4.1 for the landtake requirements that include the additional areas required for detention purposes

Wetlands “I” and “B” are required to meet to achieve the project water quality objectives and would be progressively constructed during the development. Wetlands have been proposed in this Precinct Plan but it should be noted that other WSUD water control measures such as biofiltration basins may also be considered as an alternative during the detailed design stage.

Maintenance of Water Quality Controls

The pollutant retention capability of any control device is subject to it being maintained appropriately. The efficiency of a control reduces as the device fills with pollutants and maintenance must occur before the performance of the device falls below expected levels. Thus, a maintenance schedule must be prepared for each control. There will be regular maintenance and monitoring of all pollution control mechanisms. These tasks will be undertaken by the developer for a period of three years and then taken over by Council. The initial operation and maintenance regime of the water quality controls is summarised below in **Table 4-4** these would be refined at the detailed design stage.

- **Table 4-4 Operation and Maintenance of Water Quality Controls**

Item	Maintenance Requirements
Gross Pollutant Traps (GPTs)	GPTs upstream of the basins should be maintained every three months or after each storm event, as required.
Dry Infiltration Basins	The bioretention basins should be inspected annually for trapped sediments. Excessive sediment should be removed and disposed of properly to maintain the extended detention depth and volume of the biofiltration area. Excessive dead plant debris should be removed to reduce the organic material and nutrient loads in the biofiltration area.
Constructed Wetlands	The wetlands area should be inspected annually for trapped sediments. Excessive sediment should be removed and disposed of properly to maintain the design volume of the wetland. Excessive dead plant debris should be removed to reduce the organic material and nutrient loads in the wetland area.

Maintenance manuals will be prepared for the management of the various stormwater facilities as part of the development application. These manuals will identify the timing of and requirements for:

- maintenance of grass cover within formed channels to prevent erosion of channel bed and banks;
- control of weeds;
- removal of litter, debris and coarse sediments deposited during floods to formed channels as necessary; particularly from detention storages that are located above wetlands;
- the maintenance regime for heavy and light machinery for cleaning of sediments and organic material deposited within all parts of the wetland;
- litter and sediments trapped in gross pollutant traps;
- monitoring of vegetation type and growth;
- maintenance of conditions to ensure mosquito control; and
- appropriate safety measures.

4.4 Soil and Water Management Strategy

This section describes the Soil and Water Management Strategy (SWMS) for the construction phase of the project and with respect to groundwater and salinity management measures should be read in conjunction with section 5.9 and Appendix C.

Overall Approach

A soil and water management plan would need to be prepared as part of the development application. Its purpose is to safeguard the environment during the construction stages of the development.

The objectives of the SWMS are to:

Provide an overall erosion and sediment control concept for the proposed development;

Control the erosion of soil from disturbed areas on the site;

Limit the area of disturbance that is necessary;

Protect downstream water quality; and

Prevent any sediment-laden water from entering South Creek.

In addition to the controls that have been identified in the SWMS, Erosion and Sediment Controls Plans (ESCP) for the site would need to be prepared at the development application stage in accordance with the requirements of : *Penrith City Council, Erosion and Sediment Control DCP, December 2006- section 2.4*, and the Landcom "*Soils and Construction* " *Manual, 2004*, known as the "Blue Book". The ESCP would describe the requirements for erosion and sediment controls, such as handling of excavation and filling, sediment fences, diversion drains, top soil stockpiles and reuse of soils, barrier fences, energy dissipaters, check dams, temporary culvert crossings and sedimentation basins.

Management Measures

The following soil and water management measures would be used during the construction phase of the development.

Land Disturbance Protection

Land disturbance during construction will be minimised to reduce the soil erosion hazard on site and may include the following;

- Clearly visible barrier fencing will be installed at the discretion of the site superintendent to minimise unnecessary site disturbance and to ensure construction traffic is controlled. Vehicular access to the site will be limited to only those essential for construction work and they will enter and exit the site only through the stabilised access points;

- Soil materials should be replaced in the same order that they are removed from the ground. It is particularly important that all subsoils are buried and topsoils are replaced on the surface at the completion of the works;
- The duration of all works, and thus the potential for soil erosion and pollution, should be minimised;
- Where practical, foot and vehicular traffic will be kept away from all recently stabilised areas; and
- Stockpiles should be seeded.

Erosion and Sediment Control Measures

The relevant measures listed below to address erosion and sedimentation should be used on site:

- Stabilised entry/exit point;
- Sediment filter fences;
- Weed-free straw bales;
- Barrier fences;
- Diversion drain banks/channels;
- Check dams;
- Temporary sedimentation basins; and
- Top soil stockpiles.

These control structures are described in the following sections.

Stabilised Entry/Exit Point

A stabilised entry/exit structure should be installed at the access point to the site to reduce the likelihood of vehicles tracking soil materials onto public roads. A shaker ramp (cattle grid) will also be used in addition to the stabilised gravel access.

Sediment Filter Fences

Sediment filter fences should be installed where needed to confine the coarser sediment fraction (including aggregated fines) as near to their source as possible.

Barrier Fences

Barrier mesh fences should be installed to define those areas on site that should not be entered to avoid unnecessary soil/land disturbance.

Diversion Drain Banks/Channels

Diversion banks intended to remain effective for more than 2 weeks will be rehabilitated when possible. Hessian cloth can be used if tacked with an anionic bitumen emulsion (0.5L/m^2). Foot and vehicular traffic will be kept away from these areas. Pipe culvert crossings that can withstand the maximum expected trucks loads will be installed where required. Concrete encasement for the pipe may be used if needed.

Check Dams

Check dams should be installed on diversion drains that are laid on longitudinal slopes greater than 2.5% to reduce runoff velocities. Check dams are to be located at intervals of approximately 100m.

Temporary Sedimentation Basins

Sediment basins will need to be constructed. These basins would be located at the furthest downstream point in their sub-catchment to maximise the capture and treatment of surface runoff during the construction phase. The sedimentation basins will need to be designed to suit type D (Dispersible) soils. Stored contents of the basins should be treated with gypsum or other approved flocculating agents where they contain more than 50mg/L of suspended solids. An energy dissipater rip rap may be installed at the weir outlet located at the downstream end of each sediment basin outlet to reduce runoff velocities where required.

Top Soil Stockpiles

Stockpiles will be constructed away from hazardous areas, particularly areas that are likely to have concentrated water flows. Stockpiles may be seeded.

Main Principles of Erosion and Sediment Control during Construction

The main principles for erosion and sediment control are summarised below:

- Stockpile and reuse all topsoil;
- Divert clean runoff water from the upstream drainage system around the disturbed open trench area;
- Restrict vehicular access to stabilised entry and exit points with controls to reduce soil export attached to excavators and truck tyres exiting the site;
- Restrict access to areas that do not require land disturbance;
- Provide adequately designed sediment fences, barrier fences, catch drains, check dams, sediment fences and other required structures;
- Ensure that the temporary top soil stockpiles are protected from erosion when works are unlikely to continue for long periods. Ensure that stockpiles are not placed in the flow path of upslope runoff;
- Make provisions for emergency quick clean-up and removal of any accidental spills of soil on to public property and provide tanker with pump to cope with accidental runoff;

- Provide wire mesh and gravel inlet filters at stormwater kerbs (if any) located downstream of the entrance to the site to trap any accidental spill of soil material;
- Monitor and maintain all sediment and erosion control measures;
- Minimise additional solid disturbance activities during wet weather;
- Undertake water quality monitoring at the outlet of the sediment basins to ensure compliance with the DECC (formerly EPA) guidelines;
- Stabilise rehabilitated surfaces as soon as possible; and
- Obtain additional information needed from the *"Soils and Construction", Landcom 2004* manual.

4.5 Flooding

The Western Precinct lies to the west of South Creek and the site is not at risk of flooding from South Creek in the 1 in 100 year ARI event.

4.6 Flood Evacuation Strategy

The Probable Maximum Flood (PMF), the regional flooding in the Hawkesbury-Nepean River system, does not impact on the Western Precinct which is demonstrated on the SREP30 Structure Plans.

4.7 Conclusion

The MUSIC model results, as provided indicate that the proposed stormwater management wetlands would meet the SREP30 water quality objectives of ensuring that there is no net increase in the annual pollutant load in the developed case compared to the existing case.

This assessment identifies fewer stormwater management ponds across the St Marys Project site compared with the 1998 Study. This result is an expected one, as the proposed area to be developed by MDC has been reduced since the 1998 SKM report was produced. In summary, the modelling results indicate that the proposed stormwater management wetlands would meet the water quality and quantity objectives.

4.8 References

1) ANZECC Guidelines for Fresh and Marine Water Quality, 2000.
2) Environmental Investigation Services, *Soil and Groundwater Investigation*, December 2006
3) eWater, *MUSIC User Guide*, Version 3.1
4) Healthy Rivers Commission of New South Wales, *Independent Inquiry into the Hawkesbury Nepean River System, Final Report*, August 1998.
5) Landcom, *Soils and Construction*, 2004

6) Penrith City Council, *Erosion and Sediment Control DCP, December 2006- section 2.4*

7) Penrith City Council, *Stormwater Quality Control Draft Policy*

8) Sinclair Knight Merz, *Flood Assessment in South Creek*

9) Stormwater Trust, *South Creek Stormwater Management Plan*, 1999-2000,

10) SREP No 30

11) *St Marys Environmental Planning Strategy*, 2000

5. Soils, Groundwater & Salinity Management Strategy

5.1 Background to Soils, Groundwater and Salinity

Potential Salinity Concerns

Urban development has been identified as having the potential to increase the salt load in western Sydney landscapes that may already exhibit significant salinity. Although salinity has been identified as being natural to the western Sydney environment and not a consequence of previous industrial land uses, it poses a concern to developers of new subdivisions in the western Sydney region.

The main factors which lead to salinity in western Sydney have been identified as:

- The low rainfall and high evaporation potential with a considerable range in wet and dry years;
- The input of salts from natural rainfall (cyclic salts);
- The extensive area of saline groundwater underlying much of the plain which is known to rise near to the surface at some geologic and topographic boundaries;
- The common presence of duplex soils (of the Luddenham and South Creek soil landscapes) which are prone to water logging on lower slopes; and,
- Subsoil layers in these soils which have a high susceptibility to sodicity and/or salinity.

Salinity can occur in one of the following ways:

- When brackish or saline groundwater rises near to the surface and where plant-evapo-transpiration or capillary rise encourages salts to concentrate over time.
- Where salts from the drainage water gradually accumulate at the top of impermeable clay subsoil. This can lead to surface salinity when a hydraulic link allows salts to rise through the profile. Alternatively the subsoil is exposed by excavation.
- Where cyclic salts in rainfall accumulate over time in areas with poor drainage and are concentrated by evaporation. This may occur when the sub-surface flow is blocked by building foundations.
- Where salt from deeply weathered soil landscapes is mobilised by perched water tables. These salts contain a high proportion of sulphates, which adds to the importance of this type of salinity because of the aggressive impact of sulphates on concrete and brickwork.

Development Requirements

The SREP30 and the EPS specify the following requirements with respect to groundwater and land salinity issues, which are applicable to the site:

- There should be no significant rise in the water table or in groundwater salinity as a result of this development;
- An electromagnetic induction (EMI) survey of the Precinct should be carried out; and,
- A Groundwater Management Strategy should be prepared for the site.

Objectives

The objectives of this investigation works were to:

- Satisfy the requirements of the SREP30 and the EPS with respect to groundwater and land salinity issues in the site;
- Assess the existing salinity conditions in soil and groundwater at the site;
- Predict the potential impact of urban development on the site's landscape, especially the potential to increase surface runoff salt load and rising water table which might bring saline groundwater to the surface; and,
- Provide mitigation and management measures to ameliorate potential salinity impacts in the proposed urban development.

Scope of Works

In order to achieve the objectives described above, the following scope works was undertaken:

- Review of previous investigations, published technical literature, aerial photographs, and existing regional, data relating to geology, soil landscape, hydrogeology, topography and geochemistry relevant to the site and salinity in particular;
- Evaluation of past and current soil and groundwater salinity data at the site to determine the potential source, transport, transformations and fate of geochemical species, including the potential for salt load increase due to rise in groundwater recharge;
- Evaluation of past and current groundwater data to infer groundwater contours and potential groundwater flow at the site, including the potential extent of interaction between groundwater and the surface water;
- Onsite walkover with cable locating contractor to confirm presence underground services prior to undertaking intrusive investigations works;
- Mapping subsurface conductivity across the site and, by extension, soil salt content, using electromagnetic induction (EMI) methods; and,

- Development of a conceptual hydrogeologic model and groundwater management strategy for the site, incorporating past and current regional, local, and site specific data on geology, topography, groundwater, and geochemistry.

The scope of works undertaken for the salinity assessment of the Central Precinct is described in detail in this report, which also aims to respond appropriately to the requirements specified in the SREP30 and the EPS. This report includes recommendations towards the mitigation and management of potential salinity issues in urban development.

5.2 Review of Previous Investigations

Groundwater and salinity investigations have been carried out on the St Marys site in several phases since 1991. The earliest work was undertaken by Mackie Martin and Associates (MMA), and was primarily concerned with potential soil and groundwater contamination resulting from the use of the St Marys site over the preceding fifty years as an explosives production facility. The results from this investigation phase are reported by Mackie Martin (1991) in two report volumes. More detailed investigations and remedial work were later carried out by ADI Ltd and are described in their validation reports (including ADI Ltd, 1996). In addition to the contamination results, these reports reveal much about the natural groundwater system and about the salt cycle in the area.

Later studies, from 1998, were largely directed towards geotechnical and water cycle investigations for those portions of the site proposed for residential development. These comprised:

- Water cycle investigation at ADI St Marys site by SKM (Sinclair Knight Merz, 1998);
- Soils, salinity and groundwater in the Western Precinct, investigated by SKM (Sinclair Knight Merz, 2001);
- The Eastern Precinct, investigated by Jeffery and Katauskas (J&K) for Patterson Britton (Jeffery and Katauskas, 2003); and
- Soils, salinity and groundwater investigation in the Dunheved Precinct (Sinclair Knight Merz, 2004).

Concerns had been expressed in 1998 by the then DLWC that urban development in the Western Precinct might cause the water table to rise, because of tree clearing during construction or as a result of subsequent garden watering and pipe leakage. It was known from earlier investigations that the water table is naturally present within a few metres of the surface in most places and that this groundwater is often saline. Surface salting or waterlogging of low-lying land might result from a rising water table. In addition, the salt load carried by South Creek and Ropes Creek, which cross the St Marys site though not the Western Precinct, could increase.

5.3 Precinct Description

Topography

The terrain at St Marys is typical of western Sydney's geology – Bringelly Shale bedrock, weathered to depths of several metres, overlain on valley floors by alluvial floodplain deposits along the tributaries of South Creek and Ropes Creek. The alluvial deposits are predominantly composed of clay, but include thin and discontinuous layers of gravel and sand, and are up to 12m deep (though 3-4m is more usual). The low level floodplain alluvium below about RL 20-25m AHD is of Quaternary age, but higher-level and much older terrace deposits of Tertiary age may occur at up to RL 35m in the Eastern Precinct. The Western Precinct differs from the overall St Marys geology in having a higher proportion of shale bedrock at the surface, and less alluvium.

The lower slopes of the hills are mantled by 1-4m of clay colluvium, which is being moved slowly downslope by soil creep and is merging with the floodplain alluvium that it closely resembles. Shale bedrock does not outcrop except in artificial excavations, although it is present at shallow depth on hill crests beneath 1m or less of residual clay soil. The Bringelly Shale formation includes thin sandstone beds as well as shale, mudstone and siltstone. These rocks are dark grey when fresh but weather brown.

Regional Geology

Based on the Penrith 1:100,000 geological map (Jones and Clark, 1991) shown in **Figure 5-1**, the site is underlain by Triassic Bringelly Shale (from the Wianamatta Group) and Pleistocene to Tertiary alluvial sediments.

The Bringelly Shale formation has a maximum thickness of about 300 m, although at the site this is expected to be about 90 m, when combined with the underlying Ashfield Shale. Both of these shales in turn overlie the Hawkesbury Sandstone. The Bringelly Shale is composed of shale, mudstone, claystone and some sandstone. The shale rocks are dark grey when fresh but weather brown. Fresh shale bedrock does not outcrop except in artificial excavations, although it is present at shallow depth on hill crests beneath 1 m or less of residual clay soil.

The Penrith geological map also shows a major geological structure, known as the Narellan Lineament, running in a north-south direction 500 m east of the site. This lineament could be a zone of either closely-spaced jointing or faulting, which defines the straight course of South Creek upstream from the St Marys area. Within the site area it may be responsible for the deep shale weathering noted in several subsurface investigations.

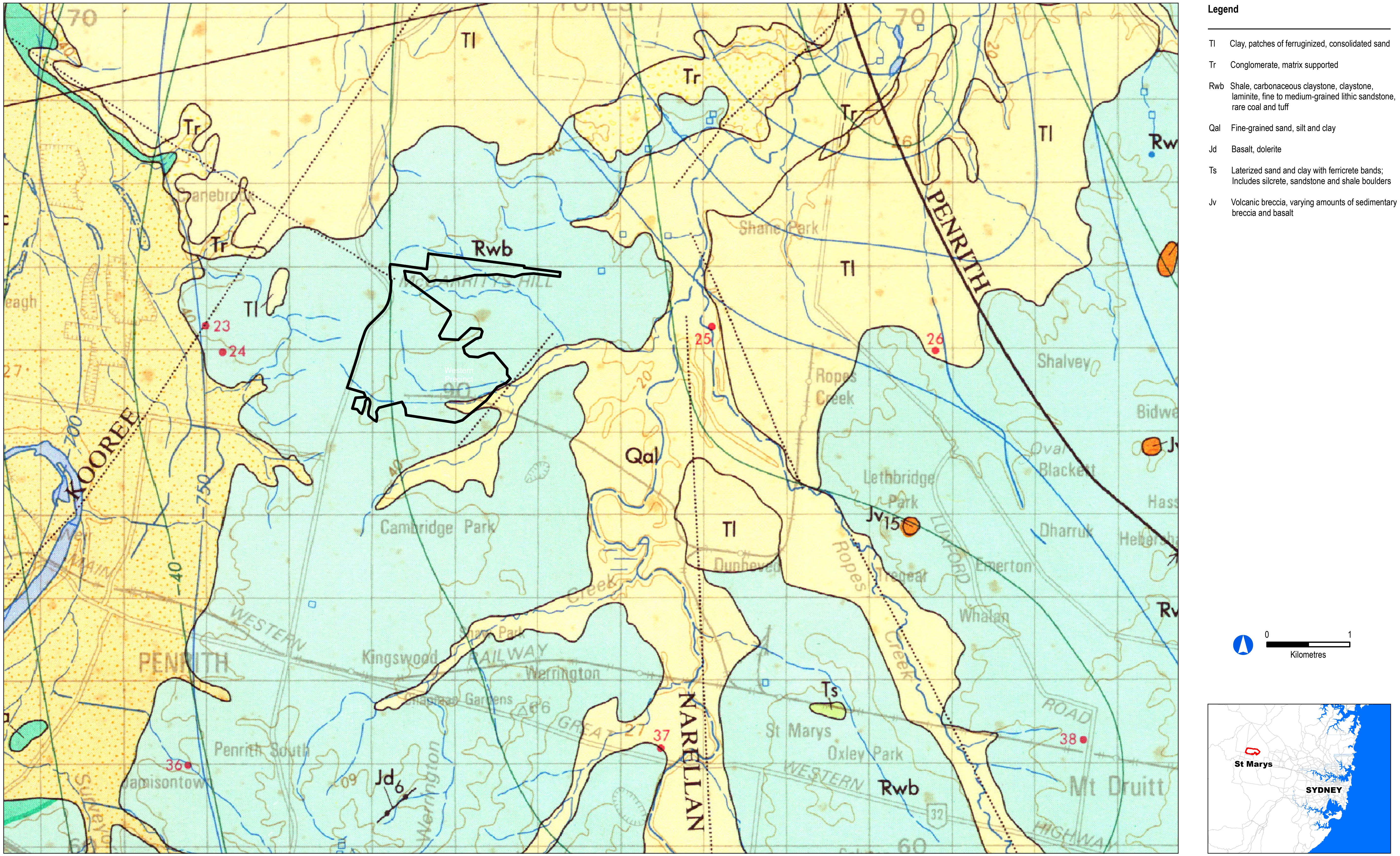

Figure 5.1 Regional Geology Map (Extract From Penrith 1:100,000)

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Site Geology

The low level floodplain alluvium (from RL 17 to 28 m AHD) is of Quaternary age and the higher level weathered shale bedrock (from RL 29 to 40 m AHD) is of much older Triassic age. No surface outcrops of the fresh shale bedrock were observed during current investigation works and the predominant rock type encountered in soil bores drilled was weathered shale. The depth of weathered shale and residual clay cover in soil bores was everywhere greater than 3 m.

The lower slopes of the hills are generally mantled by 1 to 4 m of clay colluvium, which is being moved slowly downslope by soil creep and is merging with the floodplain alluvium that it closely resembles.

Soils

Based on the Penrith 1:100,000 soil landscapes map (Bannerman and Hazelton, 1990) an extract from which is shown in **Figure 5-2** the two soil units within the site area include the Luddenham (lu) and South Creek (sc) soil landscapes (SLs). The first is predominant within the southern and western third portion of the site, while the South Creek SL covers the remainder. The Luddenham soil units are of residual origin, derived from weathered Bringelly Shale bedrock. The South Creek clay soil units of alluvial origin are derived from weathering, erosion and fluvial transport of the Bringelly Shale bedrock.

They differ in that the Luddenham SL is developed on older (Triassic age) higher level bedrock terrains, while the South Creek SL comprises those alluvial clay soils on the near-recent (Pleistocene) and present-day, active flood plain of watercourses such as South Creek.

Although these soils have many similarities, they differ in that the South Creek SL tends to have a shallower depth to the water table and hence to be more prone to waterlogging, more erodible and subject to more frequent flooding. The Luddenham SLs is typically found on gently undulating rises on Bringelly shales. The typical Luddenham soil is a brown hard-setting silty clay loam overlying strongly pedal mottled brown clay, with texture increasing with depth. In the highest part of the landscape the clay extends only about 1 m before fresh shale bedrock is encountered. However, the heavy clay can extend for several metres in the lower parts of the landscape. Particularly on lower slopes, this soil type has poor drainage characteristics and is prone to salinity and sodicity. Shallow saline water tables also commonly occur beneath this landscape.

Figure 5.2 Soil Landscape Map (Extract From Penrith 1:100,000)

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For much of the western Sydney region, the Luddenham soil landscape lies above the South Creek soil landscape. The soil limitations are summarised in **Table 5-1**.

- **Table 5-1 Summary of Soil Limitations**

Soil Landscape	Soil Unit	Soil Depth	Limitation
Luddenham (lu)	lu2	up to 40 cm	Very hard setting surface
			Low available water capacity
	lu3	>50 cm	Low wet strength
			Low permeability
			Low fertility
			High shrink-swell
			Low available water capacity
	lu4	<90 cm	Low wet strength
			Low permeability
			Low available water capacity
			High shrink-swell
South Creek (sc)	sc2	15 cm	High erodibility
			Hard setting surface
			Strongly Acid
			Low fertility
	sc3	60-85 cm	Shrink-swell potential
			Very high erodibility
			Low fertility

Salinity potential maps released by the then Department of Land and Water Conservation (DLWC 2002) show the Luddenham, soil landscape as having a moderate salinity potential and the South Creek soil landscape as having a high salinity potential. Identified areas of existing salinity are usually found on the South Creek soil landscape and the boundary between the South Creek and Luddenham soil landscape.

Regional Hydrogeology

Two groundwater-bearing systems are present within the St Marys site. These are referred here as the shallow and deep aquifers, but regolith (soil) and fractured shale bedrock aquifers would be more accurate titles. Neither would normally be regarded as true aquifers because of their low permeability, limited storage capacity, inhomogeneity and indefinite boundaries. A true aquifer is a soil or rock layer able to store and transmit groundwater in sufficient quantity and adequate quality to sustain producing wells.

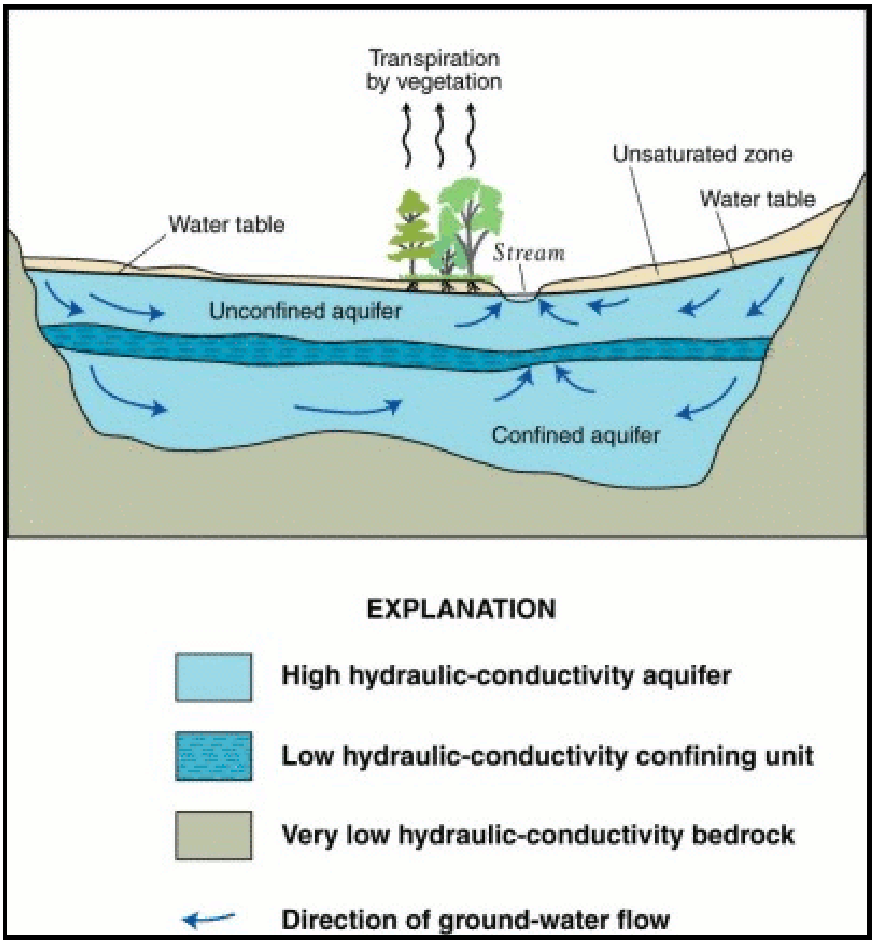
The main difference between these two ‘aquifer systems’ is that the shallow ones are more-or-less fresh, relatively permeable, but only ephemerally saturated; while the deeper aquifers are tighter, permanently saturated and much more saline (with salt content approaching that of sea water in places). The use of the plural recognises that both systems comprise a complex of scattered and discontinuous sub-aquifers of limited area and volume. The two systems are interconnected to varying degrees, such that in many places they cannot be distinguished. Many piezometers penetrate both aquifer systems, so their response (in terms of water level and salinity) is therefore a composite one.

5.4 Site Hydrogeology

Two groundwater-bearing systems are present within the St Marys site. These are referred here as the shallow and deep aquifers, but regolith (soil) and fractured shale bedrock aquifers would be more accurate titles. The relationship between them is illustrated by **Figure 5-3**. Neither would normally be regarded as true aquifers because of their low permeability, limited storage capacity, inhomogeneity and indefinite boundaries. A true aquifer is a soil or rock layer able to store and transmit groundwater in sufficient quantity and adequate quality to sustain producing wells.

The main difference between these two ‘aquifer systems’ is that the shallow ones are more-or-less fresh, relatively permeable, but only ephemerally saturated; while the deeper aquifers are tighter, permanently saturated and much more saline (with salt content approaching that of sea water in places). The use of the plural recognizes that both systems comprise a complex of scattered and discontinuous sub-aquifers of limited area and volume. The two systems are interconnected to varying degrees, such that in many places they cannot be distinguished. Many piezometers penetrate both aquifer systems, so their response (in terms of water level and salinity) is therefore a composite one.

- Figure 5-3 Relationship between Shallow (Unconfined) and Deep (Confined) Aquifers



Shallow Aquifers

The shallow or soil aquifer system is composed of residual soil, colluvium (slope creep deposits), floodplain alluvium, lateritic ironstone and weathered shale bedrock. This heterogeneous mixture is referred to as the *regolith aquifer* in McNally (2004, 2005a) because it includes all those soil materials down to the unweathered shale rockhead (‘from fresh air to fresh rock’ being the colloquial definition of the regolith).

The shallow aquifer system in the Western Precinct essentially comprises the deeper soils covering footslopes and creek floodplains – the lower ground within the landscape. As well as having a much smaller area than the underlying shale bedrock aquifer, the shallow aquifers discharge into nearby streams rather than to the distant South Creek. The margins of the shallow aquifers are indicated by low ECe values on the EM conductivity map, which are taken to indicate low salinity groundwater at shallow depth. The Western Precinct EM map highlighted saline outflows from a culvert on Northern Road, but failed to show a conspicuous area of saline scalding nearby.

Although the materials making up the shallow aquifers are predominantly impervious clay, significant hydraulic conductivity can nevertheless develop along shrinkage fissures, root tubes, weathered rock joints, the A/B soil profile interface and the deeper soil/rock interface. The shallow aquifer permeability in borehole tests ranges through more than two orders of magnitude (25m/d to 0.12 m/d) and averages 5m/d, about ten times that of the underlying shale bedrock. If anything, this understates the bulk permeability of the soil, since the test results were obtained from piezometer rising head tests which sample only a cubic metre or so of surrounding soil and may miss a nearby fissure. A better indicator of bulk soil permeability can be found in the almost instantaneous rise of the shallow water table following rainfall, which is characteristic of throughflow-dominated soil profiles and shallow unconfined aquifers.

Another distinguishing feature of the shallow aquifer systems is its low salinity, although this is masked in many piezometer records by the influence of salt water rising from the deeper shale bedrock. The characteristic salinity of the shallow aquifers appears to be less than 1000mg/L, which matches the surface stream salinity of 100 to 2510 mg/L (though generally <1000mg/L) and supports the hypothesis that discharge from this aquifer maintains stream baseflow.

Finally, the shallow aquifers are typically unconfined, whereas the deep bedrock aquifer system is generally confined or at least semi-confined. In other words, the upper surface of the shallow saturated zone is the water table, which is at atmospheric pressure; the highest water cut in a borehole is close to the final standing water level. This contrasts with the deeper pressure aquifers, where the first water cut is usually several metres below the eventual SWL. Water can infiltrate from the surface and the water table may rise close to ground level in low-lying areas, possibly causing water-logging in especially wet years. However because this shallow groundwater has a salinity generally less than 1000 mg/L, especially in wet years, its potential for salting is much less than the deep aquifer water, although concentration by evaporation is nonetheless possible in places.

Deep Aquifers

As noted above, the deeper or *fractured shale bedrock aquifer* system is much more extensive than the shallow one – in fact it covers the Western Precinct, which is entirely underlain by Bringelly Shale. The contours on the ‘piezometric surface’, defined by standing water levels in boreholes drilled into this confined aquifer indicate that the shale groundwater flows towards the northern end of South Creek and is not greatly affected by minor streams.

Surprisingly, given that its hydraulic conductivity is dependent on fracture intensity (m^2 per m^3), fracture continuity and aperture, the as-tested shale permeability at St Marys is relatively uniform. Rising head tests, based on SWL recovery after bailing (‘purging’), indicate an average permeability of 0.5 m/d, with a range of 0.05-1.90 m/d. This is at the high end of permeability ranges of 10^{-5} to 10^{-10}m/s (approximately 1m/d to 0.00001m/d) recorded in unweathered shales of the Sydney region (McNally, 2004). The reason for this relatively high permeability is considered to be the stress-relief fracturing in the fresh shale rock mass, which tightens with depth.

For our purposes, the most significant property of the deep aquifer system is its salinity, which is generally 10,000-30,000 mg/L TDS (say, equivalent to an EC range of 15-45dS/m). The maximum salinity recorded was 35,000mg/L, similar to sea water. Values less than 10,000mg/L are thought to indicate that mixing with fresh water from the upper aquifer has occurred. At this stage it is not clear whether there are any mappable salinity trends across the site, as distinct from local salinity variations and the effects of local dilution.

Another distinctive characteristic of the deep aquifers, and of shale aquifers elsewhere in western Sydney, is their slow piezometer response. Water levels in piezometers may take hours or days to reach equilibrium SWL. Thus a well that appears dry on completion of drilling may be found full to within a few metres of collar level after a week. Boreholes in which no water cuts were observed may contain standing water next day, while test pits excavated below the inferred water table may appear quite dry during the hour or so that they remain open.

This well behaviour is a consequence of the generally low bulk permeability of the shale rock mass, the random distribution of fractures and the poor hydraulic connections within this fracture network. Water cuts are commonly not observed until the borehole has advanced some metres below what is the later recorded SWL. Because of this variable but usually poor fracture connectivity the shale aquifer may be unconfined (below hill crests), confined (especially below thick clay regolith on valley floors) or semi-confined. The latter is probably the most common situation in the Western Precinct, for it describes a ‘leaky’ aquifer (or ‘aquitard’) in which water is stored in fractures or perched water tables. This water can move upward under pressure, but encounters frictional resistance along narrow and tortuous seepage paths. Hence a fresh aquifer can exist above a saline one, provided its water level (ie, its ‘head’) is high enough to resist rising salt water.

Groundwater Conceptual Model

The discussion so far has emphasised the differences between the two Western Precinct aquifer systems, because this helps to explain the fundamental question – why is the groundwater in the shale so saline, yet water courses such as South Creek remain fresh at most times. In reality the two systems are connected, albeit via narrow conduits through a leaky aquiclude. Groundwater flows from high levels to low the same as surface water does, or more correctly from high to low pressure zones, but its movement is hindered by frictional resistance along the way. The longer its passage through the shale bedrock the more head pressure it loses and the more salt it gathers.

Rainfall is presumed to infiltrate mainly on upper slopes or along watercourses, but its uptake is extremely low because of the tightness of the shale bedrock; most precipitation runs off or is lost to vegetation. Windblown sea salt accompanies the rain and becomes stored within the soil B-horizon as moisture is lost by evapo-transpiration. It is presumed that some of this stored salt, at depths around 1m in the soil profile, is periodically dissolved and flushed downwards with the sinking groundwater or moves laterally with throughflow (McNally, 2005b). Were it not for such a salt-depleting mechanism, western Sydney would become a desert. The proportion of salt removed by throughflow to that infiltrating to groundwater is not known, though field evidence suggests the former is much the more effective salt-depleting mechanism. Once within the shale, which may be present at only 1-2m depth, the infiltrating water 'steps' slowly downwards through vertical joints and laterally along bedding planes. The groundwater distribution in the shale can be envisaged as a multitude of stacked and sporadically distributed perched water tables. Boreholes only 100-200 m apart may differ in SWL by 10m or more, as they register different perched water tables. It would appear that the water table in Bringelly Shale is not quite the smoothly inclined surface often portrayed.

Hydraulic Connection between Aquifers

Because water moves from higher to lower pressure, saline shale water tends to move downwards beneath hills and upwards to major watercourses such as South Creek, though the dominant source of the creek water remains the fresh upper aquifer. The processes controlling salinity in South Creek – and indeed in all permanent water courses in the shale terrain of western Sydney - appear to be as follows:

- Following heavy or prolonged rain the upper aquifer is replenished, the water table rises and its salinity (never high) diminishes. Because of the much lower permeability of the shale, and despite its much larger outcrop area, little rainfall infiltrates to the bedrock aquifer. In fact most of the water penetrating below the plant root zone is directed down slope but within the soil profile by throughflow, without entering the groundwater cycle.
- For most of the time between significant rainfall events, which may range from months to more than a year, the base flow to South Creek (and similar streams) is provided by the upper aquifers. High pressure in these layers normally inhibits salt entry from the lower aquifer, but this leakage increases as the water table subsides.
- In drought years the discharge of South Creek and the level of the water table both fall, and salinity of the surface water increases. At the St Marys site we know that stream salinity may vary from about 100 mg/L to 2500 mg/L, but this is probably not the full extent of its seasonal variability, due to the limited monitoring period.
- In extreme droughts South Creek could dry up entirely, but salt can still be brought to the surface by capillary rise. This salt enrichment of the creek bed by evaporation would be apparent as a temporary conductivity spike following drought-breaking rains, as discharge from the replenished upper aquifer flushes out remnant salt.

5.5 Investigation Methodology and Results

The results summarised below refer to soils, salinity and groundwater investigations carried out by others in the Western Precinct during the period 1991 to 2000 and listed in the References. Investigations carried out by SKM in 2008 were restricted to walkover surveys and airphoto interpretation to confirm, where possible, the findings of earlier testing, drilling and monitoring.

Investigations in the Western Precinct

Salinity and groundwater investigations completed in or near the Western Precinct since 1990 have comprised:

- Drilling of two boreholes (SM53, 61) during the 1991 MMA program, both completed as standpipe piezometers;
- Drilling of 14 boreholes (P1-7, G1-6) by J&K in 2000, with paired piezometers penetrating the shallow and deep aquifers (total of 21 holes);
- Excavation and logging of 38 test pits to maximum depths of around 3m, with associated soil salinity testing;
- Monitoring water levels and salinity in piezometers, along with associated rising head permeability testing; and
- Mapping subsurface conductivity and, by extension, soil salt content, using electromagnetic induction (EMI) methods.

Soil bore locations are shown in **Figure 5-4** and drilling logs are presented in **Appendix C**.

Legend

▨ SREP 30 boundaries

— Site boundary

(Sydney Regional Environmental Plan No 30 – St Marys Structure Plan Amendment No 1. Environmental Planning and Assessment Act, 1979. 11/04/2006. NSW Department of Planning.)

— Property boundaries (LPI 2007)

- - LGA boundaries (LPI 2007)

🟥 Soil Bore Locations

2007 Aerial Photography by AUSIMAGE

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Metres

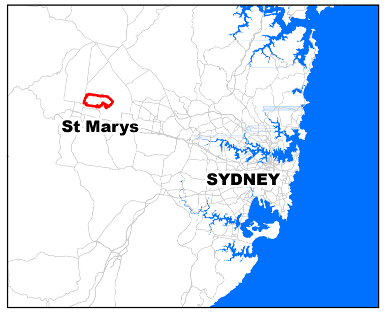

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Fig 5.4 : Soil Bore Locations

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Soil Borehole Details

Three series of boreholes are recorded:

- SMs 53 and 61 from the original 1991 Mackie Martin (MMA) survey, which covered the whole of the St Marys ADI site and which was mainly concerned with defining areas of contaminated land, rather than with identifying saline soils and groundwater.
- The P series of piezometer pairs drilled by Jeffery and Katausakas (J&K) in 1999, mainly at proposed wetland sites. The S suffix indicates a piezometer set in the shallow aquifer and D suffix identifies a deeper piezometer, registering groundwater fluctuations in the shale bedrock aquifer.
- The G series of piezometers were also drilled by J&K, apparently at alternative wetland sites in higher ground (dry gullies). Only one of these sites was equipped with a dual piezometers; the single standpipes in the other five boreholes (G1-5) record groundwater conditions in the shale bedrock.

The main findings from these boreholes were that:

- There was little difference in salinity (TDS) between the shallow and deep groundwater, though the latter tended to be slightly higher. Groundwater TDS was generally in the range 15,000-20,000mg/L, about half the salinity of sea water.
- Although groundwater salinity in every borehole was too high for any rural purpose, the upslope piezometers (G1-4) tended to be at the lower end of the range (10,000-15,000mg/L). This implies that groundwater in the shale aquifer beneath higher ground is more subject to fresh water recharge than that beneath valley floors; in fact the latter could be concentrated by evapo-transpiration.
- There was no consistent pattern of salinity change in the P and G series boreholes between monitoring rounds in November 1999 and January 2000. However, borehole SM61 was monitored over a longer period of ten months in 1994-95, and recorded a fall from 27,500mg/L to 22,000mg/L.
- Standing water level (SWL), hence water table depth, likewise fluctuated between the two monitoring dates – some rose, some fell, generally by less than 0.3m. However G1 rose by 1.92m and G3 by 1.90m.
- Contours on the shale aquifer SWLs (effectively, on the regional water table surface) indicate that groundwater in this aquifer flows to the east, towards South Creek, at an average gradient of about 1:100. Contours on the SWLs in the upper aquifer are less definitive, but suggest that its discharge is partly towards local water courses and partly towards South Creek.
- Hydraulic conductivity (permeability) in both the shale and shallow aquifers, as measured by rising head tests, is generally very low and in the range 10^{-3} to 10^{-5} m/d (0.001 to 0.00001 m/d).

However a few results are around 0.01m/d, indicating that soil fissuring and bedrock jointing may locally increase permeability by one or two magnitudes.

- One saline borehole, P6, is situated immediately downstream from the leaking toe of a small dam, in a bare ‘scalded’ area (in fact, this is the most visibly salt-affected 0.5ha in the whole Precinct). However a number of other saline boreholes (P3, P5, P7 and G5) did not have any obviously salt-affected ground nearby.

Soil Salinity Results

Soil salinity results of test pits were obtained from laboratory tests carried out in the Department of Lands soils laboratory at Scone NSW. Results from both sets of testing are summarised in **Table 5-2** and salinity contours for depths 0.2, 0.75 and 2.0 m are shown in **Figure 5-5** through **Figure 5-7**, respectively.

- **Table 5-2 Summary of Soil Salinity EC_e (dS/m) Results**

Test Pit No.	Sample Depth	Ec_e (dS/m)	Test Pit No.	Sample Depth	Ec_e (dS/m)
TP1	0.8-1	2.16	TP14	0.3-0.5	2.25
TP2	0.75-0.9	0.45	TP15	0.3-0.45	2.56
TP3	0.3-0.5	0.54	TP16	1.5-1.6	1.26
TP4	2-2.1	0.72	TP17	0.8	1.76
TP5	0.75-0.9	7.74	TP18	0.75-0.9	6.32
TP6	0.75-0.9	6.66	TP19	0.75-0.9	3.69
TP7	0.75-0.95	7.12	TP20	0.75-0.9	5.12
TP8	0.75-0.95	5.58	TP21	2.0	5.80
TP9	0.3-0.5	2.61	TP22	2-2.15	6.00
TP10	0.75-0.9	6.75	TP23	0.75-0.9	4.88
TP11	2.0	8.19	TP24	0.75-0.9	9.90
TP12	0.3-0.45	0.81	TP25	2-2.1	1.80
TP13	0.8	0.90			

Soil salinity results have been compared against the EC_e values of soil salinity classes specified by the DLWC 2002 booklet titled *Site Investigations for Urban Salinity*. These values are summarised in **Table 5-3**.

- **Table 5-3 EC_e Values of Soil Salinity Classes (DLWC 2002)**

Class	EC_e (dS/m)	Comments
Non saline	<2	Salinity effects mostly negligible
Slightly saline	2-4	Yields of very sensitive crops may be 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

Soil salinity results from 38 test pits in the Western Precinct are given in summarised form in SKM (1998). It is believed that these results refer to field conductivity testing carried out on 1:5 soil/water suspensions and are expressed in uS/cm units, though we have no further details. Based on DLWC 2002 criteria the SKM field results correspond, by depth intervals, to:

- Depth 0.3 m (in topsoil or A-horizon), approximately 40% of results non-saline, remainder slightly saline;
- Depth 0.75 m (in subsoil or B-horizon), approximately 20% non-saline, 3% moderately saline, remainder slightly saline; and,
- Depth 2 m (in lower B-horizon or weathered shale), approximately 45% non-saline, remainder slightly saline.

These results indicate that though salt accumulates with depth, the soil profile in the Western Precinct is generally of low salinity, with the exception of the areas identified as very too highly saline anomalies (refer to discussion in **Section 5.6**).

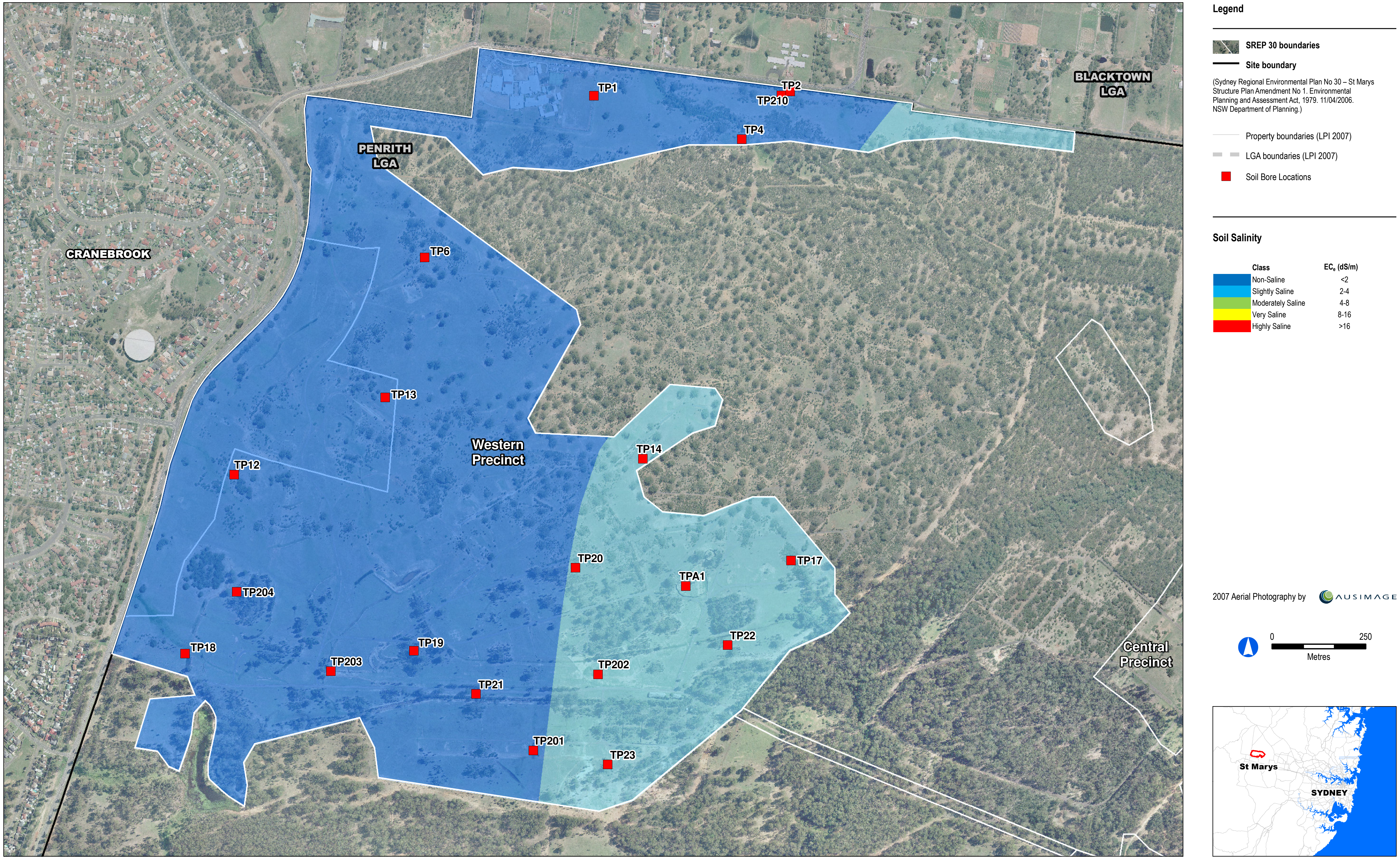

Fig 5.5 : Soil Salinity at a Depth of 0.3m (A-Horizon)

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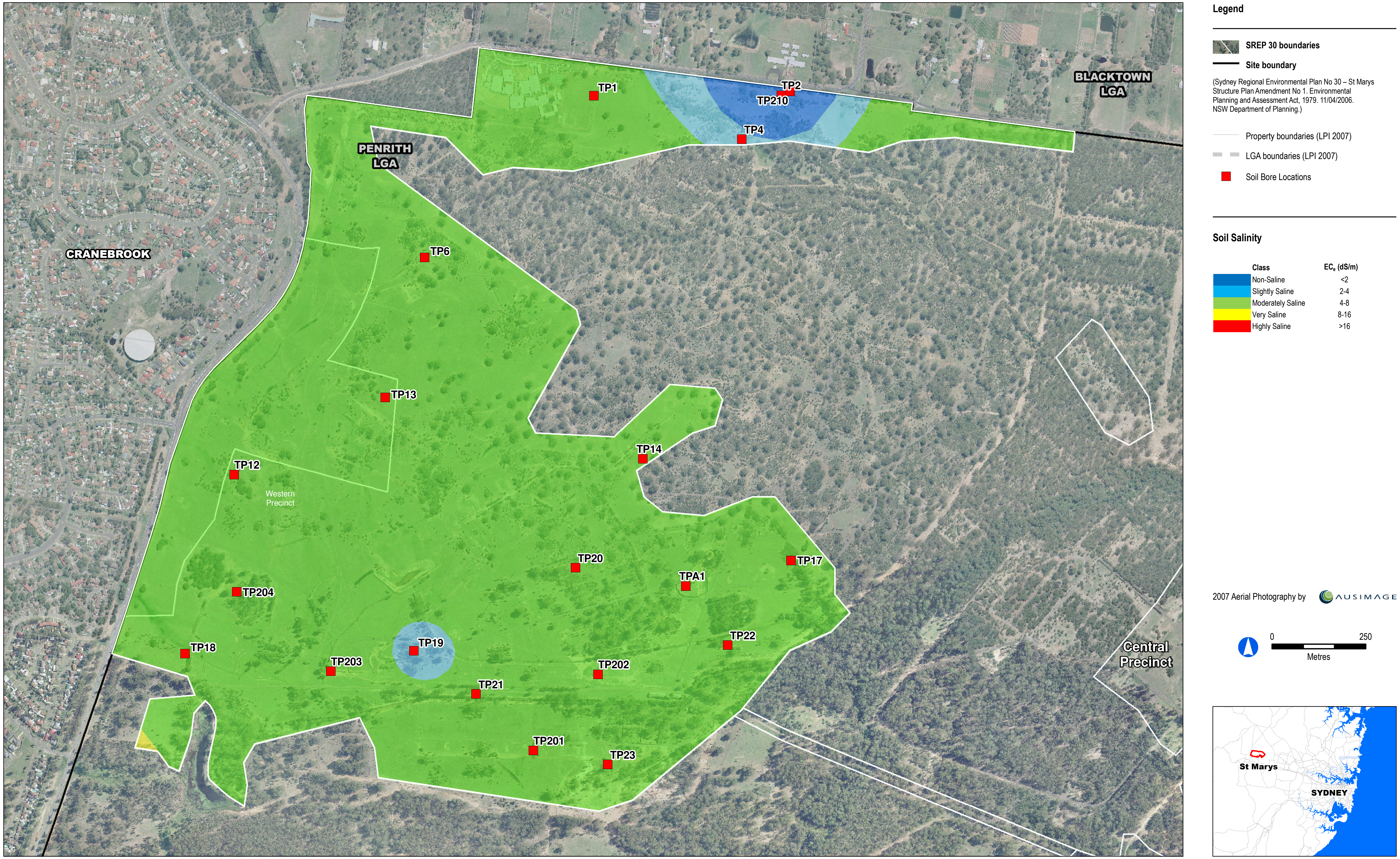

	Class	EC_e (dS/m)
🟦	Non-Saline	<2
🟦	Slightly Saline	2-4
🟩	Moderately Saline	4-8
🟨	Very Saline	8-16
🟥	Highly Saline	>16

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Fig 5.6 : Soil Salinity at a Depth of 0.75m (B-Horizon)

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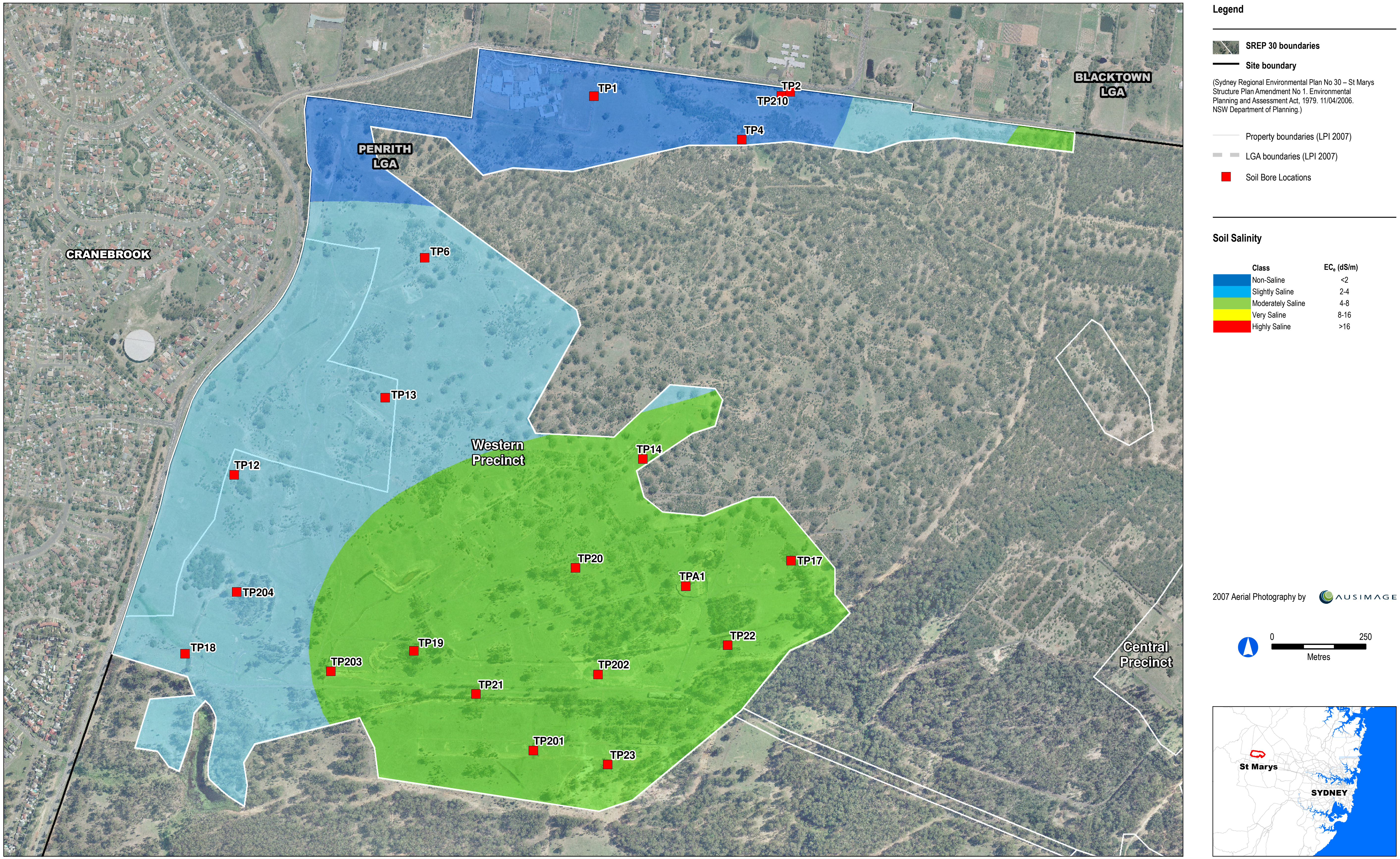

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Fig 5.7 : Soil Salinity at a Depth of 2m (Lower B-Horizon in Weathered Shale)

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5.6 Electromagnetic Soil Testing

An electromagnetic induction (EMI) survey was carried out across the site by DLWC in December 1999 and presented in Volume 2 of the EIS report dated 31 May 2000. It is understood that this survey was carried out by using a Geonics EM31 conductivity meter, although the only information available to us is a colour-coded printout of ground conductivity (ECa) readings presented as a figure in Jeffery and Katauskas (2000). This instrument probes to about 5-6m depth, though the bulk of the response is drawn from the top 2-3m (ie, the soil profile). Measurements are generally taken at 2-3m intervals, with the EM38 mounted on a GPS-equipped trail bike or quad bike. The results of this work are provided in **Appendix C** and summarised below.

Apparent electrical conductivity (ECa) was identified to be generally low in the Western Precinct with the exception of a highly saline anomaly (ECa of 17 dS/m at a depth of 0.6 m) which was detected in an area located along the central valley. This EMI anomaly was investigated further by field tests and the results indicated that salinity in this area was moderate rather than high.

5.7 Groundwater & Salinity Implications

Existing Groundwater Conditions

The hydrogeology of the St Marys property, including the Western Precinct site, is summarised in MM (1991) and J&K (1999). The results of boreholes drilled between 1990 and 1999 in or close to the site suggest that both the unconfined shallow (soil) aquifer and the confined deep (shale bedrock) aquifer are present. Both aquifers have similar characteristics to those in other parts of the St Marys property – in that they are tight, with low to very low permeability and very limited storage capacity. Both probably consist of a series of stacked and sporadically distributed perched water tables – in effect, poorly interconnected lenses of saturated ground - rather than a single homogeneous water-bearing layer. The vertical connection between the soil and shale aquifers is poor, to judge by nearly dry soils observed in test pits, and they appear to have different recharge / discharge relations.

Recharge to the soil aquifer is by direct infiltration onto the surface of the alluvial terrace (from RL 19 to 20 m), followed by throughflow across the A/B soil profile interface and temporary storage in shallow perched aquifers at depth raging from 0.5 to 1 m. Discharge is by evaporation from puddles in shallow gilgai-like surface depressions, through transpiration by trees and by seepage to shallow pools (at about RL 16 m).

Piezometers from the J&K (1999) investigation are shown in **Figure 5-8** and groundwater results summarised in **Table 5-4**.

Groundwater salinity for the November 1999 and January 2000 monitoring events are shown in **Figures 5-9** and **5-10**, respectively, and indicate that EC in groundwater ranges from 11,000 to 31,000 uS/cm.

At present most infiltration to the shale aquifer is likely to be coming from the unlined effluent discharge channel in the eastern gully, at about RL 15 m. This is believed to have raised the water table by perhaps 1-2 m and reduced the salinity and to be moving slowly through the shale aquifer. It is presumed to ultimately discharge along South Creek at about RL 12 m.

Fig 5.8 : Piezometers (J & K, 1999)

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- **Table 5-4 Summary of Groundwater Results**

BH No	Depth (m)	Perm'y (m/d)	SWL (mAHD)	TDS (mg/L)	Comments
P1S	5.90	0.048	28.39	15770	Beside lower portion of northern water course, broad valley floor
P2S	4.40	Na	Dry	na	East of WP
P3S	4.13	Na	19.67	na	On ridge east of WP
P4S	5.15	0.008	24.07	17100	Floodplain location, beside saline drain
P5S	5.70	0.004	26.95	16800	Beside saline drain,
P6S	4.20	Na	34.74	19030	Located downstream of small dam, salt scald visible
P7S	4.05	Na	Dry	na	High ground to south of WP
G6S	4.65		44.29	7200	Along western boundary, conductivity high
P1D	8.70	0.017	27.38	15510	Beside lower portion of northern water course
P2D	9.23	0.002	15.89	17600	East of WP
P3D	8.58	0.002	16.87	20200	On ridge east of WP
P4D	9.05	0.0003	23.81	17200	Floodplain location, beside saline drain
P5D	8.55	0.001	26.90	17000	Beside saline drain
P6D	7.50	0.024	37.14	18100	Located downstream of small dam, salt scald visible
P7D	7.50	0.002	32.79	19520	High ground to south of WP
G1	6.30	0.00005	23.04	10700	Located on nose of ridge
G2	5.66	Na	Dry	13600	Upstream end of northern watercourse
G3	8.20	0.00006	23.91	14300	In dry upland gully, close to ridge crest
G4	8.70	0.052	36.64	13800	In dry upland gully
G5	8.10	0.0002	26.90	18000	Midslope location
G6D	8.50	0.0007	41.68	na	Along western boundary, conductivity high

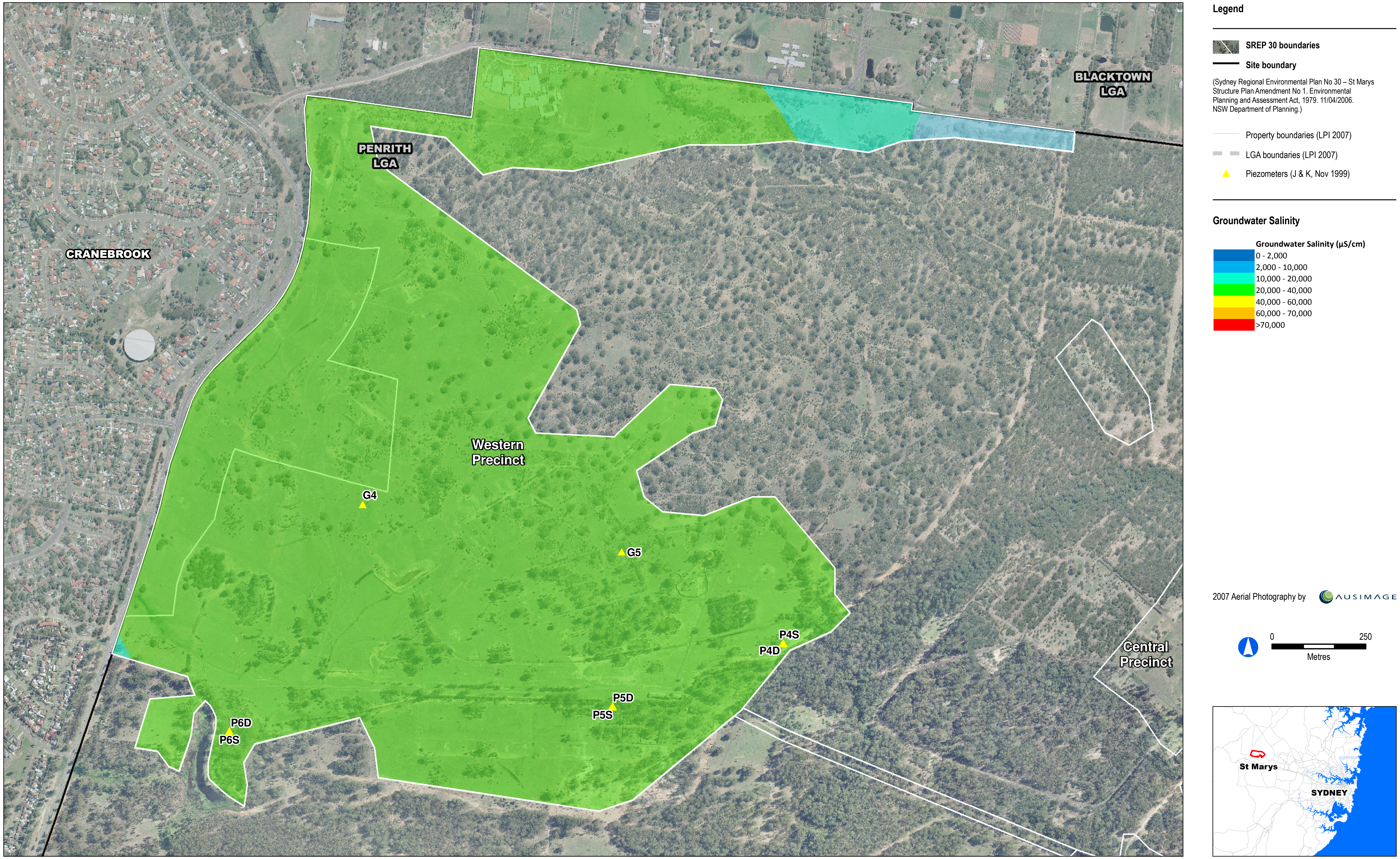

Fig 5.9: Groundwater Salinity (J & K Nov 1999)

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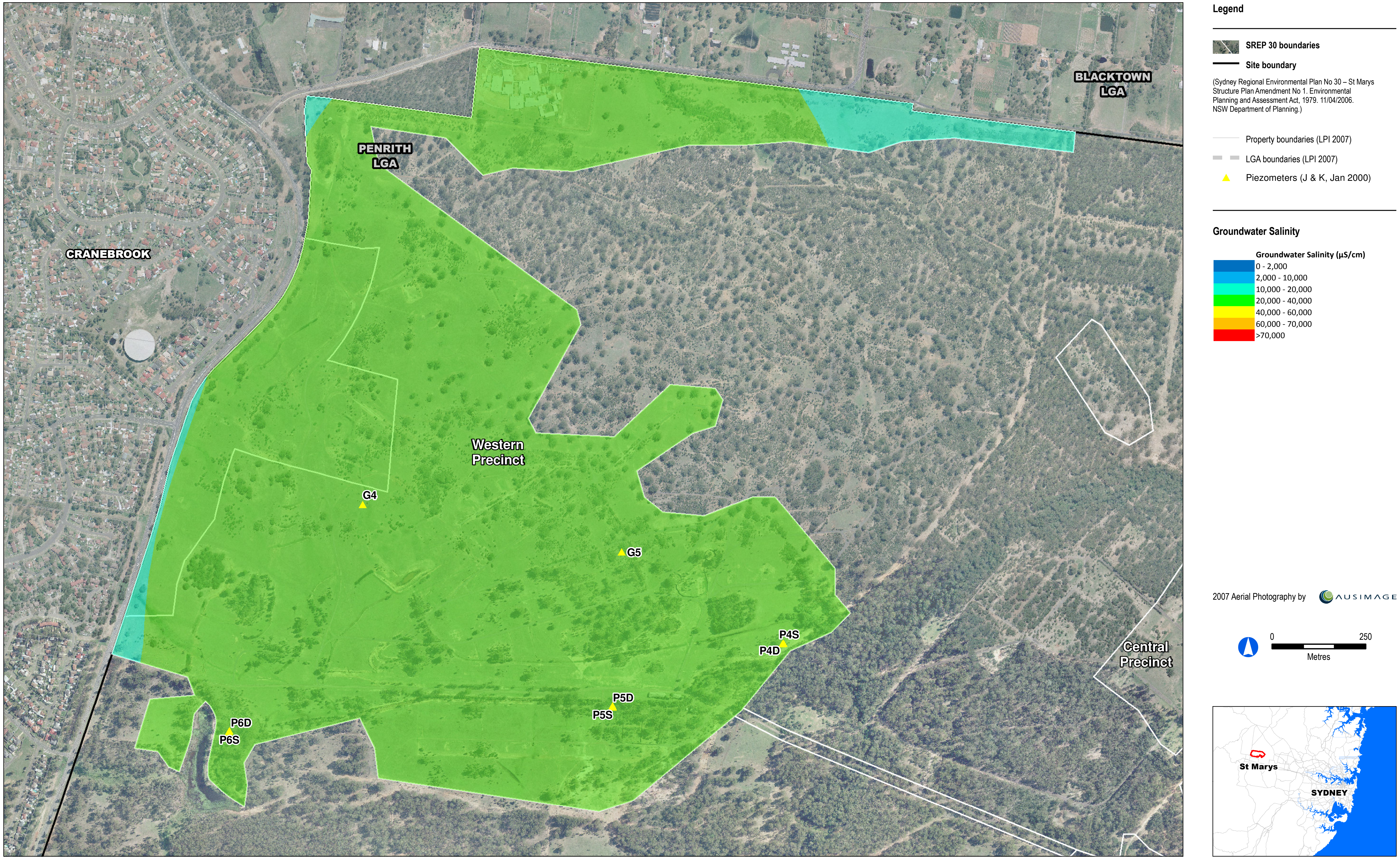

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Fig 5.10: Groundwater Salinity (J & K Jan 2000)

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Existing Salinity

Information on salinity at Western Precinct has been drawn from four sources:

- Soil salinity results from the J&K 1999 investigation (results are listed on **Table 5-2**);
- Groundwater salinity results from the MM 1991 and J&K 1999 investigations (results are listed on **Table 5-4**); and,
- Electro-magnetic induction (EMI) survey across the Precinct area to measure ground conductivity carried out by DLWC in 1999 and reported separately.

Potential water logging hazards were identified in the DLWC (1999) EMI survey and each area was assessed by test pit investigation conducted by J&K in 1999. The results showed that no significant water logging hazards exist at the site. A poorly drained area exists in the portion of the site identified as Anomaly 5 in the J&K 1999 report (ECa of 10.8 dS/m at a depth of 0.5 m). Drainage in this area should be improved during the project development phase by construction of appropriate drains and berms. Maintenance of local drainage patterns in this area is critical and should be achieved by careful attention to the road pattern layout adopted during detailed design.

Potential areas of high salinity apparent from the DLWC EMI survey were also investigated by the excavation of test pits at each anomalous area. At Anomaly 4 significantly higher salinity was encountered (ECa of 17 dS/m at a depth of 0.6 m) and protective measures should be adopted during construction of the proposed development. Apart from conditions encountered at Anomaly 4 in the J&K 1999 report salinity conditions were shown to be typical of the area in general.

Impact of Development

Salinity problems may arise when the existing stored salt is brought to the surface by a rising water table, or is washed laterally from the B-horizon by increased infiltration. We consider that though the EM results show variations in the overall ground conductivity, the soil and groundwater test results indicate relatively low salinity overall.

5.8 Groundwater Management

Management of groundwater, and hence of salinity, to meet the requirements of SREP30 and the St the EPS implies that the water table will not rise significantly as a result of the proposed development. There should also be no increase in throughflow (lateral movement of water through the soil profile, but above the water table). In practice this means that infiltration to the soil profile and from there to the water table should be reduced by all practical means.

Key Issues

Key potential groundwater-related issues resulting from urban development in areas such as the Western Precinct are taken to include:

- Decreased rain interception and transpiration by trees, hence increased runoff and/or infiltration, as a consequence of land clearing (especially removal of deep-rooted trees) during subdivision construction;
- Increased cumulative runoff (and probably more frequent peaks) from hard-surfaced areas such as roof tops, landscaped paving, roads and carparks;
- Exposure of saline soils (especially saline and sodic/dispersive subsoils) as a result of cutting, filling and erosion;
- Increased groundwater recharge due to garden watering, leaky pools, broken pipes, soakaways and parkland irrigation (especially with low salinity groundwater or recycled water); and
- Increased groundwater recharge from wetlands, stormwater detention basins, unlined drainage lines and ponded runoff generally.

5.9 Management Measures

The specific measures proposed for groundwater and salinity management at the site are in accordance with the DIPNR (2003) *Western Sydney Salinity Code Practice*, as follows:

- The design and installation of catchment wide ‘salt safe’ stormwater plans prior to the development of individual sub-divisions within the catchment. Such a system will have to demonstrably move salt emanating from home gardens, other irrigated areas and potentially existing saline hotspots to a safe discharge point- preferably the brackish waters of an existing creek system.
- Shaping the filled landform as a cambered embankment to shed water rapidly and directing this runoff into graded natural watercourses, while avoiding detention in natural and artificial ponds so far as possible.
- Making maximum use of paving, especially of car parks and storage areas, to reduce the ground available for rainwater infiltration. It is assumed that most of the Precinct will be built over in any case.

- Collection of stormwater from paved areas and roofs and directing it through sealed drains to approved discharge points along natural drainage lines.
- All basins and swales may need to be lined with an impermeable liner to prevent infiltration into groundwater.
- Grassing, mulching and tree planting in unpaved areas, with preference given to native species with high water demand (but making allowance for the relatively dry St Marys climate). Preference should also be given to deep-rooted trees and shrubs over shallow rooted grasses.
- Minimisation as far as practicable the site area from irrigation.
- On individual house blocks ensure garden areas easily drain to any catchment-wide stormwater system to ensure that salt does not accumulate within the garden beds, adjacent to building foundations or other salt sensitive infrastructure.
- Prepare garden beds and building foundations to minimise the potential for long term impacts such as soil structure decline that in turn leads to drainage problems. This could involve application of gypsum to foundation clay materials and the installation of subsoil drainage.

The observations made in previous studies suggest that poor stormwater design leads to salinity outbreaks on poorly drained soils and hence ‘salt safe’ drainage and storm water plans are critical components of any western Sydney development irrespective of the source and quality of water.

Residences

The main priority for groundwater management in house construction and landscaping is preventing excessive infiltration, bearing in mind that the proposed residential areas are largely on land that has been cleared for over sixty years and where residents are likely to greatly increase rather than decrease the number of trees and shrubs within the first few years of occupation.

Remedial/compensatory measures might include:

- Encourage residents to use water and nitrogenous fertilisers sparingly in garden irrigation, especially where slightly saline (say 500mg/L TDS) recycled water is being applied.
- Encourage planting of drought- and salt-tolerant native species and, where possible, deep-rooted trees.
- Ensure that buried pipes are fitted with leak-proof junctions to accommodate shrink and swell movements in clay soils.
- Ensure that all downpipes are linked to sealed stormwater drains or storage tanks, and that unlined surface ponding is minimized.
- In preparing the development application for the subdivision works individual lot measures would be identified and implemented through the development approval process and restrictions on the use of the land via section 88B instruments.

Stormwater Conduits

All paved areas such as roads and carparks should be kerbed and guttered, and runoff directed into stormwater pipes. Where stormwater is directed along unlined natural gullies these should, so far as possible, be configured such that recharge to groundwater is minimised by:

- Clearing the bed of obstacles such as fallen trees and eliminating breaks in gradient;
- Planting deep-rooted trees along the banks of the gully, but not in the channel; and
- Vegetating the channel floor and allowing for this vegetation to be periodically maintained.

The aim of these measures should be to reduce infiltration into the groundwater.

Wetlands

The key groundwater management issue with respect to wetlands is to provide a liner to prevent any interaction between groundwater and the water in the wetland.

Recycled Water Irrigation

At this point in time, it is unknown whether recycled water will be available for the Western Precinct. Should recycled water be proposed for irrigation purposes a land capability assessment in conjunction with Sydney Water would need to be undertaken and submitted with future development applications.

Groundwater Monitoring

In order to evaluate the infiltration reduction strategy outlined above, it will be necessary to monitor fluctuations in groundwater level and changes in water quality. It is recommended that some piezometer be constructed in the low lying east west valley. It is recommended to use the existing piezometers during this investigation (refer **Figure 5-8** and any other existing piezometers across the site.

The salinity, erosion and sediment management strategy for the Western Precinct is summarised in **Table 5-5** and should also be read in conjunction with section 4.4 and Appendix C of this report.

Soil Salinity Management Measures

Erosion

- In the design phase of the study minimise the area of disturbance, in particular the extent of vegetation clearing.
- Optimise the route where possible to avoid steep slopes in order to reduce the potential for erosion of the natural landforms, cuttings and fill embankments.
- Carry out geomorphological and geotechnical investigations at waterway crossings to determine the stability of the streambed and banks and make recommendations on control measures required to minimise erosion impacts.

Excavation Methods

- Characterise the surface profile in respect to salinity (in accordance with the DLWC 2002 *Site Investigations for Urban Salinity* manual), depth to rock and associated excavation issues during construction planning and costing.
- Optimise the route to avoid areas of difficult excavation.

Soft Alluvial and Poor Drainage areas

- Carry out detailed investigation of stream crossings, alluvial and poorly drained areas.
- Optimise the route where possible to avoid those areas requiring significant trench support and dewatering, thus minimising dewatering and construction effort (construction methods, complexity, durations);
- Where possible select alignment based on land systems, groundwater and engineering geology overlays.

Quality Control

- Implement Management Strategies in accordance with Section 8.7 of the DIPNR (2003) *Western Sydney Salinity Code of Practice* and EPA Guidelines for construction and sediment control.
- Select appropriate salt resistant construction and piping materials, and select suitable temporary pavement and backfill materials.

- **Table 5-5 Salinity, Erosion and Sediment Management Strategy Overview**

OBJECTIVE	BENEFIT	CONTROL	DETAILS	MONITORING METHOD	MANAGEMENT METHOD
SALINITY CONTROL MINIMISE GROUNDWATER RECHARGE	PREVENT RISING GROUNDWATER TABLE LEVEL AND DEVELOPMENT OF SALINE SOIL PROBLEMS	MINIMISE IMPORTATION AND USE OF POTABLE WATER ONTO THE SITE	• REUSE STORMWATER FOR IRRIGATION OF OPEN AREAS • MINIMISE POTABLE WATER DEMAND	INSTALL MONITORING BORE NETWORK	• MONITOR GROUNDWATER TABLE LEVELS • PERFORM REGULAR, RANDOM INSPECTIONS OF HOUSE SITES, AND VEGETATION AND GENERAL INFRASTRUCTURE AREAS
		REDUCE IRRIGATION REQUIREMENTS	• ADOPT SMALL GARDEN/LAWN AREAS • ESTABLISH LOW WATER REQUIREMENT PLANTS • USE MULCH COVER • USE LOW FLOW WATERING FACILITIES		
		AVOID USE OF INFILTRATION PITS TO DISPERSE SURFACE WATER	• DESIGN STORMWATER SYSTEM TO NEGATE NEED FOR HOME SITE STORMWATER STORAGE DISPOSAL • CONNECT ALL DOWNPIPES DIRECTLY TO STORMWATER		
		PREVENT LEAKAGE FROM WETLAND AND DRAINAGE FACILITIES	• LINE ALL PERMANENT STORMWATER RETENTION STRUCTURES AND WETLANDS		
SALINITY CONTROL ENCOURAGE USE OF GROUNDWATER AS A RESOURCE	MAINTAIN OR LOWER GROUNDWATER TABLE LEVEL	ENCOURAGE TREE PLANTING AND RETENTION, ESPECIALLY IN AREAS OF HIGHER RECHARGE	• USE/RETAIN NATIVE, DEEP-ROOTED, LARGE GROWING SPECIES		
EROSION CONTROL	PREVENTS SILTATION PROBLEMS IN DRAINAGE FACILITIES AND DAMAGE THAT COULD RESULT FROM EROSION	DESIGN ALL WORKS TO LIMIT GENERATION OF POTENTIAL EROSION SURFACES AND STABILISE DISTURBED AREAS AS SOON AS POSSIBLE	• STABILISE DISTURBED SURFACES • CONSERVE TOPSOIL BY STOCKPILING FOR LATER REUSE • USE FAST GROWING GRASS SPECIES • USE TEMPORARY GROUND COVER OR MULCH FOR AREAS TO BE REDISTURBED • MINIMISE AREA OF DISTURBANCE • COVER STOCKPILES WITHIN 10 DAYS • USE LIME STABILISATION DURING EARTHWORKS TO IMPROVE SUBGRADE AND REDUCE DISPERSIBILITY	• UNDERTAKE REGULAR INSPECTIONS OF ALL CONSTRUCTION ACTIVITIES • PERFORM REGULAR INSPECTION OF VEGETATION CONDITION IN DEVELOPMENT AREA	REGULAR INSPECTION REPORTS TO BE SUBMITTED TO CONTROLLING AUTHORITY
SEDIMENT CONTROL	CONTROL SEDIMENT GENERATED BY CONSTRUCTION AND OTHER ACTIVITIES	INCLUDE SEDIMENT CONTROL CONSIDERATIONS IN ALL DESIGNS	• PROTECT STOCKPILES FROM EROSION • USE TEMPORARY SEDIMENT BASINS • USE SPECIFIC SOIL STABILISATION MEASURES IN AREAS OF HIGH POTENTIAL SOIL EROSION		

5.10 Soil Implications

Residual soils derived from weathered shale bedrock in western Sydney are typically of moderate to high reactivity (shrink-swell potential in response to drying and wetting cycles) and moderate dispersivity (the tendency of sodic soils to erode rapidly when in contact with fresh water). These characteristics are especially well developed where:

- There is a sharp texture contrast between a silty, low plasticity A-horizon and a high plasticity, sodic and saline B-horizon;
- Where the soil profile, and especially the B-horizon is relatively thick, say 1-2m; and
- On low gradient slopes and in low-lying ground, with grass rather than tree cover, where seasonal moisture changes within the soil profile are likely to be greatest.

Test results summarised on **Table 5-2** indicate that the alluvial clays within the Western Precinct area are highly silty and of medium plasticity, with linear shrinkage bar test results in the low to medium range. The salinity results indicate that these clays are of low salinity, at least in the top 1m. The test pit logs demonstrate that the soil profiles, though deep (several metres), are poorly differentiated in terms of horizon development. These results suggest only moderate shrink-swell potential, by the standards of western Sydney clay soils.

Surface observations of widely spaced but narrow aperture shrinkage cracks under the present drought conditions confirmed that these clays are of only moderate reactivity, despite the presence of shallow surface depressions resembling gilgais. In other parts of Australia gilgais are associated with the presence of high plasticity, highly reactive clay soils.

The relative absence of rill and gully erosion across the site, coupled with the low salinity of the soil B-horizon, suggest that these clays are of low dispersivity and hence comparitively non-erodible.

5.11 Conclusion

Borehole, geophysical and test pit investigations in the Western Precinct indicate that shallow groundwater occurs at depths of 3-6 m and is of low salinity. Deeper water in the shale bedrock is moderately saline, in the range 3500-13,100mg/L, which is low by the standards of the St Marys property. It is concluded that the planned development is unlikely to result in surface salinisation and that the remedial measures proposed in the report will further reduce this possibility.

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6. SERVICES INFRASTRUCTURE

6.1 Proposed Infrastructure

Sewer

The recent Developer Servicing Plan for the St Marys Wastewater System 2006 identified sewage from the St Marys Project (which includes the Western Precinct) would be treated at St Marys Sewerage Treatment Plant (STP). The St Marys (STP) has sufficient capacity to accommodate the additional flows from the Western Precinct.

Discussions with Sydney Water have revealed that sewerage from the Western Precincts could be delivered to the STP by either tapping into the carrier that runs through the St Marys Project “Werrington Downs Carrier”, direct connection to the treatment plant or connection to existing pumping station SPS366. Further investigations would be required to ascertain the appropriate method of transferring sewage and connection to Sydney Water system.

Drinking Water

The Precinct will be linked with the Central Precinct and will be serviced from the Orchard Hills drinking water supply system It is likely that upgrades to the existing system will be required, including potentially an additional reservoir at Cranebrook and trunk watermains.

Sydney Water is undertaking investigations, which will confirm the required major infrastructure necessary to service the Western Precinct. Easements over public or private lands will be created where absolutely necessary as a last resort.

Electricity

Discussions with Integral Energy have revealed that they are able to service the Western Precinct subject to some augmentations to their existing network. Integral Energy has advised that ultimately a new zone substation would be required to service the entire Western Precinct. Integral have further advised that initially a temporary zone substation would be established which would be supplied via existing high voltage network from Cranebrook Zone Substation.

Development within the Western Precinct will require the extension of the electricity reticulation network throughout the project. Internal electricity reticulation within the Western Precinct will be provided under Integral Energy’s usual developer arrangements for the supply of underground electricity. Easements over public or private lands will be created where absolutely necessary as a last resort.

Communications

Underground telecommunications cables (optical fibre and/or copper cables) will be extended throughout the Western Precinct under the usual developer arrangements. Telstra will be updated when more accurate data on the number and type of users are known. Easements over public or private lands will be created where absolutely necessary as a last resort.

Gas

Agility Management Pty Ltd provides network management expertise for AGL, the organisation responsible for the extension and reticulation of the gas supply network. Agility will be updated when more accurate data on the number and type of users are known. Easements over public or private lands will be created where absolutely necessary as a last resort.

6.2 Design and Ecological Sustainable Development Initiatives

An opportunity exists to incorporate Ecologically Sustainable Development (ESD) principles in the services infrastructure for the Western Precinct.

Sewer

The following initiatives could be used in the design and construction of sewerage infrastructure:

- The gravity reticulation system for the site could be a ‘Low Infiltration System’ or 'Low pressure System' to reduce ground-water infiltration.
- Vitreous clay pipes should not be utilised in the construction of sewerage reticulation systems. uPVC or similar pipes should be used for all sewerage construction with compatible access chambers and house connections.

Drinking Water

The following initiatives could be used in the design, construction and use of potable water infrastructure:

- Specifying the use of low water demand fixtures (showerheads, toilets and other AAA rated devices etc) and appliances in buildings where appropriate.
- Rainwater collection tanks on lots for irrigation.

Recycled Water

- The potential future use of treated effluent, if available from Sydney Water for toilet flushing, irrigation (when rainwater is unavailable) and industrial purposes will reduce potable water demand and reduce the pollution load on South Creek.

Electricity

The following initiatives could be used in the supply and reticulation of electricity:

- Passive design and built form controls that reduce the demand for electricity should be promoted as an integral requirement for the Precinct.
- Specifying the use, where appropriate, of "energy efficient" electrical appliances in buildings.
- Examining the use of solar powered and water heating systems lighting where appropriate.

Communications

The following initiatives could be used in the design and construction of telecommunications infrastructure:

- Provide adequate 'spare' conduit capacity in all street reticulation networks to facilitate future expansion and technology.
- Provide an optical fibre network throughout the site.

Gas

Gas reticulation is recommended for the development due to:

- Provision of gas services reduces the expected load on Electricity Infrastructure and therefore reduces the emission of greenhouse gases.
- Gas reticulation provides commercial customers within the development with options and pricing power, particularly for contestable works.

Common Trenching

Best practice development allows for "Common Trenching Agreements" between the developer, Telstra, AGL and Integral Energy. Benefits of Common Trenching Agreements include:

- Reduced costs due to a shared trench between the three service providers.
- Lower land take within the road reserves throughout the site.
- Increased efficiency and shorter time frame for provision of services.

6.3 Conclusion

Essential services, (water, sewer and electricity) would be made available for the development. Sydney Water and Integral Energy have indicated that they are able to service the Western Precinct.

Appendix A Assessment of Drainage Controls

A.1 Hydrological Model

A XP-RAFTS model was developed for the Western Precinct to represent the hydrological network. The model simulates runoff hydrographs at defined points for a given set of catchment conditions and rainfall events. The generated runoff hydrograph is routed through the system to provide flow results at a number of node locations throughout the network.

The model was used to determine peak flows at specified locations in the drainage system for the following conditions:

Existing catchment conditions

Proposed developed catchment conditions (without flow mitigation)

Proposed developed catchment conditions with flow mitigation

A.2 Model Input Data

Catchment Data

Catchment delineation was undertaken for the previous St Marys study in 1998. These catchment boundaries were reviewed using 2m contours from Airborne Laser Survey (ALS) data. Some adjustments were made to ensure contributing areas to proposed wetland/detention basins were correct. Each catchment was subdivided to represent the rural and urban portion in the existing and developed case. The percentage impervious adopted in the model are as follows;

Existing Case

Urban Area outside the site – 50% impervious

Rural (within and outside the site) – 5% impervious

Developed Case

Urban (within the site) – 70% impervious

Urban (north catchment overlapping site boundary) – 60% impervious

Rural – 5% impervious (unchanged from existing case)

These values are based on the following assumptions:

No development will occur in the regional park therefore % impervious does not change;

Areas allocated for urban development (including education and road areas) will have varying impervious percentages between 50-70%. For the purpose of the Precinct Plan the more conservative 70% has been adopted for all areas; and

Existing urban areas external to the site will be unchanged from existing, i.e. 50% impervious.

Rainfall Intensities and Loss Parameters

Penrith City Council IFD data was used in the RAFTS model. A suite of storm durations were input for each ARI rainfall event. IFD data is shown in **Table A 1**below.

- **Table A 1 Penrith City Council IFD Rainfall Data**

Duration (min)	2yr ARI	5yr ARI	10yr ARI	20yr ARI	50yr ARI	100yr ARI
20	52.82	69.66	79.08	91.89	108.85	121.9
30	42.83	56.47	64.09	74.46	88.19	98.75
60	29.05	38.28	43.43	50.44	59.72	66.86
90	23.04	30.31	34.36	39.89	47.19	52.81
120	19.48	25.6	29	33.65	39.79	44.51
180	15.33	20.12	22.78	26.41	31.21	34.89
360	10.16	13.3	15.04	17.42	20.56	22.97
720	6.75	8.81	9.95	11.51	13.57	15.15

Loss parameters used in the model are as follows:

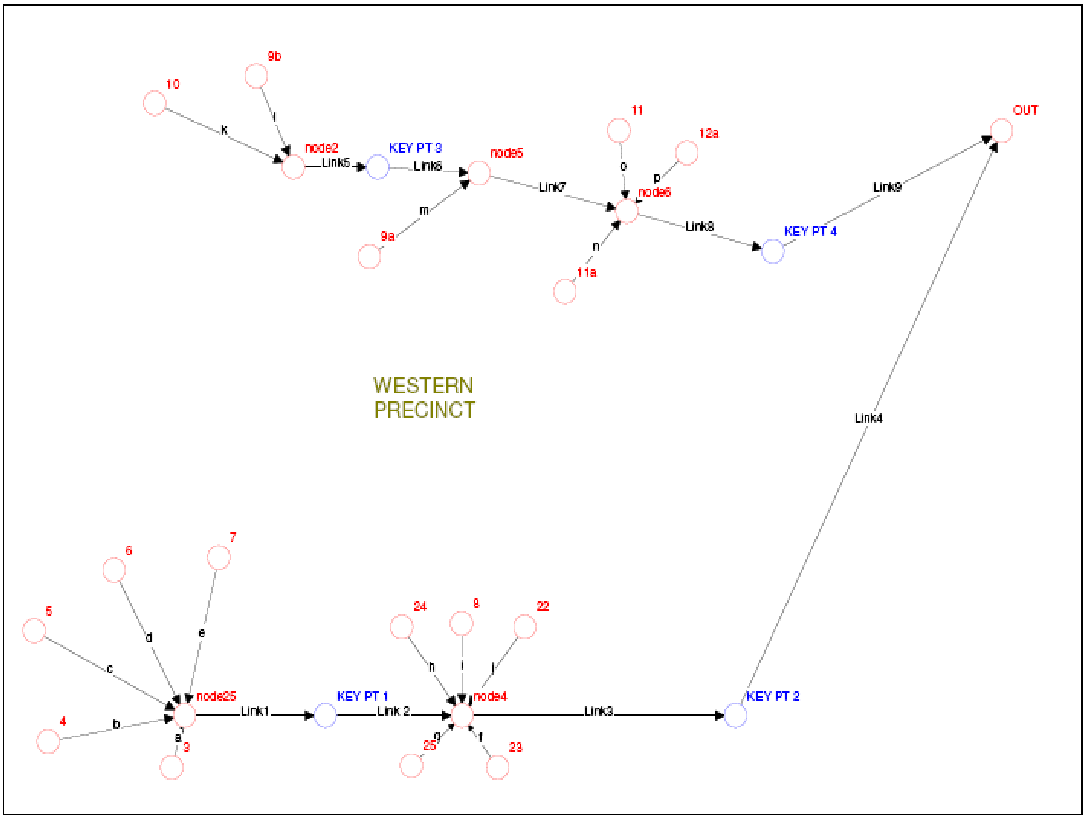
Impervious Losses;	Initial 1.0mm	Continuing 0.5mm
Pervious Losses;	Initial 10.0mm	Continuing 2.5mm

Bx factor 1.0

A.3 Existing Model

The layout of sub catchments of the existing RAFTS model is shown in **Figure A 1**. Sub catchment parameters are listed in **Table A 2.**

- **Figure A 1 RAFTS Model Schematic Layout – Existing**



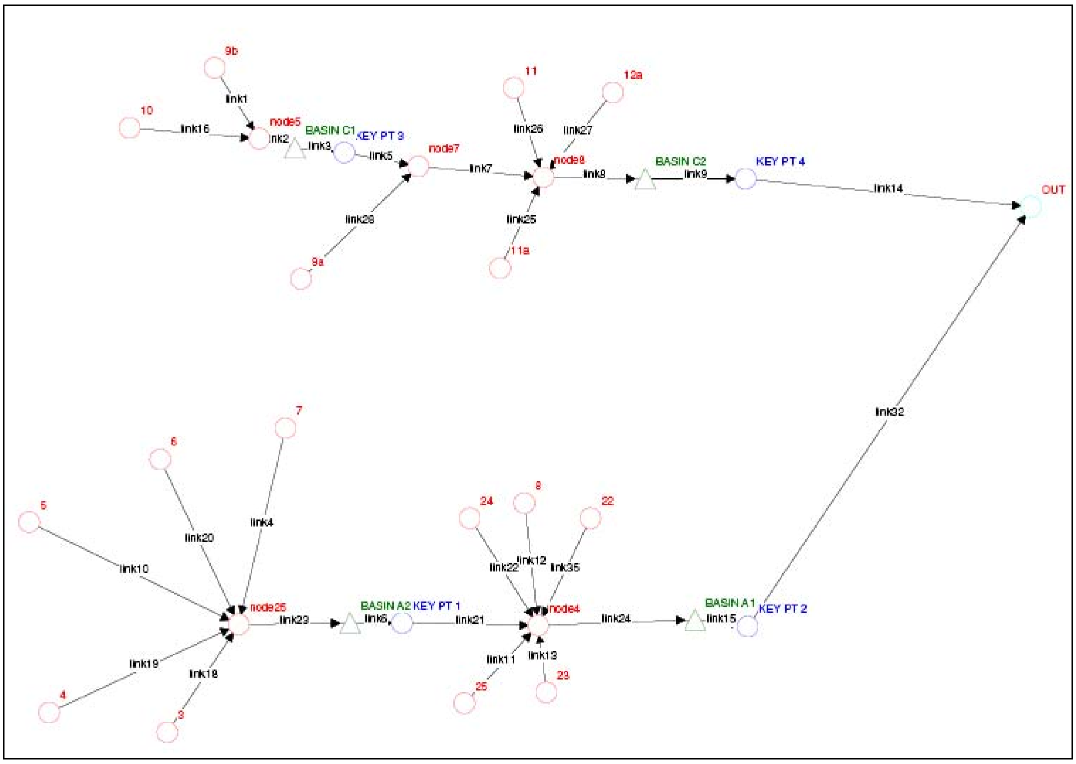
- **Table A 2 Sub-catchment Parameters – Existing**

Catchment	Area (ha)	% Impervious	Catchment	Area (ha)	% Impervious
3	13.6	46	24	56.4	0
4	21.3	63	22	15.8	0
5	8.7	47	9a	71.9	5
6	49.9	31	10	62.2	40
7	27.9	13	9b	33.5	50
8	51.9	5	11	33.7	5
25	9.95	0	11a	21	5
23	18.5	0	12a	21.6	5

A.4 Proposed Model

The layout of sub catchments of the existing RAFTS model is shown in **Figure A 2**. Sub catchment parameters are listed in **Table A 3.**

- **Figure A 2 RAFTS Model Schematic Layout – Proposed**



- **Table A 3 Sub-catchment Parameters – Proposed**

Catchment	Area (ha)	% Impervious	Catchment	Area (ha)	% Impervious
3	13.6	46	24	56.4	70
4	21.3	65	22	15.8	73
5	8.7	66	9a	71.9	54
6	49.9	72	10	62.2	94
7	27.9	100	9b	33.5	96
8	51.9	100	11	33.7	3
25	9.95	92	11a	21	36
23	18.5	74	12a	21.6	8

A.5 Existing Peak Flows

In order to meet the water quantity objective, post development peak flows must not exceed existing peak flows for a range of events from 2 year to 100 year ARI. The existing RAFTS model was run for a range of storm durations and events. The existing peak flows at a number of key points in the catchment for the 100 year and 2 year storms are presented in **Table A 4** and **Table A 5** respectively.

A.6 Developed Site Peak Flows

Hydrological analysis of the developed site conditions was undertaken using the RAFTS model (initially with no onsite detention included). Peak flows were extracted at the fore-mentioned key locations and compared to the existing case. A comparison of developed (without detention) and existing flows for the 100 year and 2 year events are provided in **Table A 4** and **Table A 5.**

- **Table A 4 100 Year ARI Existing and Developed (with no detention) Peak flows**

Event	Peak flows (m^3/s)	
	Existing	Proposed (no detention)
Key Point 1	25	58
Key Point 2	35	101
Key Point 3	21	42
Key Point 4	28	59

- **Table A 5 2 Year ARI Existing and Developed (with no detention) Peak flows**

Event	Peak flows (m^3/s)	
	Existing	Proposed
Key Point 1	10	26
Key Point 2	12	42
Key Point 3	8	18
Key Point 4	10	25

The results in indicate that without detention, the proposed development would increase peak flows within the site for a range of storm events. This is due to the increase in impervious catchment area attributed to the proposed Precinct development. Detention facilities are required to reduce the peak flows from the development to ensure they do not exceed existing flows.

A.7 Detention Basins

Four detention basins are proposed for the Western Precinct for peak flow mitigation for 2 year to 100 year ARI storm events. Three basins (A1, A2 and C1) are located within the Western Precinct, whilst the remaining basin (C2) is situated outside the Precinct boundary in the Regional Park as shown on **Figure 4-1**. The detention basins have been designed for events up to and including the 100 year ARI storm; peak flows were checked in the 2, 10 and 100 ARI events, to ensure that peak developed flows would not exceed peak existing flows.

Each of these basins would have both a low-level outlet and a spillway. In most storm events, the low-level outlets would control the flow and the basins would not fill to the level of the spillway. However in the case that the low-level outlets are fully or partially blocked submerging the low-level outlets, storm flows could still safely exit the site via the spillways. The detained water will be discharged within a day and be temporarily stored above the permanent pools in the basin (which are present for water quality treatment).

Results

Peak flows for the developed case in comparison to the existing case are presented in **Table A 6** and **Table A 7** for the 100 yr and 2yr ARI events.

- **Table A 6 Predicted Developed Peak Flows – 100 year ARI**

Event	Peak flows (m^3/s)	
	Existing	Proposed
Key Point 1	25	15
Key Point 2	35	28
Key Point 3	21	21
Key Point 4	28	28

- **Table A 7 Predicted Developed Peak Flows – 2 year ARI**

Event	Peak flows (m^3/s)	
	Existing	Proposed
Key Point 1	10	4
Key Point 2	12	9
Key Point 3	8	6
Key Point 4	10	4

The results indicate that the proposed detention system attenuates all flows up to and including the 100 year ARI events. Detention storage will occur above a permanent wetland area, the size of which has been determined from the water quality assessment.

Appendix B Assessment of Water Quality Controls

B.1 MUSIC Modelling

A water quality assessment was undertaken using the MUSIC water quality model (eWater CRC, Version 3.01). The main purpose of the modelling was to determine the land take required for the stormwater management wetlands to ensure that the water quality objective of no net increase in annual pollutant load into the receiving waterways is met.

Data

The following data were used in the model:

Rainfall data: Pluviograph data for use in the model was obtained from the Bureau of Meteorology for station 67113 Penrith Lakes AWS for the period December 1996 to November 2003. Since the model was run at a small (6 minute) timestep, one year of rainfall data was used with 1997 chosen as the average rainfall year.

Catchment areas: The study area was split into smaller catchment areas as used in the 1998 SKM report. The catchment characteristics were then updated according to information from the latest land use plan. **Table B 1** provides all the subcatchment areas used in the Music model; these are shown in **Figure B 1**.

Event Mean Concentrations: Long term water quality monitoring data for the site is currently not available. In order to estimate the existing pollutant runoff loads and determine the effectiveness of the proposed stormwater management ponds, the Event Mean Concentrations (EMCs) for Total Suspended Solids (TSS), Total Phosphorus (TP) and Total Nitrogen (TN) have been based on data from the 1998 SKM report with some modifications made. The EMCs used in the model for the existing and developed cases are provided in **Table B 2**. Data from *Stormwater Flow and Quality and the Effectiveness of Non-Proprietary Stormwater Treatment Measures* (Monash University and CRC for Catchment Hydrology, 2004) was reviewed. The CRC data on EMCs was similar to the concentrations given in **Table B 2**. These EMCs are also similar to the measured stromwater concentrations for typical urban catchments in Sydney in the early 1990s by Sydney Water. For consistency purposes, the previously adopted EMC in the 1998 report were used.

- **Table B 1 Music Model Catchment Areas**

Catchment Name	Area (ha)
1	61.7
2	176.3
3	13.6
4	21.4
5	8.7
6,7,8,25	137.2
9a 10a	83.6
9a 10b	49.5
9b,11,12a	102.4
1.2,12-15,20-22	308.7
C3	55
23-24	74.9
17ab,16	18.1
27	58.1
18,19ab	42.5
19a	22.3
28	21.2
26	47.1
20	22.2

- **Table B 2 Event Mean Concentrations**

Site conditions	TSS (mg/L) Storm Flow (Wet)	TSS (mg/L) Base Flow	TP (mg/L) Storm Flow (Wet)	TP (mg/L) Base Flow	TN (mg/L) Storm Flow (Wet)	TN (mg/L) Base Flow
Existing	50	7.9	0.075	0.075	1	0.75
Developed	110	12.6	0.2	0.1	1.5	1.0

B.2 Methodology

The following methodology was adopted in the MUSIC model:

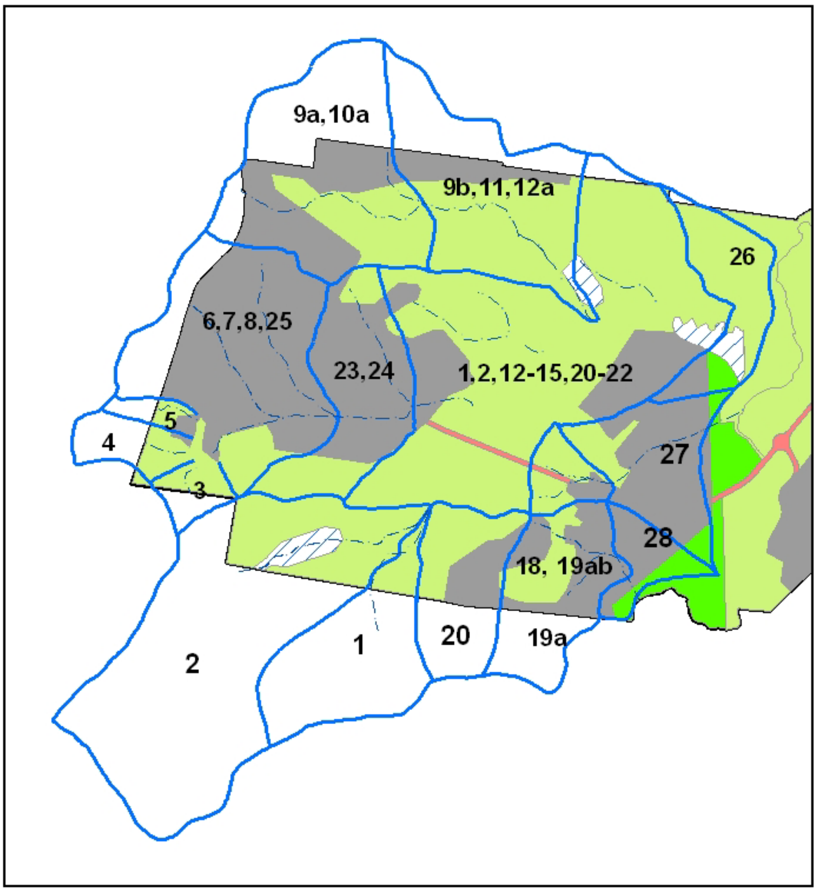
The Western and Central Precincts have been considered together for water quality purposes. There are three discharge areas for these two precincts: at S1, S2 and S3 as shown **Figure 4-1.** The combined annual pollutant load at the discharge points for the existing case was compared to the combined annual pollutant load in the developed case. This is similar to the approach that was adopted in the 1998 SKM Watercycle Management Report. The objective for the Western and Central Precincts is that the combined annual pollutant export from the developed site does not exceed the existing.

- It has been estimated that the actual stormwater management wetland surface area is approximately 75% of the land take required. The remaining approximated area would be required for detention, pathways and benching purposes. The modelling assumes a concept design whereby twenty percent of the total wetland area would be an inlet zone. The remaining 80% represents the open water and macrophytes zone areas. The stormwater management ponds for the Western and Central Precinct have been modelled assuming an average 1.5m depth across the pond.

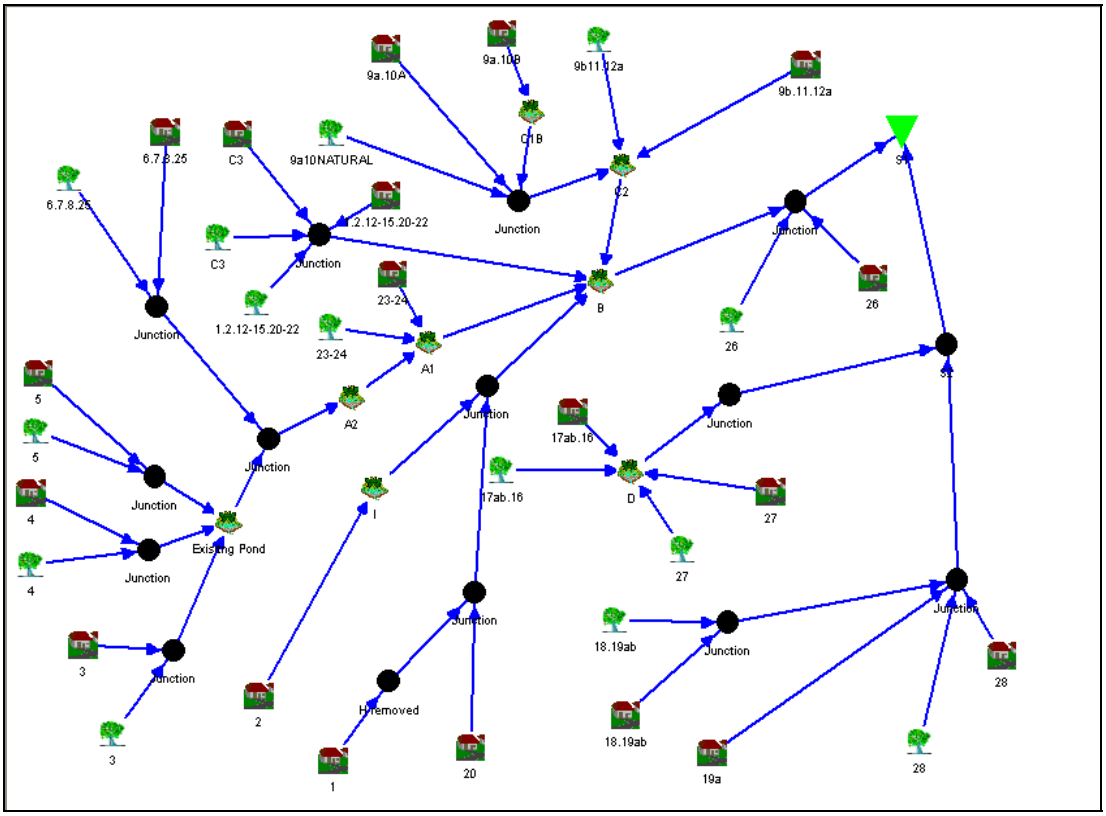
- There is an existing pond in the southern portion of the Western Precinct that not been included in the modelling for this assessment. For the future development case the function of this existing pond will not change compared to its existing function and can be therefore omitted from the modelling.

- Other WSUD water quality controls such as those listed in this report have not been included in the Music model. These details will be considered during the subsequent stages (ie: development application) when other water quality controls such as the additional WSUD controls and GPTs on site would also be assessed. This represents a conservative modelling approach for the Precinct Plan assessment.

- **Figure B 1 Music Model Sub-catchment Areas**



- **Figure B 2 Water Quality MUSIC Model Layout for the Western and Central Precinct**



B.3 MUSIC Results

Western and Central Precincts

The indicative locations of the proposed stormwater management wetlands that would meet the water quality objective for the Western and Central Precinct are shown in **Figure 4-1.** The exclusion of the other WSUD controls from the water quality modelling provides a conservative approach and hence the results in this Precinct Plan report would be conservative. The estimated land take for the proposed wetlands ponds are provided in **Table B 3.**

- **Table B 3 Proposed Stormwater Management Pond Sizes for the Western and Central Precincts (Water Quality Only)**

Stormwater management pond ID	1998 Study (Basis of SREP 30) Wetlands Land Take (ha)[1]	SREP 30 Draft Amendment (2005) Drainage Zones Land Take (ha)	Precinct Plan[2] Minimum[3] land take (ha) for water quality purposes only
A1	2.2		1
A2	3.7		1.8
B	6	8	8
C1	3.4		1
C2	2.8	4.5	4.5
C3	1.4		0
D	0.6		2
E	1.4		0
F	0.6		0
G	0.7		0
H	1.6		0
I	4	7.4	7.4
EX1	2.6		0
Total	**31**	**19.9**	**25.7**

1- These 1998 Study landtake estimates are for water quality and detention requirements. These areas do not include benching or pathway areas.

2- For this Precinct Plan assessment, it has been assumed that the actual stormwater management wetland surface area is approximately 75% of the land take required shown in the above table.

The MUSIC model can provide the annual pollutant load exported for Total Suspended Solids (TSS), Total Phosphorus (TP) and Total Nitrogen (TN). The results for the existing case, the developed case with no water quality controls and the developed case with controls are provided in **Table B 4.** The values in brackets are the results compared to the existing case.

- **Table B 4 MUSIC Results for the Western and Central Precincts**

	TSS (kg/year)	TP (kg/year)	TN (kg/year)
Existing	240,000	426	3,900
Developed, no controls	357,000 (+50%)	620 (+46%)	4,920 (+26%)
Developed, with controls	113,000 (-53%)	290 (-32%)	3,620 (-7%)

Note: The % values in brackets are the results compared to the existing case. The target reduction is -5% for the worst pollutant which provides a safety margin. The actual margin is in the range of approximately 5% for TN and up to 50% for TSS.

Appendix C Groundwater and Soils

C.1 EIS Investigations Volume 1

ENVIRONMENTAL INVESTIGATION SERVICES

REPORT

TO

LEND LEASE DEVELOPMENT

ON

SOIL AND GROUNDWATER INVESTIGATION

FOR

PROPOSED RESIDENTIAL REDEVELOPMENT

AT

COMLAND, ST MARYS

VOLUME 1: OVERVIEW

31 MAY, 2000

REF: E13431F – VOL1

Associate Director and Principal : E H Fletcher BSc (Eng) ME CPE
39 BUFFALO ROAD GLADESVILLE NSW 2111 TELEPHONE: (02) 9809 7322 (02) 9807 0200 FAX: (02) 9809 7626
EIS IS A DIVISION OF JEFFERY & KATAUSKAS PTY LTD A.C.N 003 550 801
Directors: R P Jeffery BE DIC MSc B F Walker BE DIC MSc P Stubbs BSc MIEAust

EXECUTIVE SUMMARY

The Lend Lease and Comland Joint Venture (JV), commissioned Environmental Investigation Services (EIS), a division of Jeffery & Katauskas Pty Ltd (J&K), to undertake a soil and groundwater investigation over part of the property at St Marys, currently owned by Comland. The site has a total area of approximately 1,538 Hectares (ha). The west area of the site (Western Precinct) to the west of South Creek is to be developed initially, for predominantly residential purposes. The overall development includes construction of 14 significant wetland areas and creation of a central Biodiversity Zone (Regional Park). Six of the proposed wetland areas are located within the Western Precinct.

The purpose of the investigation was to obtain and assess preliminary soil and groundwater data from the Western Precinct section of the site, in order to meet the planning requirements set by the Department of Urban Affairs and Planning (DUAP). The DUAP requirements for the development in relation to soil and groundwater management plans are summarised in this report.

The results of the investigation are presented in three volumes. This volume (Volume 1) provides an overview of the investigation and presents the management strategies. The technical results and documentation are presented in Volumes 2 and 3.

EIS retained Perrens Consultants Pty Ltd and Woodlots and Wetlands Pty Ltd to undertake soil salinity, fertility and erosion studies for the project, in relation to urban capability development. An Electro-Magnetic Induction Survey (EMI) was also undertaken by the Department of Land and Water Conservation, together with laboratory testing at Scone. The JV retained Sinclair Knight Merz directly to prepare urban capability maps for the Western Precinct. The maps are presented in Volume 3 of this report.

A range of soil parameters were assessed for the investigation including dispersion, erodibility, salinity, fertility, cation exchange capacity, and lime and gypsum requirements. Preliminary geotechnical conditions were also assessed, together with groundwater conditions.

The scope of work undertaken for the investigation included:

- Installation of 13 groundwater piezometers;
- Soil profile assessment and sampling at thirty one test pit locations (locations selected to support data collection for the urban capability mapping);

- Analysis of soil and groundwater samples to assess the range of parameters outlined above;
- An EMI survey to map soil salinity conditions;
- Preparation of management plans to address soil and groundwater related issues associated with the proposed development;
- Collection of baseline data for future comparison purposes.

The site investigation has indicated that the soils and groundwater conditions at the site are typical of those in western Sydney. These conditions are not considered to be such that will restrict the proposed development. The soils are to a variable degree acidic, unstable, erodible, reactive, and have very low fertility and salinity develops with depth in the profile. The shale groundwater is saline. These characteristics can be readily accommodated by careful planning and management. Standard methods as described in the Standard Department of Housing (1998), Managing Urban Stormwater: Soils and Construction (3rd edition) "Blue Book" should be used during construction for sediment and erosion control. A series of additional techniques to control and manage salinity, stability, acidity, fertility, and reactivity are presented.

Appropriate location of the various facilities for the St Marys development will assist salinity control by minimisation of both groundwater recharge and mobilisation of salt to the surface soils in higher areas of the site. All open recreation and sports areas should be located in the lower parts of the landscape. All other facilities, including commercial/industrial and residential areas should be located in the upper parts of the landscape. All runoff should be piped to the major drainage lines.

Careful monitoring of the development should be undertaken on a regular basis, both during and after construction to assess the impact of the project on the environment. This programme should be designed to facilitate corrective action where required to prevent the development of adverse impacts.

The intensity of investigation at this time is considered to be sufficient to provide a rational basis for decisions to permit the project to proceed in association with the appropriate development controls.

The use of gypsum and lime will overcome aluminium toxicity, soil instability and acidity. A total of 10 t/ha (2 to 3 t/ha of high grade agricultural lime and 7 to 8 t/ha of gypsum) is recommended for the site in the proposed development area. A dual axle truck mounted spreader equipped with a hopper, vibrating feed and spinner can be used to apply lime and gypsum. The application should not involve any cultivation or ripping, in order to maintain the calcium near the surface. This will stabilise the topsoil, improve vegetative cover and minimise mobilisation of salinity from the subsurface soils. Application of the combined lime and gypsum treatment at an early stage of the overall project development timeframe will provide significant environmental benefit in reducing soil loss to streams and minimising erosion. The application can be staged with a desirable lead time of approximately one year. Further applications may be necessary during construction.

All soils have a relatively high erodibility rating. An effective erosion and sediment control plan will be required during the development process until the completion of construction to ensure that sediment discharge from the site is kept to acceptable levels.

Salinity at depth can be controlled by minimising the hydrological load on the site. Specific design and management controls are presented to detect and subsequently limit the development of rising groundwater table conditions.

Plant growth in the low fertility site soils can be encouraged by the application of fertiliser where required. A fertiliser a mix of nitrogen (N), phosphorous (P) and potassium (K) is recommended. The application should be a minimum of 40 kg/ha of P and 100 kg/ha of K.

Single and double storey residential structures and similar infrastructure buildings will be founded typically on residual clayey soils that are generally dispersive and moderately to highly reactive. Detailed investigation will be required to assess individual or groups of sites in relation to lot classification and specific site preparation requirements. Due to the relatively deep clay profile (ie >2.0m) over most of the site, and the moderately to highly reactive nature of the soils, (based on the Atterberg Limits results) most sites can be expected to classify as M to H in accordance with AS2870. Sites with trees located in areas of high potential clay shrink/swell behaviour will require detailed assessment of moisture equilibrium conditions for design.

Roads that involve cut and fill may be constructed using the dispersive, moderate to high plasticity expansive clay soils but precautions are required. Shale excavated from other infrastructure construction may be available for use as fill and should prove to be a better material, both to handle during earthworks and in relation to engineering properties. The dispersive clays will soften substantially on saturation and will have low California Bearing Ratio (CBR) values and resulting relatively thick pavements. Use of these soils as a subgrade materials should be avoided if possible. The effects of the dispersive and expansive nature of the clayey soils as well as low CBR values can be improved by conventional lime stabilisation/modification of the soil during earthworks and construction. The amount of lime should be assessed from the results of CBR tests on stabilised samples. All batter slopes in the relatively dispersive clayey soil will require stabilisation. "Blue Book" stabilisation methods should be satisfactory to control erosion. The stabilisation works should be undertaken as soon as possible after completion of the batter.

Development in the area of the Western Precinct will involve construction of 7 major wetlands. The base of the ponds may in some cases be below the groundwater table level. Based on the available information, provision of a liner to the wetland facilities may be necessary to limit leakage of water into the groundwater system. Conditions at each specific wetland location should be further investigated and assessed in relation to liner requirements. The permeability of the stabilised material should be checked as permeability may increase with lime stabilisation. Groundwater conditions should be monitored by piezometers located at each wetland.

The soils and groundwater conditions at the site are such that specific management plans should be prepared to ensure that the development does not exacerbate the following conditions:

- Surficial soil salinity;
- Erosion;
- Sedimentation;

A management strategy has been outlined that should effectively deal with conditions that will be encountered during construction and occupation of the proposed development. A monitoring system is also presented that interfaces with the management strategy.

All design and construction teams should be formerly inducted to the management strategies developed for the site in relation to the control of salinity and erosion. This will assist orderly development of the site with due consideration to the controls required for the range of soil conditions encountered.

The results of the Lend Lease, Comland JV St Marys soils and groundwater investigation have indicated that the conditions are typical of those in western Sydney. The site is considered to be suitable for the proposed development. Careful management and monitoring is recommended during design, construction and occupation of the site in order to control potentially adverse conditions related to the soil conditions. The soils are to a variable degree, acidic, unstable, erodible, reactive, and of low fertility. The shale groundwater is saline and salinity develops with depth in the soil profile. Control of salinity is recommended by prevention of a rising groundwater table condition. The study recommends that a management strategy be formulated and that the development be monitored on a regular basis to assess the impact of the project on the environment. The monitoring programme should be designed to permit appropriate corrective action to be taken to prevent the development of adverse impacts.

TABLE OF CONTENTS

1 INTRODUCTION

1.1 General

The Lend Lease and Comland Joint Venture (JV), commissioned Environmental Investigation Services (EIS), a division of Jeffery & Katauskas Pty Ltd (J&K), to undertake a soil and groundwater investigation over part of the property at St Marys, currently owned by Comland. The site has a total area of approximately 1,538 Hectares (ha) and is shown on Figure 1. The west area of the site (Western Precinct) to the west of South Creek is to be developed initially, for predominantly residential purposes. The overall development includes construction of 14 significant wetland areas and creation of a central Biodiversity Zone (Regional Park). Six of the proposed wetland areas are located in the Western Precinct.

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The results of the investigation are presented in three volumes. This volume (Volume 1) provides an overview of the investigation and presents the management strategies. The technical results and documentation are presented in Volumes 2 and 3.

EIS retained Perrens Consultants Pty Ltd and Woodlots and Wetlands Pty Ltd to undertake soil salinity, fertility and erosion studies for the project, in relation to urban capability development. An Electro-Magnetic Induction Survey (EMI) was also undertaken by the Department of Land and Water Conservation, together with laboratory testing at Scone. The JV retained Sinclair Knight Merz directly to prepare urban capability maps for the Western Precinct. The maps are presented in Volume 3 of this report.

The scope of the work for this investigation included the development of management strategies in relation to impacts of the development associated with the following site features:

- Landform;
- Geology;
- Soils;
- Groundwater.

1.2 Proposed Development

The planning strategy for the development of the Comland site includes:

- Establishment of a 630ha regional park under NPWS Act;
- Dedication of 48ha of regional open space for parks, and passive and active recreational areas;
- Development of approximately 730ha of land for urban uses including three urban villages for at least 8000 dwellings, schools, retail areas, community uses and 98ha for employment (business park and extension to Dunheved industrial estate), together with appropriate infrastructure. This land designated for urban development is presently cleared and was used previously for cultivation, and more recently for Defence Purposes).

The site is proposed to be developed in the following stages:

- Stage 1: Western Precinct and Dunheved North and South Precincts;
- Stage 2: Eastern Precinct and Ropes Creek Precinct;
- Stage 3: Central Precinct.

This investigation has addressed conditions in the Western Precinct.

1.3 Draft Sydney Regional Environmental Plan No 30 (SREP) and Draft St Marys Environmental Planning Strategy (EPS)

The draft Sydney Regional Environmental Plan was prepared by the Department of Urban Affairs and Planning (DUAP) under the Environmental Planning and Assessment Act 1979.

One of the aims of this plan is to support the draft DUAP St Marys Environmental Planning Strategy (EPS) by providing a framework for the sustainable development and management of the St Marys land.

The draft SREP and EPS documents contain a set of performance objectives that include the watercycle and soils. The REP stipulates that development consent must not be granted unless the consent authority is satisfied that the proposed development will not be inconsistent with achievement of due performance objectives.

In relation to soil and groundwater impacts the performance objectives include the following considerations (flooding considerations are not discussed in this document and were excluded from the scope of this investigation):

(CLAUSE 28) WATERCYCLE:

- The use of the land to which this plan applies is to incorporate stormwater management measures that ensure there is no net adverse impact upon the water quality (nutrients and suspended solids) in South Creek and Hawkesbury-Nepean catchments;

- During construction, impacts upon water quality are to be minimised;
- Water usage on and the importation of potable water onto the land to which this plan applies are to be minimised;
- Development is to be designed and carried out so as to ensure that there is no significant increase in the water table level and that adverse salinity impacts will not result;
- There is to be only minimal impact upon flood levels upstream or downstream of the land to which this plan applies as a consequence of its development;
- Drainage lines are to be constructed and vegetated so that they approximate as natural state as possible;
- Development is to be carried out in a manner that minimises flood risk to both people and property;
- Changes in flow regimes due to development are to be minimised for rainfall events up to the 50% AEP rainfall event.

(CLAUSE 29) SOILS:

Development is to have regard to soil constraints to ensure that the risk of adverse environmental and economic impacts are minimised.

The draft SREP requires that the development controls contained in the EPS be considered in the Western Precinct as a part of the development assessment process. The proposed development controls that relate to soils and groundwater issues are summarised below:

- Additional investigations are to be undertaken to assess soil types and to assess urban development capability;
- A watercycle management strategy is to be prepared to address the following:
  - minimisation of potable water usage onsite;
  - development of best practice measures for stormwater reuse for open space irrigation;
  - reduction of potable water demand;
  - minimisation of adverse impacts on local groundwater regimes;
  - minimisation of change in local flow regimes;
  - preparation of watercycle maintenance and monitoring management system.
- An Electro-Magnetic induction (EMI) survey of the site is to be undertaken to identify areas of high recharge and zones of salts in discharge areas;
- A groundwater management strategy is to be prepared for each release area, in conjunction with the EMI survey that includes the following;

  - layout and location of roads, dwellings, wetlands and stormwater detention basins;
  - cumulative development impacts;
  - groundwater management strategy related to;
    - adoption of small garden/lawn areas to reduce irrigation requirements;
    - use of low water requirement plants;
    - use of mulch cover (not in drainage lines);
    - use of low flow watering facilities to avoid overwatering of gardens;
    - implementation of tree planting program, especially in high recharge areas of native, deep rooted, large growing species to assist retention of the groundwater at existing levels;
    - retention of existing native tree cover where possible;
    - not permitting infiltration pits or tanks to disperse surface water;
  - An assessment of soil and rock conditions at the site, including erosion, expansive and dispersive soil problems, and plant growth potential;
  - The NSW Department of Housing "Managing Urban Stormwater: Soil and Construction (1998)" (the Blue Book) is to be used as a guide to prepare soil and water management plans. The approved plan and subsequent works are to be supervised by appropriately qualified experienced personnel.
- In addition to the Blue Book requirements, the soil and water management plans will deal with and be consistent with the following;
  - Stabilisation of disturbed surfaces within 10 days of formation;
  - Erosion protection of temporary topsoil stockpiles if not to be used within 10 days and upslope run-off erosion protection;
  - Minimisation of soil disturbance;
  - Temporary sedimentation basins to be located to maximum effectiveness and minimum sediment transport, together with erosion control works;
  - Minimisation of long-term degradation of the soil, water and native vegetation, due to potential adverse impacts by salinity;
  - Specific stabilisation measures for areas of high potential soil erosion both during and after construction, including turf stabilisation, straw and other mulches, soil binders and various types of stabilisation blankets;
  - Sedimentation control structures for each construction area including sediment traps and fencing, grass and other types of filter system, and sump pit and sediment basins;
  - Site inspection program to be developed. A management plan is to be prepared to ensure that the various soil and water management works are carried out and maintained satisfactorily.

2 SCOPE OF WORK

The scope of work undertaken for the field investigation included the following;

- Installation of deep shale and shallow clay groundwater piezometers at each of the seven proposed wetland locations in the Western Precinct;
- Drilling, sampling and installation of six additional groundwater piezometers in selected area adjacent to drainage lines upstream of the wetland areas generally representing the higher portions of the site;
- Soil profile assessment and sampling at twenty eight test pit locations (together with an additional three surface sample locations) at selected strategic positions over the site, with sampling at various depths down to 2m (locations selected to support data collection for the urban capability mapping). Sixteen test pits were located in the general development site area and twelve in drainage line and wetland areas;
- Electro-Magnetic Induction Survey to map soil salinity conditions and to assess areas of significant recharge;
- Preparation of management plans to address ground related issues associated with the proposed development and to provide baseline data for future comparison purposes.

The following soil parameters were included in the investigation and assessment: electrical conductivity, erosion, pH, organic carbon content, dispersion, Emerson Aggregate Test Class Numbers, particle size analysis, cation exchange capacity, exchangeable sodium, potassium, calcium, magnesium and aluminium, available phosphorous content, lime requirements, K rating (soil erodibility factor for R-USLE), bulk density and wet strength.

Geotechnical soil conditions were assessed including: soil particle size, Atterberg Limit tests, SPT tests, reactivity and permeability.

Groundwater conditions were assessed and included the following: depth and AHD levels, flow conditions, salinity, pH and chemistry.

3 SITE HISTORY

The St Marys site was first surveyed and land grants issued in 1803. By 1810, the family of Governor King used the land for grazing stock and their homestead named Dunheved was built.

During World War 2, the Commonwealth Government acquired the land for defence purposes.

In 1993, the St Marys site was identified for inclusion in the Sydney Region Urban Development Program (UDP). The St Marys site was identified as an opportunity to provide housing for Sydney's growing population within an environmentally sustainable framework. Over the next 15 to 20 years this area could provide approximately 8,000 homes, add approximately 678ha of land to Western Sydney's open space network and generate additional employment opportunities.

Decontamination processes were carried out between 1993 and 1997. These have been audited by an independent auditor and the land has been cleared for urban land use.

4 REGIONAL AND LOCAL CONDITIONS

4.1 Regional Geology

The site is located within an extensive outcrop of the sedimentary Wianamatta Group of rocks. The 1:100,000 geological map of Penrith (Map 9030, 1:100,000 Department of Mineral Resources – 1991, Edition 1) indicates that at the east and west portions of the site, residual soil is underlain by Bringelly Shale deposits consisting of shale, carbonaceous claystone, laminite, fine to medium grained lithic sandstone, rare coal and tuff. The central section of the site consists of fluvial deposits of fine grained sand, silt and clay associated with South Creek. The central north section consists of clay with patches of tertiary ferruginised (iron-bearing) consolidated sand.

The Wianamatta Group is characterised by very low rock permeability and high salinity, associated with the marine depositional environment during the middle Triassic period. This typically renders the groundwater unsuitable for any use due to low yield and poor quality.

Residual soils derived from the Bringelly shale are expected to show higher salinity levels than the alluvial soils due to derivation from a relatively saline geological unit.

4.2 Hydrogeology

South Creek and Ropes Creek cross the site in a south-north direction. Immediately to the north of the site, Ropes Creek joins South Creek which flows approximately 15km further north prior to joining the Hawkesbury River. These water courses discharge into the Hawkesbury-Nepean River system. The west portion of the site drains toward the east and into South Creek.

4.3 Soils

Details of the soils at the site are presented in the Soil Conservation Service, DLWC publication – "Soil Landscapes of the Penrith 1:100,000 Sheet" (1990). Four soil landscape types have been identified over the whole of the site:

- Blacktown soils - characterised by primarily moderate erodibility with some high localised occurrences, low dispersivity and localised areas of moderate salinity;
- Berkshire Park soils - characterised by localised erodibility with high erodibility in some cases, low dispersivity and low salinity;
- Luddenham soils - characterised by highly erodible topsoils, moderate to high dispersivity and low salinity;
- South Creek soils - characterised by primarily high to severe, widespread erodibility, moderate dispersivity and high salinity.

The soils in the Western Precinct consist principally of the Luddenham soil landscape type and those in the Biodiversity Zone, the South Creek soil landscape type.

4.4 Topography

The site is located within an area of Sydney known as the Cumberland Plain – a gently undulating area within the Hawkesbury-Nepean catchment in Western Sydney. The site is characterised by the two central creeks (Ropes and South Creeks) with relatively flat flood plain areas in their vicinity lying at approximately 10m to 20m AHD. To the west the land is moderately undulating and rises up to approximately 50m AHD with several hills at the north-west of the site. To the east of the creeks the land rises to 30m to 40m AHD and is gently undulating.

5 INVESTIGATION PROCEDURES AND RESULTS

The investigation methodology and the results of the investigation are presented in Volume 2 of this investigation report.

6 DISCUSSION

6.1 General

The St Marys development is relatively unique in that soil and groundwater assessment at the pre-development stage has been undertaken in order to identify and manage important factors which will influence both the short and long term success of the project. The planning to date has involved various NSW government departments and the site owner/developers: Comland and Lend Lease Pty Ltd.

Details of the soils and groundwater investigation and the results are presented in Volume 2 of this report.

6.2 Previous Investigation

EIS previously reviewed the regional soil and groundwater conditions, including existing borehole log information, groundwater levels and soil salinity measurements obtained during ADI field investigations at the site. Documentation of this review was published as Technical Appendix E: Soil and Groundwater to the *"ADI St Marys Watercycle and Soil Management Study"* produced for the ADI St Marys Draft REP Steering Committee by Sinclair Knight Merz (1998). This work was also used in the preparation of the Draft St Marys Planning Strategy (DUAP, 1999) referenced above.

Previous investigations indicated that the groundwater depth at the site varies from 2 to 6 metres (m) below ground level. The typical depth was approximately 3m and the groundwater table lies primarily in the alluvial soils and in some instances in the underlying shale. The recorded groundwater conductivity results indicate a wide variability ranging from 0.2dS/m to 55.83dS/m.

The groundwater environment comprises:

- A probable perched aquifer system in the alluvial soils in the central section of the site;
- Regional groundwater system with very low permeability and very low storage shale at variable but unknown depth;
- A possible perched aquifer system above the shale characterised by relatively low permeability clayey soils, with relatively low storage;
- Flow in the alluvial aquifer generally to the north, in sympathy with the regional drainage;
- Flow in the shale in the west section of the site to the east and in the east section of the site to the west, toward the central creek system.

Reported soil salinity measurements at the site obtained from depths of 0.1m to 1.0m, indicated the majority of the electrical conductivity readings to be less than 0.28dS/m, with some values up to 0.8dS/m and a few to 2.4dS/m (unadjusted for texture). Levels of less than 0.3dS/m are generally considered to be relatively low.

6.3 Site Investigation

Collection of soil and groundwater data has been based on a broad investigation of conditions at a range of locations in the Western Precinct. An Electro-Magnetic Induction Survey (EMI), designed to locate anomalies in relation to groundwater and salinity conditions, was used to assess variation of the electrical conductivity at a higher level of detail.

The intensity of investigation at this time is considered to be sufficient to provide a rational basis for decisions to permit the project to proceed in association with the appropriate development controls.

The investigation has identified a number of parameters that require specialised design, management and construction techniques to ensure satisfactory site development. The techniques commonly required for development in the western area of Sydney are well documented in various site development guidelines, including The NSW Department of Housing "Managing Urban Stormwater: Soil and Construction (1998)" (the Blue Book). No soil or groundwater constraints that would preclude residential development of the site were identified in the investigation, apart from the obvious limitations to the development of building sites within existing or future drainage features.

The parameters that require special treatment are listed below:

- Expansive soil behaviour;
- Dispersive soil behaviour;
- Low soil pH;
- Soil erosion potential;
- Limited areas of potential seasonal soil water logging;
- Limited areas of saline soils (the salinity increases with depth within the soil profile).

6.4 Soil Behaviour

The Western Precinct soils are residual in nature, derived from in-situ weathering of the parent Bringelly Shale bedrock. This sedimentary formation was deposited in a marine environment and the shale, and associated groundwater within the shale, is well known for the resulting relatively high salt content. The high concentration of salt, (ie sodium chloride) in the residual soil leads to a condition of relatively high soil sodicity, as measured by the concentration of exchangeable sodium cations as a percentage of the total cation concentration. The effect is more pronounced with depth as the some of the salt has leached from the surficial soils. Due to the presence of significant exchangeable sodium, the clay mineralogical structure is affected and the complex bond system between clay particles is weak compared to the bond system in soils where calcium is the dominant cation. The weaker nature of the bonds causes the clay to disperse more readily in the presence of water (particularly fresh or rainwater). The clay volume change with a change in moisture content is more pronounced, although the clay volume change characteristics are less affected by the sodicity than by the specific clay mineralogy. The sodicity does not imply high salinity as this is a result of the presence of free salt in the soil. The nature of the site soils leads to the need for special consideration of dispersivity, reactivity and salinity, together with low soil pH and low fertility soil properties.

The addition of calcium to sodic soils replaces the exchangeable sodium, resulting in a consequent reduction in sodicity, dispersion, softening (in the presence of water) and reactivity. Lime or gypsum is often used as such a source of calcium. The use of lime corrects a low pH and is also used to stabilise soils to improve the strength, and hence improve the soil subgrade properties for engineering purposes. Excessive addition of calcium should be avoided to minimise salt release. The reactions take time to occur and therefore the addition of lime and gypsum to the soils to reduce sodicity should be undertaken well in advance of construction.

6.5 Soil Salinity

Low soil salinity was encountered in the upper levels of the site soils to a depth of approximately 0.3m. The surficial soil salinity is considered to be satisfactory in relation to the proposed development. The soil salinity increases with depth and becomes relatively high at 1m. The proposed development should be designed not to mobilise salinity from depth and thereby untowardly effect the landscape. This can be achieved by limiting the depth of excavations where possible and by the provision of surface and subsoil drains to intercept water that would otherwise remain in the subsurface, leading to a possible build up of the groundwater table level.

The salinity results on samples from test pits (TP) TP12 and TP18 located in the south-west corner of the site adjacent to The Northern Road (as shown in Figure 2), indicate that special planning may be required to accommodate the saline nature of the surficial soils in this area. Further investigation in this area is required to assess these conditions.

6.6 Soil pH

Soil pH is an important soil fertility parameter. If the pH is outside of the desirable range revegetation is difficult and bare soils can be eroded. Highly acidic soils in the upper surface layer were encountered at the location of TP11, TP15 and TP17. Virtually all of the soils are strongly acidic. Exceptions occur at the location of TP5 and TP6 where soil pH conditions are optimal.

Surface soil acidity can be corrected by the addition of lime. The indicated requirements for agricultural lime are up to 5.6 tonnes per hectare (t/ha). The average requirement is estimated to be 2.9 t/ha. An initial combined gypsum and lime application is recommended and is described in the section dealing with dispersivity.

The acidic nature of the sites soils is not considered to be a limitation to the proposed development as conventional treatment by the addition of lime at the appropriate stage of a development process will overcome this deficiency.

6.7 Soil Dispersivity

Dispersive soils are commonly associated with the following soil behaviour in urban development areas:

- Sediment loss to streams;
- Susceptibility to tunnelling or piping through earth dams;
- Limited ability to hold water within detention ponds;
- Severe soil softening when saturated.

The surface soils in the general development area are slightly to moderately dispersive. Dispersivity increases with depth and soils at TP14, A1, A2 and C are highly dispersive and will require treatment in areas where the subsoil is exposed to avoid erosion.

The results adjacent to drainage lines appear similar to those in the proposed development areas, with low to moderate dispersibility in the subsurface soils. High to very high dispersibility occurs in the subsurface soil, which is consistent with the visual evidence of slumping of water course banks in drainage line areas.

Site development will involve the exposure of subsoil. The use of conventional treatment methods including the addition of gypsum onto exposed subsoil to counteract soil dispersion should be undertaken in all such areas.

An initial application of 10 tonnes per hectare of gypsum should be applied over the entire site, well in advance of the development, to permit the gypsum to migrate through the soil profile. The final calculated quantity of gypsum to be used should take into account the lime added to the site. At the recommended average liming rate of 2.9 tonnes per hectare, the quantity of gypsum can be reduced to 7.9 tonnes per hectare.

Conventional agricultural equipment can be used to apply high grade agricultural powdered lime and gypsum. A dual-axle truck mounted spreader equipped with a hopper, vibrating feed and spinner should be able to provide 20m to 30m cover per pass. The application should not involve cultivation or ripping in order to minimise deeper soil salinity mobilisation.

Application of the combined lime and gypsum treatment at an early stage of the overall project development timeframe will provide significant environmental benefit in reducing soil loss to streams and minimising erosion. The application can be staged with a desirable lead time of approximately one year.

Additional gypsum at an application rate of approximately 1kg/sqm (ie 10 tonnes per hectare) should be applied during construction when the subsoil is exposed during any aspect of the development works.

Construction of wetlands and detention ponds will also involve exposure of sodic soils. Gypsum should be applied to exposed surfaces during pond construction and site development phase to avoid dispersion and deflocculation of pond sediments (this would create an opaque suspension which would be difficult to treat or clarify). The need to apply gypsum to the drainage lines should be assessed by site specific investigation.

Provided that soil dispersion is properly controlled and managed soil dispersibility is not considered to be a limitation to the proposed site development.

6.8 Soil Erosion Potential

During construction limited areas of the site will be exposed without vegetation cover. The principle factors that affect potential soil erosion under these conditions are the erodibility of the soil, the slope angle and the length of uninterrupted slope.

All soils analysed for erodibility exhibited high to very high erodibility. An erosion and sediment control program will be required during the development process to manage and control sediment discharge from the site. The program should remain in place during the development phase until dwelling and all other construction is substantially completed.

Soil erosion is not considered to be a limitation to the proposed site development, provided appropriate management techniques are employed to limit erosion to acceptable levels.

6.9 Soil Fertility

Plant growth in the low fertility site soils can be encouraged by the application of fertiliser where required. A fertiliser mix of nitrogen (N), phosphorous (P) and potassium (K) is recommended. The application should be a minimum of 40 kg/ha of P and 100 kg/ha of K.

6.10 Groundwater

Groundwater at the site was encountered at depths of 0.95m to 6.05m during the investigation. Previous investigation data indicated depths to be from 2m to 6m. The typical depth was approximately 3m. Groundwater levels measured in April 2000 were approximately 0.15m higher than at the end of 1999 indicating some seasonal fluctuation.

Groundwater recharge will tend to be reduced by the proposed development due to the increased surface water runoff caused by the presence of paved and roofed areas. A rising groundwater table condition is considered to be undesirable, especially if the groundwater in the shale formation nears the ground surface. This groundwater is saline and will increase salinity in the affected area. This can be avoided by appropriate planning and design, which will involve management of all factors that could lead to a rise in the groundwater table level. The fundamental aspect of this planning is to prevent any increase in groundwater recharge (any decrease would generally be beneficial). A management monitoring plan will be required to assess and correct any observed tendency for the groundwater table level to rise.

The proposed wetlands to be constructed for the development should be lined in order to prevent any increase in groundwater recharge in these areas. Liner requirements for major site drainage works should be assessed during detailed design.

6.11 Residential and Infrastructure Building Foundation Conditions

Single and double storey residential structures and similar infrastructure buildings will be founded typically on residual clayey soils that are generally dispersive, and moderately to highly reactive.

Detailed investigation will be required to assess individual or groups of sites in relation to lot classification and specific site preparation requirements. Due to the relatively deep clay profile (ie >2.0m) over most of the site, and the moderately to highly reactive nature of the soils, (as based on the Atterberg Limits results) most sites can be expected to classify as M to H in accordance with AS2870. Earthworks at the site will change these classifications and technically where fill is greater than 0.4m thick the lots would be classified as P. If the fill is tested to Level 1 certification, a reclassification to Class M or H may be achieved. Detailed shrink/swell assessment may show the site soils to be less reactive than expected as the clay soils have a somewhat higher sand fraction than those typically encountered in the western areas of Sydney.

Sites with trees located in areas of high potential clay shrink/swell behaviour will require special consideration as the time required for the development of equilibrium conditions after tree removal can be around 2 years depending on the rainfall. Detailed assessment should be undertaken in such instances to assess potential foundation movement conditions. If trees are to be cleared, this should preferentially be completed a year or more prior to the commencement of works associated with the development.

6.12 Roads

Road fill may be constructed using the dispersive, moderate to high plasticity clay soils but precautions are required. Shale excavated from other infrastructure construction may be available for use as fill and should prove to be a better material, both to handle during earthworks and in relation to engineering properties. The dispersive clays will soften substantially on saturation and will have low California Bearing Ratio (CBR) values and resulting relatively thick pavements. Use of these soils as a subgrade material should be avoided if possible. Alternatively these soils could be improved by lime stabilisation/modification.

Roads located in potential water logged areas should preferably be built up/down slope to minimise the damming effect of the roadway to the downhill flow of subsurface water. The need for subsoil drainage as part of road construction should be assessed on a case by case basis by the designer.

Site preparation should be based on good engineering practices including topsoil stripping and grubbing, and treatment of soft spots etc. The effects of the dispersive and expansive nature of the clayey soils and related low CBR values can be improved by conventional lime stabilisation/modification of the soil during earthworks and construction. The amount of lime should be assessed from the results of CBR tests on stabilised samples. Compaction of fill should generally be at or just above Standard Optimum Moisture Content, to at least a density of between 100% and 104% of the Standard Maximum Dry Density, this will minimise future dispersion and softening.

All batter slopes in the relatively dispersive clayey soil will require stabilisation. Standard "Blue Book" stabilisation methods should be satisfactory to control erosion. The stabilisation works should be undertaken as soon as possible after completion of the batter.

6.13 Wetlands

Development in the area of the Western Precinct will involve construction of 7 major wetlands to depths up to approximately 3.0m. One of the ponds may extend down into the Bringelly shale. The base of the ponds may in some cases be below the groundwater table level. The depth to groundwater and other details are shown in the table below:

Wetland Location	Wetland Designation	Approximate AHD Datum (m) Ground Level (investigation location)	Depth to Shale (m)	Depth to groundwater table (from GL) (m)	
				(1)	(2)
P1	C1	29.43	6.2	2.05	1.42
P2	C2	22.04	>9.0	6.15	6.05
P3	C3	21.97	8.5	5.10	5.24
P4	A1	25.46	5.0	1.65	1.60
P5	A2	28.70	5.7	1.80	1.95
P6	-	38.19	3.8	1.05	0.94
P7	-	34.44	2.5	1.65	1.80

Explanation:

(1) Deep Shale Piezometer
(2) Shallow Clay Piezometer (Measurements taken January 2000)

The data in the above table was obtained after a period of significant wet weather. Seasonal fluctuation of this data must be expected and should be assessed by additional monitoring.

Groundwater data and inferred contours are presented in Figures 4 and 5 and a description of groundwater conditions is presented in Volume 2 of this report.

Leakage from the wetlands into the underlying clay or shale aquifer may be significant as the wetland water level will be designed to be maintained at a constant level. Such leakage could be expected to lead to a localised rise in the groundwater table level due to the additional aquifer recharge, which may lead to the development of soil salinity problems.

Based on the available information, provision of a liner to the wetland facilities may be necessary. Conditions at each specific wetland location should be further investigated and assessed in relation to liner requirements and other design parameters.

Liners should be able to be constructed from on-site clayey soils, provided the dispersive behaviour is reduced by lime stabilisation of the soil during construction. Good quality soils should be identified by sampling and testing during the wetland construction and such materials stockpiled during site earthworks for later use. The permeability of the stabilised material should be checked as this may be reduced by the lime stabilisation.

Provision of a clay liner to the wetland facilities will reduce the loss of water from the wetlands through leakage. This will assist maintenance of a constant pond water level during dry weather periods. The thickness of the liner will be dependant on the availability of appropriate quality soils, and the construction method, together with operational methods for sediment removal from the wetlands. A liner thickness of approximately 0.5m to 1.0m is envisaged, based on the available information. A synthetic liner alternative may prove to be more economical.

Although groundwater is not considered to be a resource in the area and there are low flows and small volumes involved, monitoring of groundwater conditions is considered necessary. This work should include ongoing monitoring of the two piezometers located at each wetland location. The groundwater level and field parameters should be measured (pH, Eh, EC and T) every three months to assess variation.

Wetland construction at the St Marys site should involve sediment and erosion controls. This is required as disturbance caused by the construction will cause erosion until stabilisation measures become effective and landscaping is complete.

7 EMI SURVEY AND FURTHER WORK

An Electro-Magnetic Induction (EMI) Survey was performed to assess soil salinity conditions and to assess areas of significant areas of recharge at the site. The instrument used to survey the bulk apparent electrical conductivity (EC_a) was a EMI 31 sensor and measured average conditions to a depth of approximately six metres in the soil profile. A map was produced to show the distribution of the readings. The electrical conductivity is an indirect measure of salinity.

The EMI survey results showed a distribution of EC_a readings that would normally be associated with similar creek and flow systems that exist at the site. Generally low readings were observed on the ridges, gradually becoming higher on the lower slopes and low-lying areas of the site. This distribution of readings typically corresponds to ridges with dry sandy textured soils leached of cyclic salts and lower regions with potentially water logged clayey textured soils with higher salt concentrations.

The EMI survey results detected six anomalous zones in the Western Precinct area. These areas were subsequently investigated by a further series of test pits and the anomalies were explained in relation to the conditions established by the further investigation. No high recharge or areas of potential water logging were identified by the further investigation. One poorly drained area was identified which can be managed by provision of better site drainage in this area of the site.

The EC_a is dependent upon the relative amounts of moisture, clay, gravel (rock) and salts in the soil. The total amount of soil pore space, soil moisture or groundwater within the pore spaces, the salinity of the water, the temperature of the soil profile, the amount and type of clay and the amount of organic material within the soil also have an influence on the measured EC_a. The EMI survey report and maps are presented in Volume 2 of this report, as Appendix B.

The anomalous zones included two areas of high conductivity and were investigated by the excavation of ten additional test pits, with limited laboratory analysis of soil samples obtained from the test pits. The assessment included a detailed visual examination of the soil, measurement of the moisture content, EC and pH, grain size and measurement of the depth to bedrock. The results of the additional work are described in the section below.

7.1 Anomaly 1 and 2

During the initial EMI site inspection field measurements with a conductivity probe detected moderate to high EC values at the location of two surface water flow lines at the north and west boundaries of the site. The values were 9.2dS/m at the north boundary (Anomaly 1) and 1.2dS/m near the west boundary (Anomaly 2). Anomaly 2 may be associated with Anomaly 4, detected by the EMI survey (see later section).

Water samples were obtained from these two drainage lines (entering the property at the north and west boundaries of the site) as a part of the additional investigation to assess the EMI anomalies to check surface water quality conditions. Laboratory analysis of these samples (SW1 corresponding to Anomaly 1 and SW2 corresponding to Anomaly 2) included pH, conductivity, and total dissolved solids (TDS). The results of these analyses indicated that the surface water at the time of field work was relatively fresh with a conductivity of 0.79dS/m and 0.62dS/m and a pH of 7.78 and

7.07 respectively. The water flow at the time of sampling was relatively low (like a seep condition) and the measured EC values are not considered to be of concern, given the low flow. Significant dilution could be expected during wet weather conditions.

7.2 Anomaly 1- Soil

The survey encountered two zones with unusually low apparent bulk conductivity and these are shown as Anomaly 1 and Anomaly 5 in Figure 6. The low values were considered to possibly be related to soil chemistry and texture.

Test pits TP1, TP2, TP3 and TP8 excavated for the initial investigation in the area of Anomaly 1 gave low EC values at the surface at all locations, very low (TP2), low (TP1) and high (TP3 and TP8) at 1m depth.

Additional field work after the EMI survey included the excavation of two test pits in the vicinity of Anomaly 1 (TP209 and TP210 within the zone of lowest EC_a readings). TP209 encountered dry silty sandy clay that graded to fissured silty sandy clay, underlain by sandstone at approximately 1.5m. Laboratory analysis of soil samples taken at various depths indicated that the saturated paste EC was in the medium (2.4dS/m to 4.3dS/m) range apart from a band of greater salinity at approximately 0.25 to 0.4m (10.1dS/m). The fissured nature of the clay and shallow depth to the sandstone at this location is associated with a well drained profile. These properties are considered to be the most likely explanation for the relatively low EC_a values.

TP210 also encountered silty sandy clay with increasing bands of sandstone at a depth of greater than 1m. This material was less fissured than encountered at TP209 but appeared well drained. Laboratory analysis indicated that surface soil EC (saturated paste) reading was in the medium EC range (2.8dS/m) increasing to high range (6.6dS/m to 7.6dS/m) at depth. As above, the sandy nature of the clay, low moisture content and shallow (sandstone) rock is considered to be the most likely explanation for the lower than expected EC_a readings obtained in this area of the site. The relatively low levels of salinity in the area of Anomaly 1 are not considered to cause salinity issues associated with the proposed development.

7.3 Anomaly 3

Anomaly 3 was an area (referred to as Site 1 in the EMI report) along a drainage line with higher than expected EC_a readings, and the potential to become water-logged. Further investigation of the area was warranted as no test pits were excavated during the initial investigation. A piezometer was located in this vicinity but the borehole data does not explain the anomaly. TP207 and TP208 were located in this area of higher readings.

TP207 encountered silty sandy clay with bands of iron indurated gravel between 0.7m and 1.5m in depth. The test pit did not encounter groundwater and was terminated in clay at a depth of 2.8m. The moisture content of the samples was relatively low. Laboratory EC (saturated paste) analysis indicated medium levels at the surface (3.2dS/m), high (5.4 to 7.5dS/m) at 0.5m and extremely high at 2.0m (11.4dS/m).

TP208 encountered silty clay to a depth of 1.45m, underlain by silty sandy clay with high range EC (saturated paste) measurements in the surface soils (5.5dS/m) increasing to very high (8.3dS/m to 9.7dS/m) at depth (0.6m, 1.0m and 2.2m). Bedrock and groundwater were not encountered to a test pit termination depth of 2.2m.

The laboratory and field results for Anomaly 3 (TP207 and TP208) are considered to indicate that the high apparent EC_a readings are due to high salinity at depth in a deep soil profile. One of the piezometers installed at the edge of this anomaly showed the groundwater table to be relatively shallow compared to the site in general. This would also be expected to cause high EMI survey results. This anomaly is not considered to be a water-logging hazard.

7.4 Anomaly 4

Anomaly 4 was identified by the EMI as a drainage line within an area of relatively high salinity, and potential to become water-logged. As no site investigation data existed in this area further investigation was undertaken after the EMI survey. This included the excavation of TP203 and TP204.

Test pit TP203 encountered silty sandy clay overlying silty clay of relatively low moisture content. This pit was located adjacent to a 1.5m deep trench approximately 5 metres wide and in an area of highly disturbed soil with no vegetation cover. The laboratory results indicated that the soils to a depth 0.6m were extremely saline (13.1 to 17.1dS/m saturated paste). This reduced to the very high range (8.3dS/m to 9.9dS/m) at a depth of 1.0m to 1.6m. Groundwater and bedrock were not encountered at this location to the test pit termination depth of 1.6m.

TP204 was located in an area of moderately disturbed soil and encountered silty clay. The soils were typically of relatively low moisture content. Analysis of soil samples from various depths indicated that the surface and subsurface soils were within the medium salinity range (saturated paste) (2.2dS/m to 7.6dS/m) apart from a band of more saline soil at approximately 1.0m (8.0dS/m). Higher than expected EC_a readings may have been due to the increase in clay content of the soils at this location when compared to TP203.

The conditions encountered at Anomaly 4 are considered to reflect previous disturbance in the area and medium to high soil salinity measured on samples from the test pits. Relatively dry conditions were encountered in the test pits and groundwater was not encountered. The area is not considered to be a potential water-logging zone. The salinity conditions in this area should be investigated in more detail during the detailed design phase of the project prior to the commencement of site works.

7.5 Anomaly 5

Test pits TP21, TP22 and TP23 had formerly been excavated in the area of Anomaly 5 low EC_a readings. EC analysis of soils at these locations indicated low salinity at depth, increasing to relatively high readings at TP22 and TP23 at 1m depth.

Additional field work after the EMI survey included the excavation of two test pits located in this area (TP201 and TP202). TP201 encountered silty sandy clay with perched water seeping into the test pit from the surface soil (0.0m-0.3m). Laboratory analysis of a surface water sample (TP201W) indicated this water to be relatively fresh with an EC of 0.251dS/m. Significant areas of ponded water in the area of Anomaly 5 were observed. Laboratory analysis of the soils at various depths encountered soils with generally medium EC (2.17dS/m-3.75dS/m) apart from a band of higher salinity soil at 0.5m (10.8dS/m). The fresh water recharge at the surface and sandier nature of these soils is considered to probably be responsible for the EC_a survey readings. The soil at depth in the test pit was of lower moisture content, with a relatively dry layer at approximately 0.5m. Significant water logging at this location was not indicated. This area is not considered to be a potential water logging zone. However surface water drainage is required in this area.

TP202 encountered silty clay with fine grained sand soil of low salinity (1.12 to 2.03dS/m saturated paste) and moderate cation exchange capacity and moisture content. These soils were more clayey than those encountered at TP201 and although the surface soil was moist, there was less free surface water in the vicinity of this location. The low apparent readings at this location are considered to be due to the low salinity of the subsurface soil at this location. The relatively low levels of salinity in the area of Anomaly 5 are not considered to cause salinity issues associated with the proposed development.

7.6 Anomaly 6

Anomaly 6 was an unusually high conductivity area that lies within an area of moderate conductivity along a ridgeline. Two additional test pits were excavated within this area of higher EC_a (TP205 and TP206). Nearby investigation locations included TP207, TPA2 and TPA3, at the top of and on the north slope of the ridge line. These test pits encountered silty sandy clay and silty clay overlying sandstone at 1.2m

(TP7) and 1.4m (TPA3) and bands of extremely weathered shale (below 1.0m in TPA2). Soil analyses on samples from these test pits indicated very low salinity at the surface, increasing to medium salinity below 0.5m depth (4.4dS/m to 7.4dS/m).

TP205 and TP206 both encountered silty clay with bands of iron-stained distinctly weathered shale at depths of 1.0m and 1.4m respectively. The moisture content of the soils was generally low and no groundwater was encountered. Laboratory analysis of the soil from various depths indicated that the soils were of medium EC (saturated paste), increasing to high at depths greater than 0.3m. These results and the physical observations suggest that the high values are due to the shallow shale encountered at both locations, when compared to the sandstone in TP7 and TPA3 and the higher clay content at A2. These conditions are not considered to be significant in relation to salinity control.

7.7 Summary

Potential water logging hazards were identified by the EMI survey and each area has been assessed by test pit investigation. The results have shown that no significant water logging hazards exist at the site. A poorly drained area exists in the area of the site identified as Anomaly 5. Drainage in this area should be improved during the project development phase by construction of appropriate drains and berms. Maintenance of local drainage patterns in this area is critical and should be achieved by careful attention to the road pattern layout adopted during detailed design.

Potential areas of high salinity apparent from the EMI survey were also investigated by the excavation of test pits at each anomalous area. Apart from conditions encountered at Anomaly 4, salinity conditions were shown to be typical of the area in general. At Anomaly 4 significantly higher salinity was encountered and protective measures should be adopted during construction of the proposed development. The area showed signs of significant past disturbance. Ponding of water in this area should be prevented and the area should be properly drained to prevent moisture ingress and the release of salt to the environment. Detailed assessment of salinity conditions is recommended together with provision of good vegetation cover over the site. Further measures in selected areas may be required such as the provision of a topsoil cover and establishment of appropriate vegetation.

The conditions encountered in the anomalous areas of the site in relation to potential salinity and of waterlogging are not considered to be a constraint to the proposed development. Conventional, established treatment methods exist that can be used to manage conditions encountered at these locations.

8 MANAGEMENT STRATEGY

8.1 Purpose

The site investigation has indicated that the soils and groundwater conditions will not restrict the proposed development. The soils and groundwater conditions at the site are such that specific management plans should be prepared to ensure that the development does not exacerbate the following conditions:

- Surficial soil salinity;
- Erosion;
- Sedimentation.

Application of lime/gypsum to improve soil properties in relation to soil fertility, dispersion potential, soil structure and pH can be used to control soil behaviour during construction of the proposed development. In addition, fertiliser application is recommended at appropriate times throughout the lifetime of the development.

Both short and long term strategies are required to effectively deal with conditions that will be encountered during construction and occupation of the proposed development.

The management strategies to be developed need to consider the interaction and significance to the following groups:

- Site owner, Comland;
- Site developers, Comland and Lend Lease;
- Department of Urban Affairs and Planning;
- Department of Land and Water Conservation;
- Blacktown and Penrith Councils;
- Planning and design groups;
- Buyers of the land;
- Construction companies and builders.

The above requirements highlight the need for the management strategies to be developed at several levels. These will be influenced by the following;

- Controls and level of reinforcement of the plans feasible to be implemented during the various phases of the work;
- Level of understanding of the various groups;
- The interest that each group has in implementation of the controls.

The preparation of a St Marys management strategy handbook describing the necessity of and details of the management plans is recommended. Each plan should include the following:

- The scientific basis for the plan;
- The objective of the plan;
- The relevance of the plan to;
  1. Authorities;
  2. Planners;
  3. The designer;
  4. The constructor;
  5. The land buyer.
- Details of the plan should include sketches, notes and the importance of each part of the plan to the management strategy.

A suitable code should be used throughout the document to provide ready access for appropriate groups to applicable information. The benefits to all concerned should be clearly described and presented.

8.2 Objective

The objective of the management strategy is to ensure that the site characteristics are appropriately considered during the planning, construction and post construction phases of the project. Implementation of these strategies should result in a successful development. The work undertaken for the soil and groundwater investigation has highlighted particular factors that are outlined in this section. These are in addition to, or highlight, the factors discussed in Section 1.3 which summarises the draft St Marys Environmental Plan performance objectives.

8.3 Landuse

Appropriate location of the various facilities for the St Marys development will facilitate salinity control by minimisation of both groundwater recharge and mobilisation of salt to the surface soils in higher areas of the site.

The proposed development includes construction of the following;

- Roads;
- Schools, shopping centres and commercial/industrial facilities;
- Houses;
- Sports facilities and recreational areas.

Roads, schools, commercial/industrial facilities and houses typically have approximately 60% of the area as impervious surfaces, whereas open space typically has about 5%.

A conceptual rainfall percolation modelling exercise undertaken for the St Marys site indicates that rainfall percolation in open space areas will be up to double that for the other types of development. All open recreation and sports areas should be located in the lower parts of the landscape. All other facilities, including commercial/industrial and residential areas should be located in the upper parts of the landscape. All runoff should be piped to the major drainage lines.

Placement of sports facilities and open areas in the lower parts of the landscape will increase percolation in these low-lying zones. The increased percolation and corresponding recharge will move downwards to the top of the lower, saline groundwater table. This is of benefit as the presence of this layer of groundwater over the more saline layer will tend to suppress any potential saline groundwater table level rise.

8.4 Design Phase

During detailed design of the subdivision the following factors are critical:

- The depth of cut in all areas of the site should be minimised to reduce exposure of the deeper subsurface soil profile. This will assist the control of salinity, dispersivity and erosion conditions;
- The planned extent of areas to be disturbed should be minimised to assist erosion and sediment control (this includes definition and control of construction traffic routes etc);

Due to the need to remove surface water rapidly from the site, the subdivision, drainage design should include the following considerations:

- All roof and pavement drainage should be piped or channelled to the stormwater drainage system. Overland flow (path length and extent) over the entire site should be minimised. The system should be of appropriate capacity to prevent localised flooding;
- The construction planning should highlight the need to complete drainage works as soon as possible in the schedule of any works.
- Infiltration pits should not be used;
- Subsoil drainage (ie. aggregate drains) should be provided at locations where there is potential for the groundwater table level to rise (eg. roads that cross areas of shallow groundwater flow;
- The requirements for liners in major drainage channels should be assessed on a site specific basis;
- Where necessary the wetlands should be lined with an appropriate clay or synthetic lining system to prevent leakage into the groundwater system;

- Any identified groundwater exit points at the site should be provided with subsoil drains and the water appropriately disposed of depending on the site specific conditions.

The above factors relate to reduction of groundwater recharge which will minimise the potential for the development of surficial soil salinity.

Landscape design should be based on the following;

- Selection of plant species suitable for the given soil conditions;
- The establishment of deep rooted trees should be planned and encouraged. Such trees will draw water from the groundwater system. This is of benefit as the trees will tend to lower the groundwater table (or reduce the tendency for the groundwater table to rise).

Investigations of soil conditions at the site are presently broadly based. The design process should include further assessment as required.

8.5 Construction Phase

The following issues should be addressed by the construction management plan for the site:

- Treatment of the majority of the site area with lime and gypsum at an early stage of the development is required in order to improve soil stability conditions. Further treatment will be required during construction where new disturbance occurs. The addition of fertiliser is also required and should be undertaken at appropriate locations as required during the various stages of the works;
- Conventional topsoil removal and stockpiling for later use should be undertaken in areas of proposed site excavation;
- Surface water runoff should be directed around all stockpiles and work areas. Standard (Blue Book) methods can be used for these purposes;
- Stockpile and disturbed area erosion control should be planned during all stages of construction using standard (Blue Book) methods;
- Temporary sediment control structures should used during all of the site development works;
- In-situ lime stabilisation and compaction of the clay subgrade will be necessary or preferential for road design and construction.

The above construction phase factors and considerations apply to all of the development works, including individual dwelling/building construction.

8.6 Post Construction

On completion of construction, monitoring and maintenance of the development by the maintaining authority in relation to soil and groundwater conditions will be required. The fundamentals of the monitoring system are outlined below:

- Weekly to two weekly inspections of the major facilities built for the residential development should be undertaken. This should include major drainage lines, wetlands and sediment basins. Inspections on a daily basis should be undertaken during periods of heavy rainfall. Wetland, drainage basin and drainage water samples should be obtained and analysed. Field analyses should include for turbidity, pH, conductivity and Eh. Any marked departures from average conditions should be investigated immediately, and action taken to correct the conditions causing the problem. Standard reporting forms should be developed for recording information;
- Monthly to three monthly detailed inspections of the whole area should be undertaken to record information relating to the condition of embankments, vegetation, roads, ponds, sediment movement, rubbish accumulation etc. Any water seepage or the presence of salt should be noted and immediate action taken to assess the cause of the condition;
- A system of groundwater monitoring bores should be installed and monitored at three monthly intervals. The bores should be located each wetland (from 2 to 4 per wetland depending on size) and at regular intervals of 300m to 500m along drainage lines. The monitoring program should include water levels and water samples should be obtained and analysed in the field for the same parameters as the wetlands. Departures from average conditions should be investigated and action taken as required;
- Annual inspection of the sediment load in the drainage and wetland/pond facilities should be undertaken. Sediment and water, plus selected groundwater samples should be obtained and analysed. Standard analysis should be undertaken for BOD and nutrients, together with assessment of contaminants including heavy metals, hydrocarbons and pesticides. Any unusual odour or colour conditions should be investigated;
- During periods of drought special monitoring and maintenance may be required to ensure that liners and other features of the facilities are maintained.

Regular maintenance of drainage and wetland facilities will be required, including sediment removal and vegetation clearing. Normal security and public safety provisions for the facilities will also be required.

A summary of the soil and groundwater management strategy is presented in the following table.

ST MARYS DEVELOPMENT
SALINITY, EROSION AND SEDIMENT CONTROL MANAGEMENT STRATEGY

OBJECTIVE	BENEFIT	CONTROL	DETAILS	MONITORING METHOD	MANAGEMENT METHOD
SALINITY CONTROL MINIMISE GROUNDWATER RECHARGE	PREVENT RISING GROUNDWATER TABLE LEVEL AND DEVELOPMENT OF SALINE SOIL PROBLEMS	MINIMISE IMPORTATION AND USE OF POTABLE WATER ONTO THE SITE	• REUSE STORMWATER FOR IRRIGATION OF OPEN AREAS • MINIMISE POTABLE WATER DEMAND	INSTALL MONITORING BORE NETWORK	• MONITOR GROUNDWATER TABLE LEVELS AT 3 MONTHLY INTERVALS • PERFORM REGULAR, RANDOM INSPECTIONS OF HOUSE SITES, AND VEGETATION AND GENERAL INFRASTRUCTURE AREAS
		REDUCE IRRIGATION REQUIREMENTS	• ADOPT SMALL GARDEN/LAWN AREAS • ESTABLISH LOW WATER REQUIREMENT PLANTS • USE MULCH COVER • USE LOW FLOW WATERING FACILITIES		
		AVOID USE OF INFILTRATION PITS TO DISPERSE SURFACE WATER	• DESIGN STORMWATER SYSTEM TO NEGATE NEED FOR HOME SITE STORMWATER STORAGE DISPOSAL • CONNECT ALL DOWNPIPES DIRECTLY TO STORMWATER		
		PREVENT LEAKAGE FROM WETLAND AND DRAINAGE FACILITIES	• LINE ALL PERMANENT STORMWATER RETENTION STRUCTURES AND WETLANDS		
SALINITY CONTROL ENCOURAGE USE OF GROUNDWATER AS A RESOURCE	MAINTAIN OR LOWER GROUNDWATER TABLE LEVEL	ENCOURAGE TREE PLANTING AND RETENTION, ESPECIALLY IN AREAS OF HIGHER RECHARGE	• USE/RETAIN NATIVE, DEEP-ROOTED, LARGE GROWING SPECIES		
EROSION CONTROL	PREVENTS SILTATION PROBLEMS IN DRAINAGE FACILITIES AND DAMAGE THAT COULD RESULT FROM EROSION	DESIGN ALL WORKS TO LIMIT GENERATION OF POTENTIAL EROSION SURFACES AND STABILISE DISTURBED AREAS AS SOON AS POSSIBLE	• STABILISE DISTURBED SURFACES WITHIN 10 DAYS • CONSERVE TOPSOIL BY STOCKPILING FOR LATER REUSE • USE FAST GROWING GRASS SPECIES • USE TEMPORARY GROUND COVER FOR AREAS TO BE REDISTURBED • MINIMISE AREA OF DISTURBANCE • COVER STOCKPILES WITHIN 10 DAYS • USE LIME STABILISATION DURING EARTHWORKS TO IMPROVE SUBGRADE AND REDUCE DISPERSIBILITY	• UNDERTAKE REGULAR INSPECTIONS OF ALL CONSTRUCTION ACTIVITIES • PERFORM REGULAR INSPECTION OF VEGETATION CONDITION IN DEVELOPMENT AREA	REGULAR INSPECTION REPORTS TO BE SUBMITTED TO CONTROLLING AUTHORITY
SEDIMENT CONTROL	CONTROL SEDIMENT GENERATED BY CONSTRUCTION AND OTHER ACTIVITIES	INCLUDE SEDIMENT CONTROL CONSIDERATIONS IN ALL DESIGNS	• PROTECT STOCKPILES FROM EROSION BY RUNOFF FROM UPSLOPE • USE TEMPORARY SEDIMENT BASINS LOCATED TO MAXIMISE EFFECTIVENESS AND MINIMISE SEDIMENT TRANSPORT • USE SPECIFIC SOIL STABILISATION MEASURES IN AREAS OF HIGH POTENTIAL SOIL EROSION		

This report has been prepared for the particular project described and no responsibility is accepted for the use of any part of this report in any other context or for any other purpose. J&K has used a degree of care, skill and diligence normally exercised by consulting engineers in similar circumstances and locality. No other warranty expressed or implied is made or intended. Subject to payment of all fees due for the investigation, the client alone shall have licence to use this report. The report shall not be reproduce except in full.

Should you have any questions regarding this report, please do not hesitate to contact the undersigned.

E.H. Fletcher

Joanne Rosner
Environmental Scientist

E H Fletcher
Director

GLOSSARY[1]

AAS	Atomic Absorption Spectrometry
Acidity	The chemical activity of hydrogen ions in soil. Usually expressed in pH units
AHD	Australian Height Datum (metres)
Al	Aluminium
ANZECC	Australian and New Zealand Environment Conservation Council
Aquatic Macrophyte	A large plant capable of living in soils and sediments that are at least periodically flooded
BGL	Below Ground Level
BH	Borehole
BD	Bulk Density
C	Carbon
Ca	Calcium
$CaCO_3$	Calcium Carbonate (Agricultural lime)
$Ca(OH)_2$	Calcium Hydroxide (Hydrated Lime)
CBR	Californian Bearing Ratio
CEC	Cation Exchange Capacity: The total quantity of exchangeable cations that the soil can absorb. Includes Ca, Mg, Na, K, H and Al.
Crusting	The nearly horizontal orientation and packing of dispersed soil particles in the immediate surface layer of soil. This greatly reduces water penetration, encouraging run-off.
CSIRO	Commonwealth Scientific and Industrial Research Organisation
D%	Dispersion (percentage) The breakdown of soil particles into constituents such as clay, silt and sand via the process of deflocculation. Dispersion can lead to erosion, high rainfall run-off and turbid waters.
DUAP	Department of Urban Affairs and Planning (NSW)
EMI	Electro-Magnetic Induction Survey
EAT	Emerson Aggregate Test (Class number). Scale of 1 to 8. Highest stability is 8.
EC	Electrical Conductivity
Eh	REDOX Potential
EPA NSW	Environment Protection Authority, New South Wales
Erodibility	The susceptibility of soil to detachment and transport by water and wind (The K value in R-USLE)
GC-ECD	Gas Chromatograph-Electron Capture Detector

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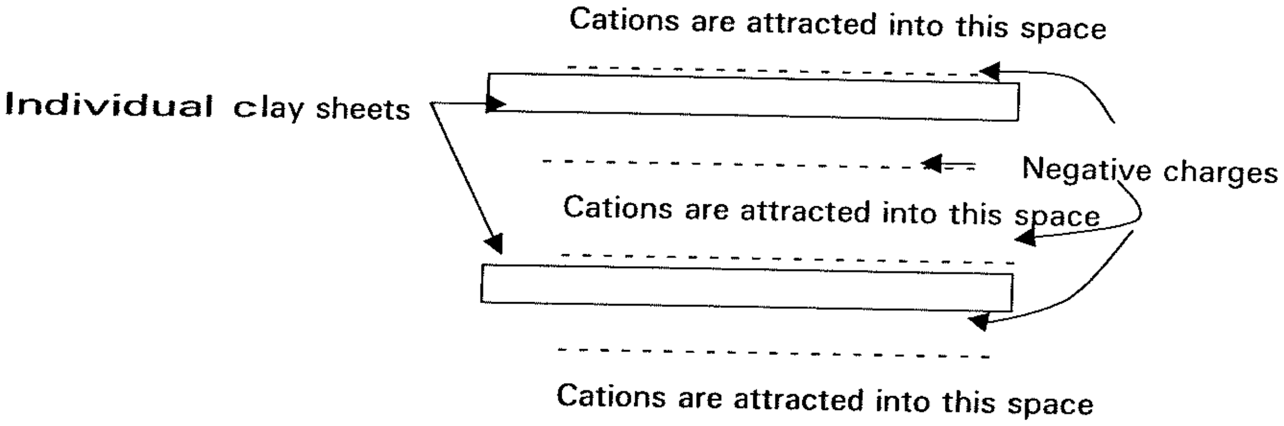
[1] Where possible definitions for industry based texts such as the "Blue Book" (1998) have been used.

GC-FID	Gas Chromatograph-Flame Ionisation Detector
GC-MS	Gas Chromatograph-Mass Spectrometer
G series	Piezometer series – upstream of wetland areas
ha	Hectare (1 ha = 100m*100m)
HCl	Hydrochloric Acid
K	Potassium
KL	Kilolitre (1000L) equivalent to 1 cubic metre of water
Mg	Magnesium
NATA	National Association of Testing Authorities, Australia
Na	Sodium
NHMRC	National Health and Medical Research Council
NH_4F	Ammonium Flouride
NO_3	Nitrate
NPWS	National Parks and Wildlife Service (NSW)
OC%	Organic Carbon Percentage
P	Phosphorus
Percentile	The percentage
pH	A measure of acidity
PD series	Piezometer series – deep shale at wetland locations
PS series	Piezometer series – shallow clay at wetland locations
PO_4	Phosphate
PSA	Particle Size Analysis – soil fractionation based on grain size
RPD	Relative Percentage Difference
R-USLE	Revised Universal Soil Loss Equation - refer to Department of Housing "Blue Book" publication
R-USLE K Value	Soil Erodibility Rating
SAR	Sodium Absorption Ratio: A measure of the ratio of sodium to calcium plus magnesium. It is used in conjunction with salinity data to determine the stability of irrigation water.
Slaking	The partial breakdown of soil aggregates in water due to clay swelling and soil gas pressure
Sodic soil	A soil whose structure is degraded due to excess exchangeable sodium. Usually applies to soil where more than 6% of exchangeable cations are sodium. More than 15% indicates a strongly sodic soil.
SWL	Standing Water Level
t	Metric tonne (1000kg)
t/ha	Tonnes per hectare
TN 37	Technical Note: Cement and Concrete Association
TP	Test Pit
USEPA	United States Environmental Protection Agency
USLE K value	Soil erodibility rating – U
UV	Ultra Violet

Notes on the Roles of Clay Type and Cations – Effect on Soil Behaviour.

Clays are formed in soils from the weathering of rocks. The parent material determines the type of clay. Clays consist of sheets of cations (largely $Al^{3+}$and Si^{4+}) and anions ($OH^-$and O^{2-}). Substitution of cations especially Mg^{2+}, Ca^{2+} for $Al^{3+}$and Si^{4+}, plus imperfections in the sheet result in the sheet surfaces having a net negative charge. The negative charge attracts cations such as H^+, Mg^{2+}, Ca^{2+}, Na^+ and K^+ (See below). This attraction is critical to soil structure. Without it the individual clay particles will not coalesce. The individual clay sheets are too small to settle via gravitational forces and therefore will remain in suspension forming a stable floc.



The distance between the clay surfaces is dependant on the equilibrium between the negative charges on the clay surface and the attractive forces of the cations. The attractive force of the cations is very dependant on the valance of the cations with higher valency cations being more attractive than lower valency ones. For example, Ca^{2+} has a much more attractive force for the clay layers than does Na^+. Additionally the attractive force is obviously dependant on the concentration of the cations. Thus adding gypsum (Calcium sulphate) has a two fold effect. It increases the proportion of cations that are divalent and it increases the total cation concentration of quantity of Ca^{2+}.

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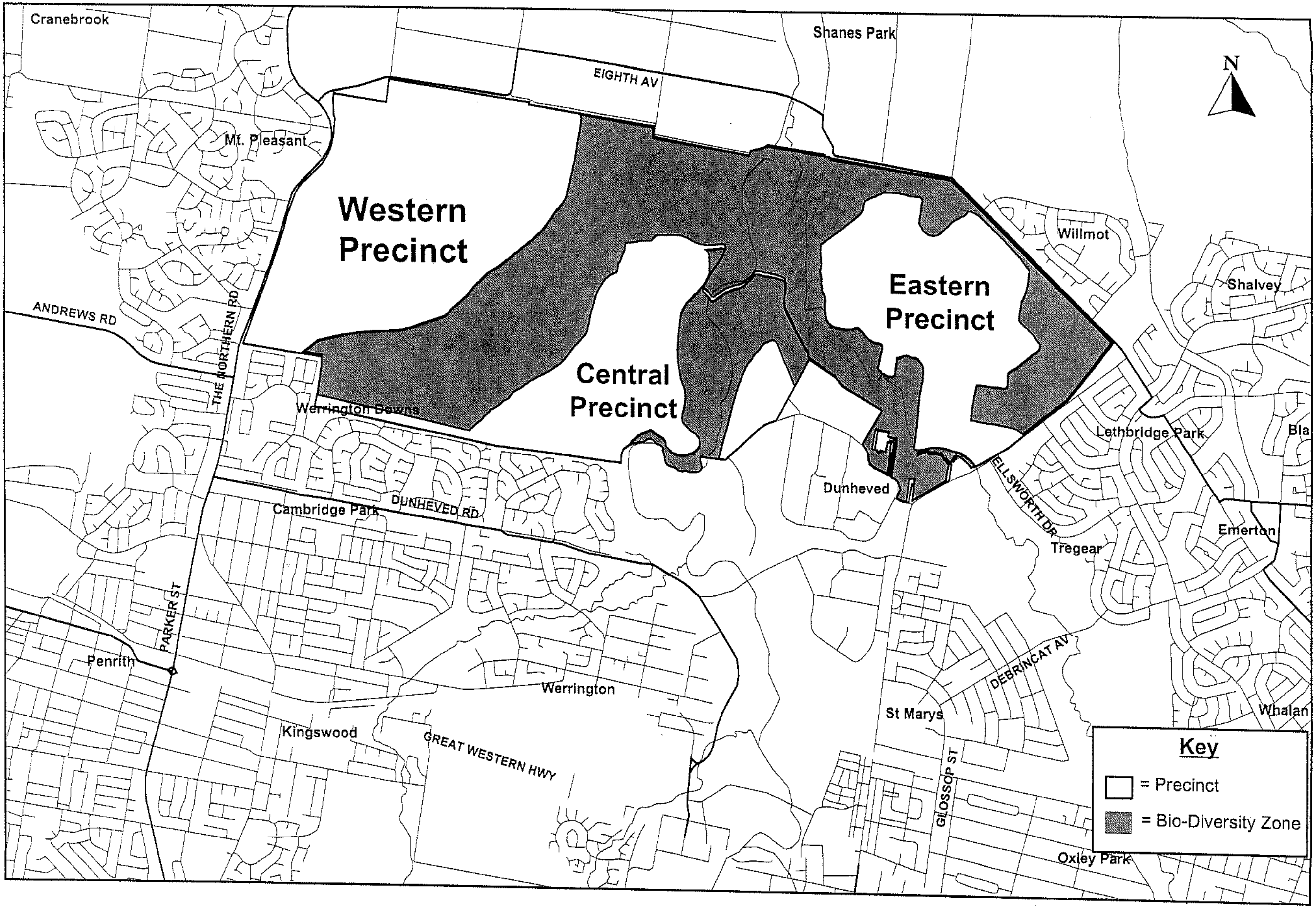
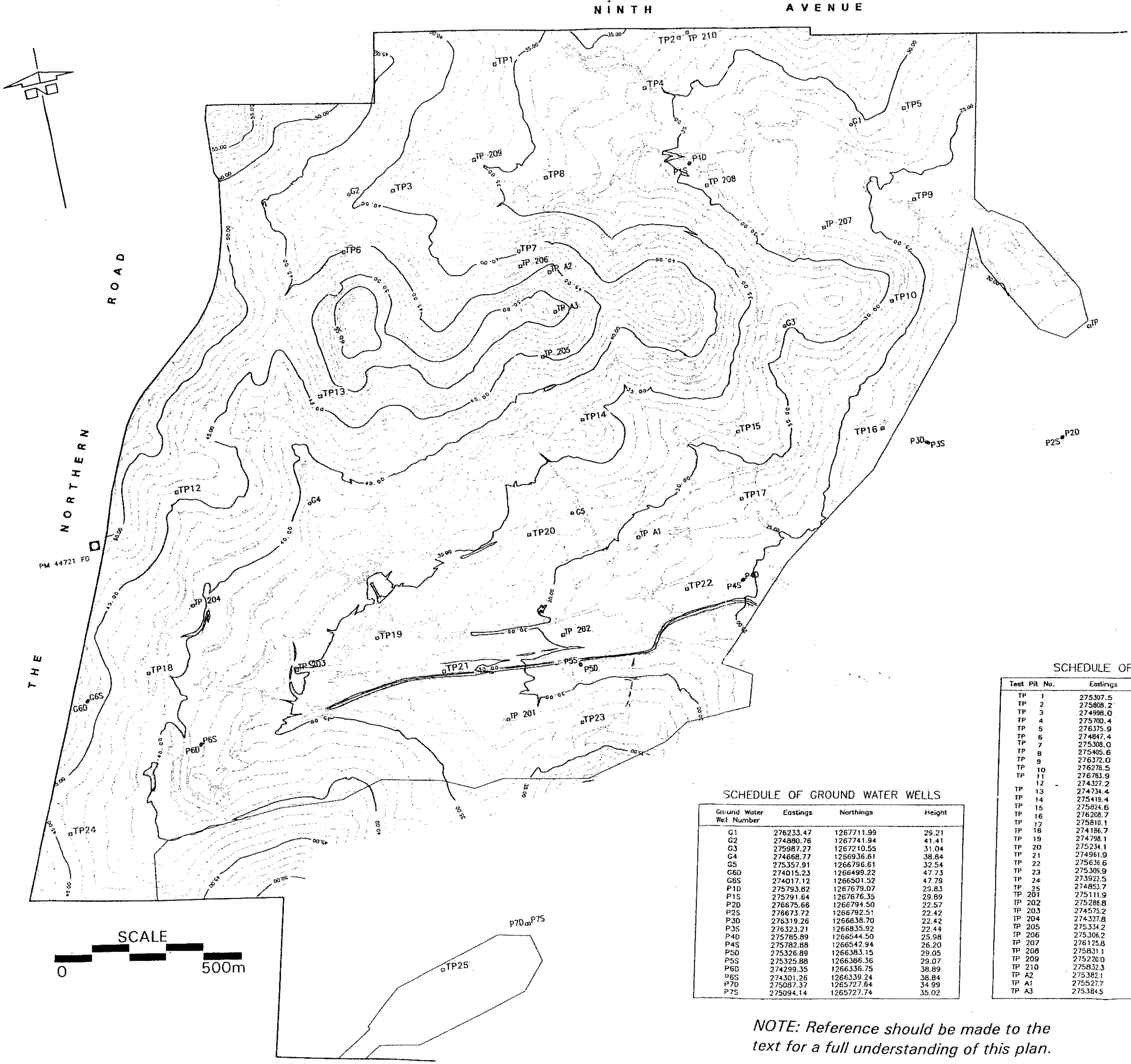


Figure 1: Locality Plan

ST MARYS REDEVELOPMEN PROJECT

LOCATION OF TEST PITS AND PIEZOMETERS ON THE WESTERN PRECINCT



SCHEDULE OF GROUND WATER WELLS

Ground Water Well Number	Eastings	Northings	Height
G1	276233.47	1267711.99	29.21
G2	274880.76	1267741.94	41.41
G3	275987.27	1267210.55	31.04
G4	274668.77	1266936.61	38.84
G5	275357.91	1266796.61	32.54
G6D	274015.23	1266499.22	47.73
G6S	274017.12	1266501.52	47.79
P1D	275793.82	1267679.07	29.83
P1S	275791.64	1267676.35	29.89
P2D	276675.66	1266794.50	22.57
P2S	276673.72	1266792.51	22.42
P3D	276319.26	1266838.70	22.42
P3S	276323.21	1266835.92	22.44
P4D	275785.89	1266544.50	25.98
P4S	275782.88	1266542.94	26.20
P5D	275326.89	1266383.15	29.05
P5S	275325.88	1266386.36	29.07
P6D	274299.35	1266336.75	38.89
P6S	274301.26	1266339.24	38.84
P7D	275087.37	1265727.64	34.99
P7S	275094.14	1265727.74	35.02

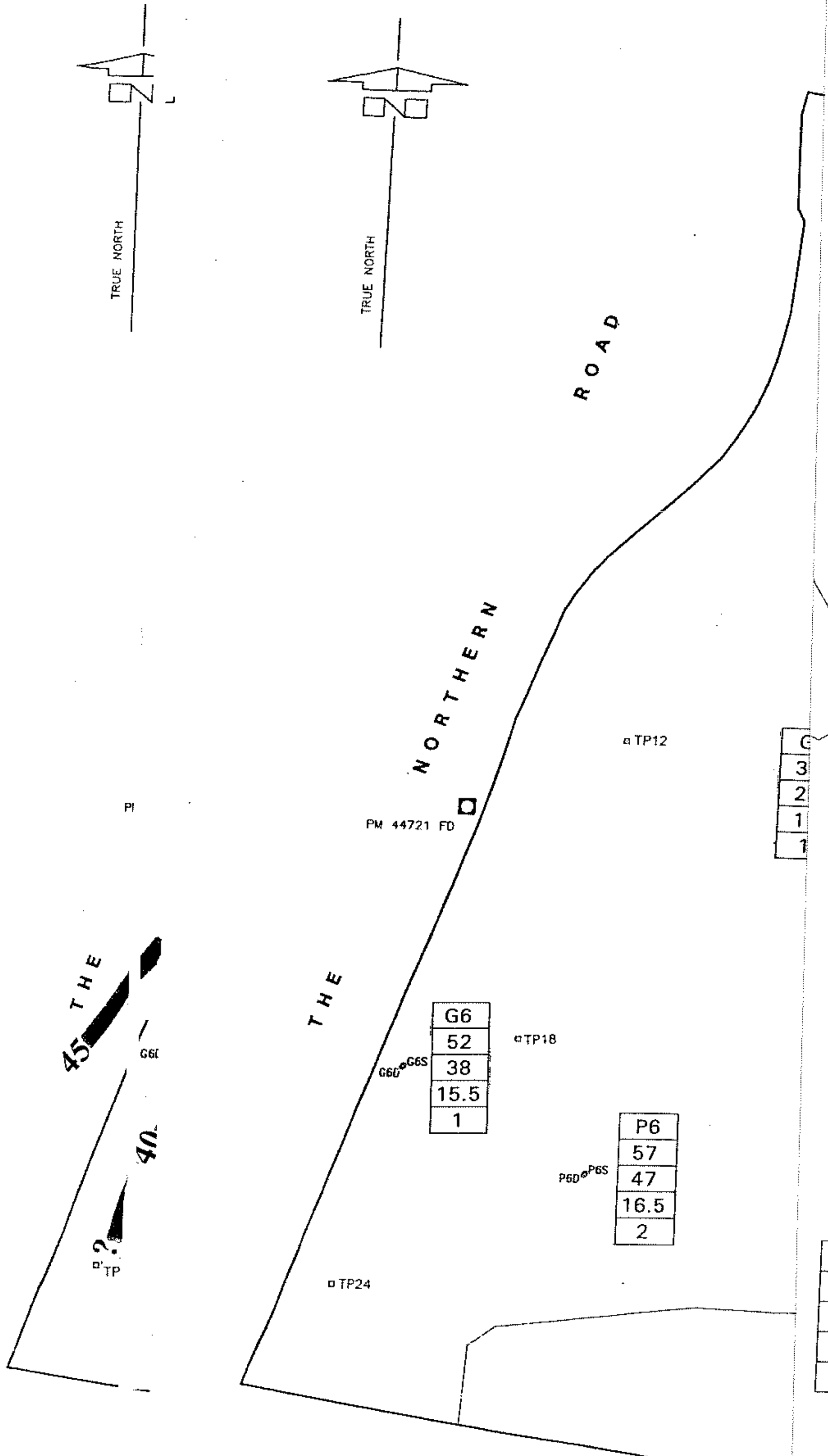
SCHEDULE OF TEST PITS

Test Pit No.	Eastings	Northings	Height
TP 1	275307.5	1268015.7	37.0
TP 2	275808.2	1268006.8	32.6
TP 3	274998.0	1267732.9	38.8
TP 4	275700.4	1267892.2	31.5
TP 5	276375.9	1267732.3	28.3
TP 6	274847.4	1267592.8	45.3
TP 7	275308.0	1267519.8	39.7
TP 8	275405.6	1267702.2	33.9
TP 9	276372.0	1267489.2	24.5
TP 10	276278.5	1267232.5	28.5
TP 11	276783.9	1267079.0	20.0
12	274327.2	1267022.7	45.7
TP 13	274734.4	1267221.0	46.5
TP 14	275419.4	1267043.8	37.8
TP 15	275824.6	1266947.2	32.5
TP 16	276208.7	1266894.2	22.9
TP 17	275810.1	1266764.6	27.5
TP 18	274186.7	1266547.6	41.8
TP 19	274798.1	1266543.4	33.3
TP 20	275234.1	1266756.8	33.2
TP 21	274961.9	1266424.8	31.6
TP 22	275636.6	1266542.2	26.4
TP 23	275309.9	1266229.8	32.8
TP 24	273922.5	1266159.3	43.8
TP 25	274853.7	1265648.1	35.1
TP 201	275111.9	1266270.7	31.0
TP 202	275288.8	1266470.6	29.5
TP 203	274575.2	1266492.8	35.6
TP 204	274327.8	1266709.7	40.9
TP 205	275334.2	1267231.0	44.0
TP 206	275306.2	1267479.2	42.3
TP 207	276125.8	1267454.0	26.4
TP 208	275831.1	1267613.4	29.3
TP 209	275220.0	1267779.3	35.9
TP 210	275832.3	1268017.0	33.2
TP A2	275382.1	1267451.8	46.3
TP A1	275527.7	1266702.0	28.7
TP A3	275384.5	1267344.8	51.7

NOTE: Reference should be made to the text for a full understanding of this plan.

EIS

Report No. E13431F
Figure No. 2



ST MARYS DEVELOPMENT PROJECT

BOREHOLE PIEZOMETER LOCATION PLAN
AND
ATTERBERG LIMIT DATA

LEGEND:

o P1	PIEZOMETER BOREHOLE LOCATION
P1	SAMPLE LOCATION
36	LIQUID LIMIT %
23	PLASTICITY INDEX %
12	LINEAR SHRINKAGE %
2	EMERSON (EAT) CLASS NUMBER

PREPARED BY:

Whelans | Surveyors | Planners | Geomatic Engineers
Whelans Australia Pty Ltd

NVIRONMENTAL
IVESTIGATION

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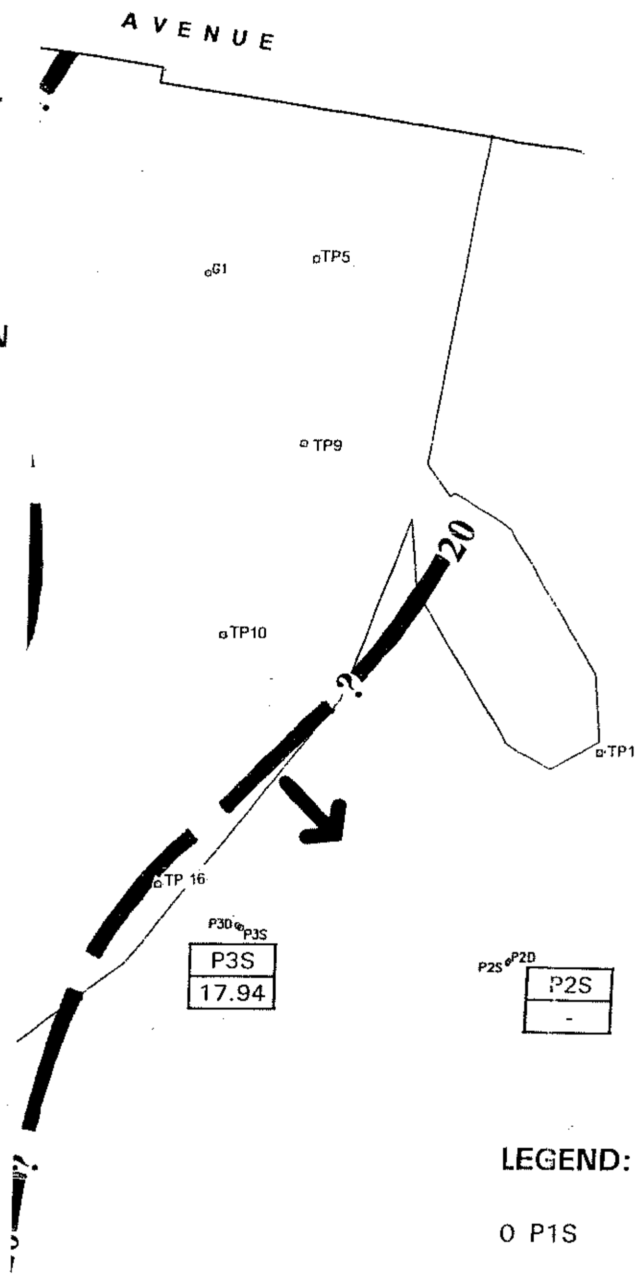
Figure No. 3



ST MARYS DEVELOPMENT PROJECT

PIEZOMETER LOCATION PLAN
GROUNDWATER LEVEL DATA
AND
AHD GROUNDWATER CONTOURS

SHALLOW CLAY AQUIFER

LEGEND:

O P1S	PIEZOMETER LOCATION AND NUMBER
→	INDICATED GROUNDWATER FLOW DIRECTION
▬	GROUNDWATER CONTOURS (5 METRE INTERVALS)
G1 25.0	PIEZOMETER LOCATION AHD GROUNDWATER LEVEL (METRES)

NOTE: Groundwater contours are judgemental.

0 SCALE 500m

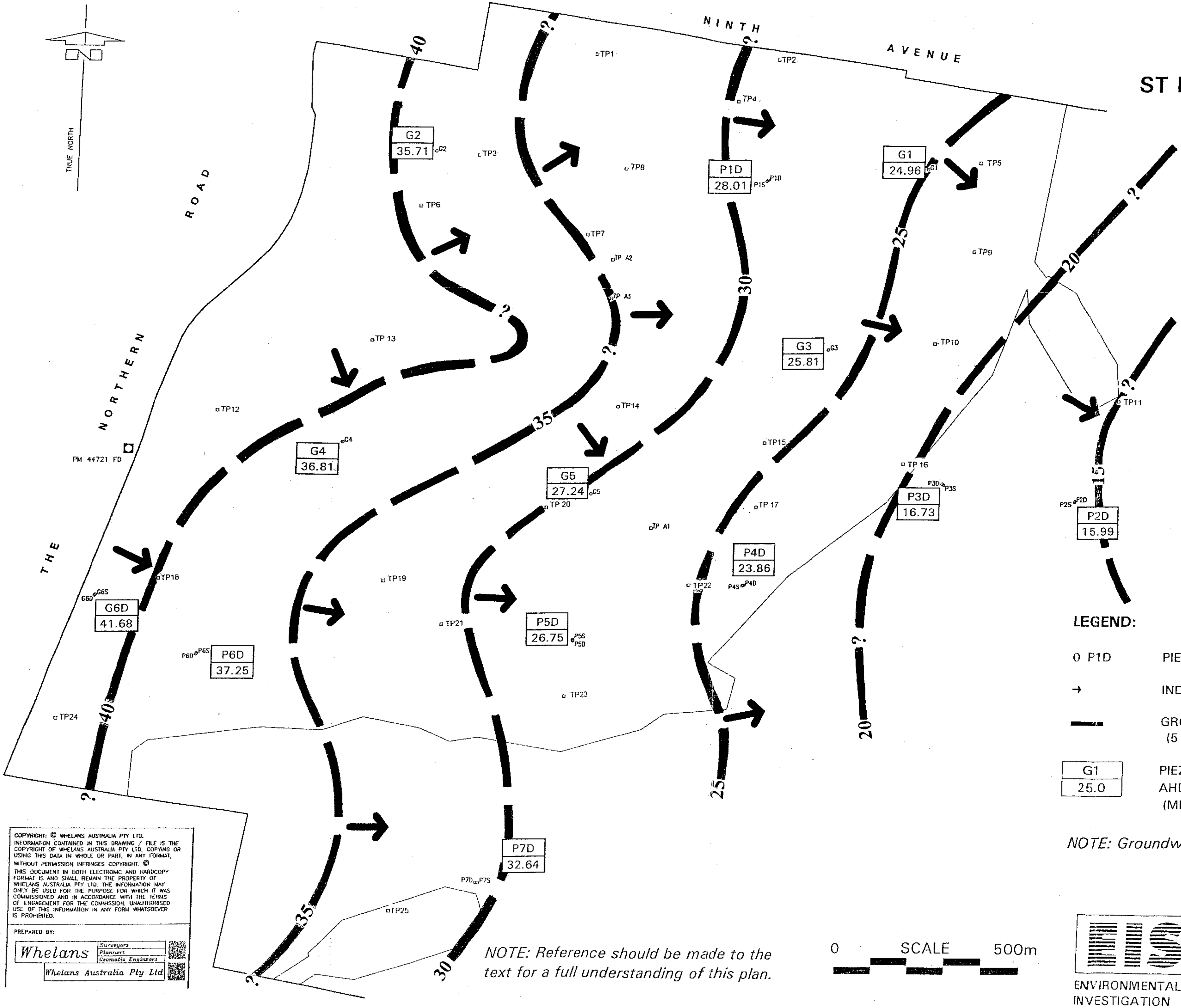
ENVIRONMENTAL
INVESTIGATION
SERVICES

Report No. E13431F

Figure No. 4

ST MARYS REDEVELOPMENT PROJECT

PIEZOMETER LOCATION PLAN
GROUNDWATER LEVEL DATA
AND
AHD GROUNDWATER CONTOURS
DEEP SHALE AQUIFER



LEGEND:	
0 P1D	PIEZOMETER LOCATION AND NUMBER
→	INDICATED GROUNDWATER FLOW DIRECTION
▬ ▬	GROUNDWATER CONTOURS (5 METRE INTERVALS)
G1 25.0	PIEZOMETER LOCATION AHD GROUNDWATER LEVEL (METRES)

NOTE: Groundwater contours are judgemental.

NOTE: Reference should be made to the text for a full understanding of this plan.

0 SCALE 500m

PREPARED BY:
Whelans
Surveyors
Planners
Geomatic Engineers
Whelans Australia Pty Ltd

EIS
ENVIRONMENTAL
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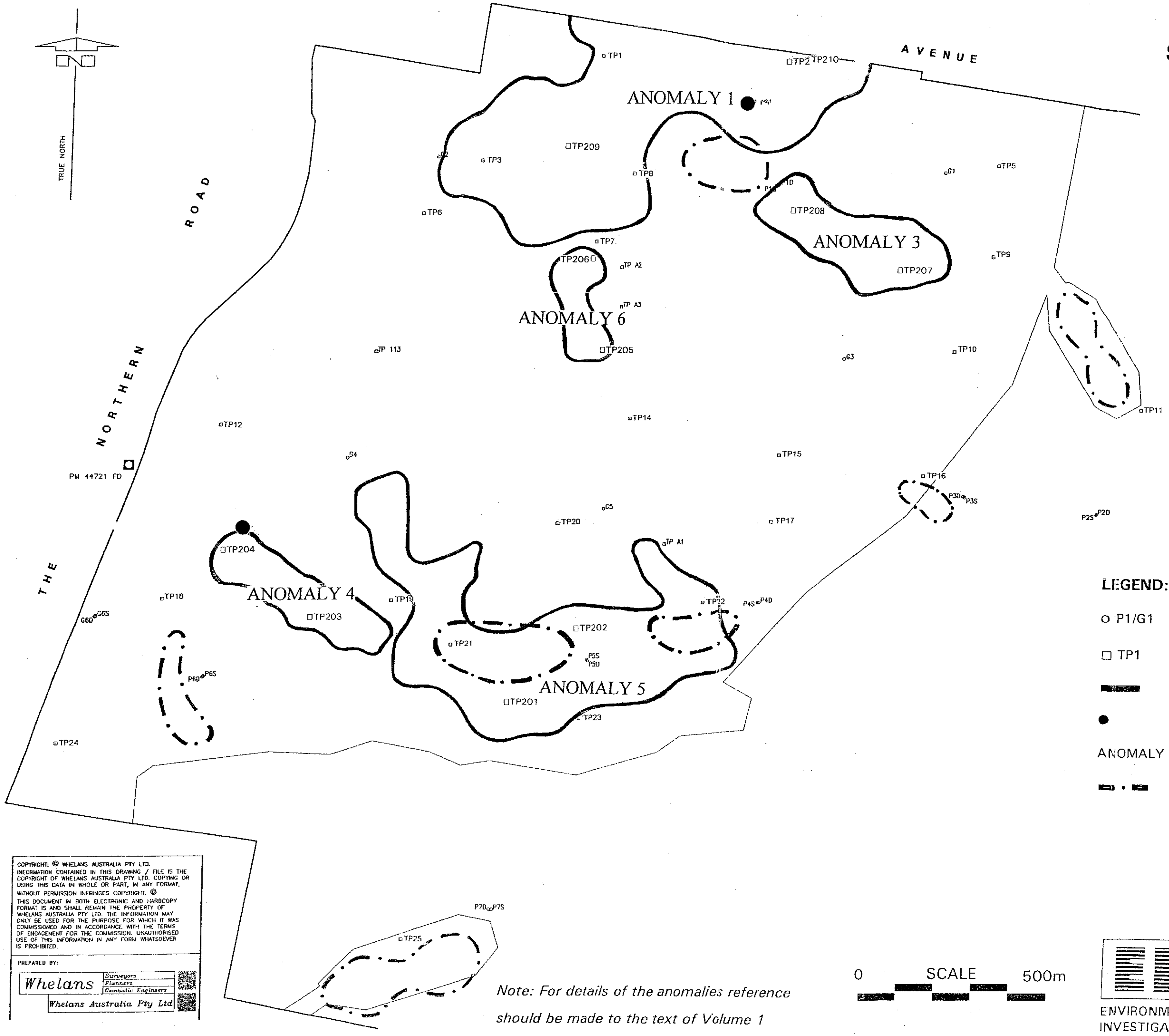
Figure No. 5

ST MARYS REDEVELOPMEN

PROJECT

ELECTROMAGNETIC INDUCTION SURVEY

AMOMALOUS AREAS



LEGEND:

○ P1/G1	PIEZOMETER LOCATION AND NUMBER
☐ TP1	TESTPIT LOCATION AND NUMBER
▬	ANOMALOUS ZONE BOUNDARY
●	SURFACE WATER SAMPLE POINT
ANOMALY 1	ANOMALOUS AREA NUMBER
▬ · ▬	PROPOSED WETLAND LOCATIONS

PREPARED BY:

Whelans | *Surveyors* | *Planners* | *Geomatic Engineers*

Whelans Australia Pty Ltd

Note: For details of the anomalies reference should be made to the text of Volume 1

0 SCALE 500m

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Figure No. 6

C.2 EIS Investigations Volume 2

ENVIRONMENTAL INVESTIGATION SERVICES

REPORT

TO

LEND LEASE DEVELOPMENT

ON

SOIL AND GROUNDWATER INVESTIGATION

FOR

PROPOSED RESIDENTIAL REDEVELOPMENT

AT

COMLAND, ST MARYS

VOLUME 2: TECHNICAL DOCUMENTATION

31 MAY, 2000 REF: E13431FRPT - VOL2

Associate Director and Principal : E H Fletcher BSc (Eng) ME CPE
39 BUFFALO ROAD GLADESVILLE NSW 211.1 TELEPHONE: (02) 9809 7322 (02) 9807 0200 FAX: (02) 9809 7626
EIS IS A DIVISION OF JEFFERY 8 KATAUSKAS PTY LTD A.C.N 003 550 801
Directors: R P Jeffery BE DIC MSc B F Walker BE DIC MSc P Stubbs BSc MIEAust

EXECUTIVE SUMMARY

The Lend Lease and Comland Joint Venture (JV), commissioned Environmental Investigation Services (EIS), a division of Jeffery & Katauskas Pty Ltd (J&K), to undertake a soil and groundwater investigation over part of the property at St Marys, currently owned by Comland. The site has a total area of approximately 1,538 Hectares (ha). The west area of the site (Western Precinct) to the west of South Creek is to be developed initially, for predominantly residential purposes. The overall development includes construction of 14 significant wetland areas and creation of a central Biodiversity Zone (Regional Park). Six of the proposed wetland areas are located in the Western Precinct.

The purpose of the investigation was to obtain and assess preliminary soil and groundwater data from the Western Precinct section of the site, in order to meet the planning requirements set by the Department of Urban Affairs and Planning (DUAP). The DUAP requirements for the development in relation to soil and groundwater management plans are summarised in a later section of this report.

The results of the investigation are presented in three volumes. This volume (Volume 2) presents the results of the investigation of the soil and groundwater parameters listed below. Detailed discussion and management options for the site are provided in the accompanying Volume 1: Overview.

EIS retained Perrens Consultants Pty Ltd and Woodlots and Wetlands Pty Ltd to undertake soil salinity, fertility and erosion studies for the project, in relation to urban capability development. An Electro-Magnetic Induction Survey (EMI) was also undertaken by the Department of Land and Water Conservation, together with laboratory testing at Scone. The JV retained Sinclair Knight Merz directly to prepare urban capability maps for the Western Precinct. The maps are presented in Volume 3 of this report.

A range of soil parameters were assessed for the investigation including: electrical conductivity; erosion potential; pH; organic carbon content; dispersion; Emerson aggregate test class number; particle size analysis; cation exchange capacity (sodium, potassium, calcium, magnesium and aluminium exchange capacity); available phosphorous content; lime and gypsum requirements; Soil Erodibility Factor (K Rating); bulk density; and wet strength.

Preliminary geotechnical soil conditions were assessed including: Soil particle size; Atterberg Limit tests; SPT tests; dispersivity, reactivity; and permeability.

Groundwater conditions were assessed and included the following: depth and AHD levels; Flow conditions; Salinity; pH; and Chemistry.

The scope of work undertaken for the investigation was as follows:

- Installation of deep shale and shallow clay groundwater piezometers at each of seven proposed wetland locations in the general Western Precinct development area;
- Drilling, sampling and installation of six additional groundwater piezometers in selected areas adjacent to drainage lines upstream of the wetland areas, generally representing the higher portions of the site;
- Soil profile assessment and sampling at thirty one test pit locations at selected strategic positions over the site, with sampling at various depths down to 2m (locations selected to support data collection for the urban capability mapping). Sixteen were located in the general development site area and twelve in the drainage line and wetland areas;
- Analysis of soil and groundwater samples to assess conditions outlined above;
- Electro-Magnetic Induction Survey by the Department of Land and Water Conservation to map soil salinity conditions and to assess areas of significant recharge;
- Preparation of management plans to address ground related issues associated with the proposed development and to provide baseline data for future comparison purposes.

This volume of the report presents the results of the investigation of the soil and groundwater parameters listed above. Detailed discussion and management options for the site conditions are provided in the accompanying Volume 1: Overview.

The results of the Lend Lease, Comland JV St Marys soils and groundwater investigation have indicated that the conditions are typical of those in western Sydney. The site is considered to be suitable for the proposed development. Careful management and monitoring is recommended during design, construction and occupation of the site in order to control potentially adverse conditions related to the soil conditions. The soils are to a variable degree, acidic, unstable, erodible, reactive, and of low fertility. The shale groundwater is saline and salinity develops with depth in the soil profile. Control of salinity is recommended by prevention of a rising groundwater table condition. The study recommends that a management strategy be formulated and that the development be monitored on a regular basis to assess the impact of the project on the environment. The monitoring programme should be designed to permit appropriate corrective action to be undertaken to prevent the development of adverse impacts.

TABLE OF CONTENTS

1 INTRODUCTION

1.1 General

The Lend Lease and Comland Joint Venture (JV), commissioned Environmental Investigation Services (EIS), a division of Jeffery & Katauskas Pty Ltd (J&K), to undertake a soil and groundwater investigation over part of the property at St Marys, currently owned by Comland. The site has a total area of approximately 1,538 Hectares (ha) and is shown on Figure 1. The west area of the site (Western Precinct) to the west of South Creek is to be developed initially, for predominantly residential purposes. The overall development includes construction of 14 significant wetland areas and creation of a central Biodiversity Zone (Regional Park). Six of the proposed wetland areas are located in the Western Precinct.

The purpose of the investigation was to obtain and assess preliminary soil and groundwater data from the Western Precinct section of the site, in order to meet the planning requirements set by the Department of Urban Affairs and Planning (DUAP). The DUAP requirements for the development in relation to soil and groundwater management plans are summarised in a later section of this report.

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EIS retained Perrens Consultants Pty Ltd and Woodlots and Wetlands Pty Ltd to undertake soil salinity, fertility and erosion studies for the project, in relation to urban capability development. An Electro-Magnetic Induction Survey (EMI) was also undertaken by the Department of Land and Water Conservation, together with laboratory testing at Scone. The JV retained Sinclair Knight Merz directly to prepare urban capability maps for the Western Precinct. The maps are presented in Volume 3 of this report.

1.2 Scope of Work

The scope of work undertaken for the investigation is outlined below:

- Installation of deep shale and shallow clay groundwater piezometers at each of the seven proposed wetland locations in and adjacent to the Western Precinct;
- Drilling, sampling and installation of six additional groundwater piezometers in selected areas adjacent to drainage lines upstream of the wetland areas, generally representing the higher portions of the site;
- Soil profile assessment and sampling at twenty eight test pit locations (together with three surface sample locations) at selected strategic positions over the site in the Western Precinct, with sampling at various depths down to 2m (locations selected to support data collection for the urban capability mapping). Sixteen test pits were located in the general development site area and twelve in the drainage line and wetland areas.
- Electro-Magnetic Induction (EMI) Survey and soil validation to map soil salinity conditions and to assess areas of significant recharge;
- Preparation of management plans to address ground related issues associated with the proposed development and to provide baseline data for future comparison purposes.

The following soil characteristics were included in the investigation: electrical conductivity, erosion potential, pH, organic carbon content, particle size analysis, dispersion, Emerson aggregate test class number, cation exchange capacity, including sodium, potassium, calcium, magnesium and aluminium, available phosphorus content, lime and gypsum requirements, soil erodibility factor (K Rating), bulk density and wet strength.

Geotechnical soil conditions were assessed including: soil particle size, Atterberg Limits, SPT tests, dispersivity, reactivity and permeability.

Groundwater conditions were assessed and included the following: depth and AHD levels, flow conditions, salinity and chemistry (pH, total dissolved solids, sulfate, flouride, chloride, ammonia, TKN, total alkalinity, carbonate alkalinity, calcium, sodium, potassium and magnesium).

I.3 Quality Control and Assurance

EIS has a Quality System in operation that forms an essential and integral part of the environmental services offered by the company.

The Company's Quality System was designed to conform with the Association of Consulting Engineers Australia (ACEA) 1990 guidelines on quality management. The system conforms to the principal requirements and philosophy on quality provided in AS3901.

The Quality Assurance System has been accepted by the NSW Public Works Department, meeting QA Audit Cover Sheet (PWF-0601) and QA Audit Checklist (PWF-0602) requirements.

NATA registered laboratories were used for all analytical work. QA procedures for each laboratory that has undertaken analyses for this screening have been provided to EIS. This information is held on our files and is considered to be satisfactory.

1.4 Site History

The St Marys site was first surveyed and land grants issued in 1803. By 1810, the family of Governor King used the land for grazing stock and their homestead named Dunheved was built.

During World War 2, the Commonwealth Government acquired the land for defence purposes that included establishment of a munitions factory.

In 1993, the St Marys site was identified for inclusion in the Sydney Region Urban Development Program (UDP). This is a land release system managed by DUAP. The St Marys site was identified as an opportunity to provide housing for Sydney's growing population within an environmentally sustainable framework. Over the next 15 to 20 years this area could provide approximately 8000 homes, generate additional employment, introduce approximately 678ha of land to Western Sydney's open space network and generate additional employment opportunities.

Decontamination processes were carried out between 1993 and 1997. These have been audited by an independent auditor and the land has been cleared for urban land uses.

1.5 Previous Investigations

EIS has previously undertaken a review of regional soil and groundwater conditions including existing borehole logs, groundwater levels and soil salinity measurements obtained during ADI field investigations at the site. Information produced during this review was published as Technical Appendix E: Soil and Groundwater to the *"ADI St Marys Watercycle **and** Soil Management Study"* produced for the ADI St Marys Draft REP Steering Committee by Sinclair Knight Merz Pty Ltd (1998). This work was also used in the preparation of the Draft St Marys Planning Strategy (DUAP, 1999). Section 4 of Volume 1 provides a summary of the findings of this report.

2 INVESTIGATION PROCEDURES

2.1 **EMI** Survey

The Department of Land and Water Conservation (DLWC) Salt Action Unit, Cowra was contracted by EIS to undertake an EMI survey using an EM31 sensor over the west section of the site as part of the investigation. Details of the methods used are presented in Appendix B. EMI techniques have been shown to be useful for detecting areas predisposed to salinity by measuring electrical conductivity as an indirect measurement of salinity. The EM31 sensor used for this survey provided data to a maximum soil profile depth of 6m.

2.2 Soil

2.2.1 Sample Collection Methods

Twenty-one boreholes were drilled for installation of the piezometers using a truck-mounted hydraulically operated drill rig equipped with spiral flight augers. Soil samples were obtained from a Standard Penetration Test (SPT) sampler at specified depths as this permitted relatively undisturbed samples to be retrieved and geotechnical information on the soil properties to be obtained. Auger samples were taken from the top half metre of each borehole and when conditions did not allow use of the SPT sampler.

Twenty eight test pits were excavated using a 4WD backhoe. Samples were obtained at various depths from the walls of the excavation using the backhoe bucket and placed in plastic bags. On completion of the fieldwork, the samples were delivered to a NATA registered laboratory for analysis.

Field activities were technically directed by Joanne Rosner, an environmental scientist, Kai Tai Ng, a geotechnical engineer, Brian Ashley, an experienced technician and Dr Peter Bacon, a specialist soil scientist sub-consultant, who were responsible for logging of the strata encountered and collection of soil samples. On completion of the fieldwork, the samples were delivered to a NATA registered laboratory for analysis.

2.2.2 Sample Analysis Details

Soil samples were analysed by the Scone Research Service Centre of the Department of Land and Water Conservation (NATA registered) as follows:

- pH – measured using a 1:5 soil: calcium chloride (0.01M) solution. (Rayment and Higginson, 1992).
- EC – measured electrometrically using a 1:5 soil: water extraction (ALHSCM, 1992).
- Organic carbon – Walkley Black Method. Organic matter is oxidised by a solution of dichromate. The amount of dichromate is then measured by back titration with ferrous sulphate using ferroin indicator.
- Dispersion (%) – Measurement of suspended (<0.005mm) particles that remain in distilled water after two hours settling time compared to the total amount of materials less than 0.005mm using hydrometer analysis (PSA) (Ritchie, 1963).
- Emerson Aggregate Test (Class Numbers) – An eight tier classification of soil aggregate coherence (slaking and dispersion) in water. The degree of dispersion for reworked samples is included in brackets for class 2 and 3 aggregates (Australian Standard AS1289).
- Particle Size Analysis (PSA) – Determination by sieving and hydrometer of percentage, by weight. Australian Standard AS1289 C6.2. (Laher and Dupreez, 1982).

- Particle Size Analysis (PSA) - Mechanical dispersion - Determination by sieving and hydrometer of percentage by weight, of particle size classes without the use of calgon (Loch and Roswell, 1992).
- Cation Exchange Capacity and Exchangeable Cations (Ca, Mg, K and Na) - Saturation with silver-thiourea followed by determination of Ag, Na, K, Ca, Mg and Al using AAS (Pleysier and Juo, 1980).
- Bray Available Phosphorus - Extraction of absorbed Phosphorus with HCl and NH_4F. Concentration is then determined by spectrophotometer analysis (Manage and Pridmore, 1973).
- Chloride - Water extraction followed by titrametric determination.
- Sodium - Water extraction and analysis using AAS (APHA 3111-B)
- Soil pH adjustment - (Lime Requirement) - Various amounts of $Ca(OH)_2$ solution are added to soil samples and distilled water to a 1:5 soil solution ratio. Following three days of equilibration, pH is measured and the amount of $Ca(OH)_2$ to bring pH to the required value is interpolated and the equivalent amount of $CaCO_3$ calculated (Chapman and Pratt, 1961).
- Bulk Density Determination - Air dry soil aggregates are weighed then coated with a thin layer of wax and the volume is determined by displacement in water (Black, 1965).
- Gypsum Requirement - Dispersion percentage tests are undertaken in parallel with various amounts of added gypsum. 1.0% gypsum is equivalent to 10kg per tonne of soil (Ritchie, 1963).

2.3 Groundwater

2.3.1 Piezometer Installation Methods

Seven pairs of piezometers consisting of one deep shale piezometer screened within the bedrock (to a maximum depth of 9 metres) and one shallow clay piezometer screened in the residual soils, were installed at the proposed wetland locations. A further six piezometers, screened in the shale, were installed adjacent to existing drainage lines upstream of the proposed wetland locations.

At each location a 50mm ID Class 18 PVC well screen and casing was installed with a 2mm grain size quartz sand filter pack around the screen. A bentonite seal was placed over the filter pack and the remainder of the annulus between the borehole and casing backfilled with sand or auger cuttings. A lockable steel standpipe was placed over each well and set in concrete, providing a surface seal to the piezometer. Piezometer completion details are shown the on borehole logs in Appendix A.

2.3.2 Sample Collection Methods

Groundwater was purged and sampled from temporary piezometers using a submersible electric pump or new disposable polyethylene bailer. During purging the pH, temperature, conductivity and redox potential were monitored (where possible) in order to assess the development of steady state conditions. Steady state conditions were considered to have been achieved when the difference in the pH measurements was less than 0.2 units and the difference in conductivity was less than 10%. The piezometers were allowed to recharge prior to sampling where necessary. Between sampling events, the pump and hose were washed and flushed with tap water.

Samples were placed in glass bottles with plastic caps. Samples for metals analysis were filtered within one hour of collection using a 0.45µm filter and placed in an acid washed HDPE plastic bottle. During the investigation, samples were preserved by immediate storage in an insulated sample container with ice. On completion of the fieldwork, the samples were delivered in the insulated sample container to a NATA registered laboratory for analysis under standard chain of custody procedures.

2.3.3 Sample Analysis Details

Groundwater samples were analysed as follows:

- Conductivity (EC) - measured electrometrically (APHA 2510 B).
- pH - (APHA 4500 - H^+B).
- Sulphate - Precipitation using barium chloride to produce barium sulphate and measured by a photometer - (APHA 4500SO_4^{2-} E).
- Ammonia-N - Sample buffered at pH 9.5 and distilled using boric acid, the released ammonia is the determined using an ion-selective electrode (APHA 4500 NH_3 BID).
- Fluoride - Ion selective electrode (APHA 4500 - F C).

- TKN – Sulfuric acid, potassium sulphate and copper sulphate digestion followed by distillation with sodium hydroxide-thiosulphate and determination by ion-selective electrode. (APHA 4500 – Norg-B).
- Chloride – Titration using silver nitrate and potassium chromate as a an indicator (APHA 4500 – Cl^- B).
- Metals – Atomic absorption spectrometer (AAS).
- Alkalinity (total) and carbonate alkalinity – (APHA 2320 B). Potentiometric titration using hydrochloric/sulphuric acid and a mixed indicator.

3 RESULTS OF INVESTIGATION

3.1 Subsurface Conditions

Site details and borehole locations are shown on Figure 1. Limited fill was encountered at several locations, underlain by residual silty sandy clay, underlain in turn by Bringelly shale or occasionally sandstone bedrock of the Wianamatta Group. For details of the subsurface soil profile reference should be made to the borehole logs in Appendix A. A summary of the subsurface conditions encountered by the boreholes is presented below:

Fill

Fill was encountered in boreholes P2D and P3D located in the north-east section of the site to respective depths of 0.5 and 1.7m. The fill consisted of silty clay with varying sand and gravel content. The fill contained medium grained gravel, concrete fragments and some ash and the clay was of low to medium plasticity. Fill was not encountered in the test pits.

Natural Soils

The fill and remainder of the site was mostly underlain by a variable thin veneer of topsoil, underlain by residual silty sandy clay (ie. soil derived from *in-situ* weathering of the bed rock) and was typically of medium to high plasticity. The clay contained variable but minor proportions of gravel which was mainly ironstone. The strength of the silty sandy clay typically increased with depth and generally varied from stiff to hard.

Bedrock

The depth to the Wianamatta Group Bringelly Shale (occasionally sandstone) varied from 2.0m to greater than 9.0m depth. The variable depth is related to the topography and variable rock weathering profile over the site. The typical depth to shale was 3m to 6m. The strength of the shale ranged typically from very low to medium, and increased in strength with depth.

3.2 Soil Laboratory Results

Laboratory analyses were scheduled on selected samples obtained from the fill materials and natural soils at the site.

3.2.1 Dispersion %

Dispersion describes the tendency of the clay fraction of a soil to go into colloidal suspension in water. Soil dispersion analyses predict the tendency for subsurface piping and erosion to occur in the presence of rain or surface water flows.

Dispersion percentage analysis was undertaken on twenty five samples obtained from various depths below the surface at the test pit locations and the results are presented in Table *1*. The percentage dispersion ranged from *0%* to 88% with an average of 59%. Large variations were observed in the dispersion percentages with three samples classed as very low and five as very high. The remainder fell between these classes.

All results apart from two locations (TP2 and TP18) were above the dispersible soils classification defined as greater than *10%* of fines (clay fraction) being dispersible with a range (excluding the two non-dispersible soils) of 21% to 51% and an average of 33%.

3.2.2 Emerson Aggregate Test (Class Numbers)

Emerson Aggregate tests (EATs) are a method for predicting soil dispersion in addition to the dispersion tests described above.

EATs were assessed for samples obtained from various depths down to 1.0m at all test pit locations. The results are presented in Tables 1 and 2. Surface soils in the development areas were generally found to have slight to moderate dispersibility (Classes 3 and 5). Dispersibility was found to increase rapidly with depth. Subsurface soils at TP14, Al, A2 and TP19 in the centre of the site were classed as highly dispersive. Classification of the remainder of the subsurface soils ranged from slight to high.

Samples obtained from generally wet areas (at the time of the field work) adjacent to drainage lines (TP3, TP9 and TP8) were similar to those of the remaining areas of the site, with low to moderate dispersibility in the surface soil and high to very high dispersibility in the subsurface soils.

Surface soils at the proposed wetland locations showed generally moderate to slight soil dispersion potential. The dispersion increased significantly with depth to moderate to high, apart from TP16 and TP25 which remained slight.

Emerson Aggregate Class Numbers were also assessed for 13 soil samples obtained typically at a depth of 0.5m to 0.95m from boreholes drilled for piezometer installation. The results are presented in Table 6. The majority of the sample results were Class 1 with four samples assessed as Class 2 (P1, P6, P7 and G2). The results indicate moderate to mostly strong dispersion potential for the depth interval of 0.5m to 0.95m.

3.2.3 Gypsum Requirement

Gypsum (calcium sulphate) is often applied to soil to increase stability by reducing soil swelling and clay dispersion associated with sodicity. Gypsum requirement analyses were undertaken on six subsurface soil samples. The results are presented in the table below as the quantity of added gypsum as a function of the dispersibility of the soil and the clay content:

Gypsum Requirement of Selected Soils and Critical Dispersion.

Location	**Sample**	**Critical Dispersion %***	**Gypsum Requirement**			
			0%	**0.2%**	**0.3%**	**0.4%**
			Soil Dispersibility %			
TP5	0.3m	17	50	29	29	18
TP6	0.3m	16	71	40	18	nt
TP11	0.3m	24	36	20	nt	nt
TP14	0.3m	17	71	50	42	2
TP18	0.3m	16	23	4	nt	nt
TP23	0.3m	16	45	24	2	nt

- **Critical dispersion % is defined as (clay % plus half silt %) times dispersion % is >10% (Department of Housing 1998). nt: not tested as dispersion controlled using lower additions of gypsum**

The quantity of gypsum required is a function of the dispersibility of the soil and the soil clay content. Clayey subsoils such as that at TP14 require more gypsum to achieve a desired level of stability.

3.2.4 Conductivity

The electrical conductivity of a soil/water extract is commonly used as an indicator of soil salinity conditions as the reading is directly related to the electrolyte (salt) concentration of the extract.

Analyses were undertaken on samples obtained from various depths at all test pit locations. The results are presented in Tables 1 and 2. Conductivity was found to generally increase with depth at all Test Pit locations. Electrical Conductivity measurements on a 5:1 soil:water extract ranged from 0.04dS/m (TP17) to 0.12dS/m (TP4) in the topsoil with an average of 0.08dS/m. Subsurface conductivity measurements ranged from 0.04 dS/m to 1.10dS/m. The soils at sampling locations (TP5, TP7, TP11, TP12 and TP24) were found to have conductivities of greater than 0.8dS/m.

Selected soil and shale samples obtained during the installation of the piezometers were also analysed for electrical conductivity. The results of these analyses are presented in Table 6. Surface soil samples ranged from 0.02dS/m to 0.07dS/m, apart from BHG4 with a conductivity of 0.13dS/m, with values generally in the range of 0.02dS/m to 0.04dS/m.

Electrical conductivity generally increased or remained stable with increasing sample depth in the clay overburden to a maximum of 2.1dS/m at BHP2D (at a depth of 8.5 to 9.0m). At the remaining locations the results were generally within the range of 0.50dS/m to 1.95dS/m.

The electrical conductivity of the underlying shale bedrock was also assessed. Maximum readings were recorded at BHP4D (2.15dS/m). Apart from this location the shale measurements were similar to those of the overlying soil.

3.2.5 pH

Soil pH has been assessed as an indicator of soil fertility. Laboratory pH analyses were undertaken on samples obtained from various depths at all test pit locations. The results are presented in Tables 1 and 2. Results from varying depths at the test pit locations indicate that the soils are moderately to very strongly acidic with pH values within the range of 3.9 (TP17) to 6.0 for all locations apart from TP5 (0.75m-0.9m) where the pH was near neutral (6.90).

Selected soil and shale samples obtained during the installation of the piezorneters were also analysed for pH. The results of these analyses are presented in Table 6. Surface soil pH values ranged from 3.99 to 6.22. The pH generally increased (ie. a decline in acidity) with depth to a maximum of 7.25 in the subsurface clay material. The pH increased further in the shale bedrock with a maximum pH of 8.77 (BHG2).

3.2.6 Lime Requirements

Lime is commonly applied as a remediation technique for the stabilisation of expansive soils and the neutralisation of acidic conditions. Lime addition is also a method of treating aluminium toxicity.

Lime requirement analyses were undertaken to estimate the quantities of lime addition required at the site for the remediation of acidic soil conditions to a pH of 6.5, thereby increasing soil stability and fertility. Fifteen surface and subsurface samples obtained from selected test pit locations were analysed and the results presented in Table 2. Values ranged from 0.41kg to 4.31kg of

$CaCO_3$ (agricultural lime) per tonne of soil with an average of 1.64kg of $CaCO_3$ kg/tonne.

3.2.7 Soil Erodibility Test (K) for the Revised Unified Soil Loss Equation (RUSLE)

The soil erodibility is a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff. The soil erodibility (K) values presented in Table 3 have been calculated from measured soil properties including particle size analysis, organic carbon content, soil structure and profile permeability. The K values were obtained for use in the Urban Capability Mapping prepared by SKM.

Using the soil structure and profile permeability approximations, one test pit sample (TP 24) was rated as moderate (<0.02), 20 were rated as high (0.04-0.06) and 4 very high (>0.06). Using the first approximation derived from particle size analysis and organic carbon, 18 samples were rated as moderate, with the remaining 7 classed as high.

Highly dispersive soils are known to exhibit higher erodibility than soils with the same K value. The "***Blue*** Book" (Department of Housing, 1998) suggests that the K value be increased by 20% for EAT Class 1 and 2 soils. The final column in Table 3 presents the erodibility rating based on the adjusted values.

3.2.8 Organic Carbon %

Analysis of the organic carbon content of soil was undertaken as part of the soil erodibility test for USLE (K value) calculations presented in the previous section.

Organic carbon analyses were undertaken on twenty five samples obtained from the test pits. Results are presented in Table 1. Organic carbon contents were generally very low ranging from 0.08% to 0.49%, apart from TP2 (0.52%) and TP113 (0.56%) where low range values were recorded.

3.2.9 Particle Size Distribution Analysis

Particle size distribution analysis of selected soil samples was undertaken in the laboratory for use in the calculation of the Soil Erodibility Test for the R-USLE (K) and to confirm field observations. Particle size distribution results are presented in Table 4. A total of 25 analyses were undertaken using both hydrometer and mechanical dispersion methods.

Based on the clay/silt/sand/gravel grain size ranges in the tables the soils are predominantly classified as silty sandy clay, although four samples are clayey silty sand and one is classified as sandy clay.

Based on the Australian Standard (AS 1726-1993) 'Geotechnical Site Investigation Grain Size Range', the samples were typically classified as silty sandy clay.

Samples occasionally showed gravel contents of up to 11%, but most values were between 3% and 6%.

3.2.10 Cation Exchange Concentration (CEC) - Sodium (Na), Potassium, Magnesium (Mg), Calcium (Ca) and Aluminium (Al).

The cation exchange concentration is an important indicator in relation to soil behaviour, stability and dispersibility, the availability of some nutrients for plant growth and soil pH. In urban areas a low CEC is likely to be associated with leaching of nutrients into streams. The cation exchange concentration is also a measure of the ability of a soil to retain nutrients.

The CEC and exchangeable cations expressed in cmol(+)/kg were measured in soil samples from the test pits at depths down to Im. Three samples were typically analysed from each test pit (a total of 85 tests were undertaken and results are presented in Table 2).

The CEC values were typically low to moderate and generally increased in value with sample depth from the surface to approximately Im. This is typical of most Australian soils where the CEC is lowest in the sandy topsoil and increases as the clay content increases with depth. TP1 shows the typical pattern where the surface sample CEC was 7.7 cmol(+)/kg. This increased to

17.8 at 0.3m with a slight further increase to 18.1 at lm. Lower CEC values were encountered in an east to west band of soils (TP16 to TP18) in the centre of the site, however, even these soils exhibited adequate to high levels of CEC at depth.

Exchangeable sodium (Na)

Exchangeable sodium is an important soil stability parameter. An excess of exchangeable sodium together with exchangeable potassium may indicate dispersive and possibly expansive soils, potential salinity and water logging of the profile. Normally the sodium content is expressed as a percentage of the CEC as other cations 'counter' the negative effects of sodium.

The results indicate that all the surface soils are non-sodic (ie. less than 6% of exchangeable cations are sodium). However, sodicity increases with depth. TP3 and TP5 were severely sodic within 0.3m of the surface. All other sample sites (apart from TP4 non-sodic, TP11 and TP16 sodic) were extremely sodic (ie. more than 15% of exchangeable cations are sodium) within 1m of the surface.

Exchangeable Potassium

The exchangeable potassium ranged from 0.1 cmol(+)/kg at TP3 to 1.6 to 1.7 in the subsoils at TP5 and TP14. Concentrations less than 0.2 cmol(+)/kg are considered low for pastures (Metson, 1961). Table 2 shows that only TP3 and TP8 have low potassium concentrations. Potassium deficiency can be readily corrected with fertiliser.

Exchangeable Calcium (Ca)

Calcium is critical for maintaining plant growth and soil structure. Exchangeable Ca concentrations less than 2 cmol(+)/kg are considered very low (Metson, 1961). This occurs in soils at TP1, TP8, TP15 and TP17. These soils lie in a north-south band in the central northern portion of the site.

Exchangeable Magnesium (Mg)

Magnesium is essential for plant growth but too much, relative to the quantity of calcium, can result in loss of soil structure. Ideally there should be 4 to 6 times the amount of calcium to magnesium (Eckert, 1987). Table 2 shows that the ratio of Ca to Mg at the site is typically 1:2.5. The use of lime and gypsum will add calcium and improve this ratio.

The critical concentration of magnesium is approximately 1 cmol(+)/kg. The soils at the sampling locations have an average of 8.3 cmol(+)/kg.

Exchangeable Aluminium (Al)

Aluminium is usually found in large quantities in soils. However it only becomes exchangeable, and therefore potentially toxic, when the pH is less than 4.5 ($CaCl_2$). Al toxicity is also related to Ca availability and if Ca is more than 4 cmol(+)/kg, toxicity is unlikely (Cregan, 1980). Soils with pH<4.5 and low Ca require liming to reduce Al availability. This applies to soils at TP1, TP8, TP9, TP14, TP15, TP17, TP18, TP19, TP20, and TP24.

3.2.11 Available Phosphorus (P)

Available phosphorus analyses were undertaken to assess soil fertility and the suitability of the soil for revegetation following disturbance. Soil with less than 8mg/kg is considered phosphorus deficient (NSW Agriculture and Fisheries, 1980).

Available phosphorus analyses were undertaken on selected surficial topsoil samples obtained from seven of the test pit locations in open grassed areas. The results are presented in Table 2, and were all extremely low with values close to, or below the method detection limit of 1 mglkg available phosphorus. These results are typical of soils in the region.

3.3 Groundwater Laboratory Results

Laboratory analyses were scheduled on groundwater samples obtained from the piezometers on 17 November 1999 and a second round of sampling, undertaken on the 12, 13, and 17 January, 2000. Laboratory groundwater analysis data was compared with National Health and Medical Research Council: Guidelines for Drinking Water Quality (1996). The comparison was made on the basis that the quality of the groundwater in the shale in Sydney is known to be very salty and poor.

During the initial purging and sampling activity groundwater samples could not be obtained from P2S, P6S, P7S and G5 due to insufficient groundwater in these piezometers. During the subsequent sampling round, samples were obtained from all piezometers apart from P2S, P3S and P7S. Rising head permeability tests were also undertaken at this time. Results of the chemical analysis undertaken are discussed below and the data is presented in Table 7a and 7b. Groundwater parameters including pH, temperature, redox potential (Eh) and electrical conductivity (EC), were measured in the field during purging and sampling and the results are presented in Appendix D.

3.3.1 Conductivity, pH and Total Dissolved Solids

The pH results indicate that the groundwater is relatively neutral in the deep shale piezorneters with pH values ranging from 6.25 to 7.58 and slightly more acidic in the shallow clay soil piezometers with pH ranging from 5.6 to 6.9. The NHMRC guideline pH is 6 to 8.

Laboratory analysis indicated the groundwater conductivity varied from 1.9dS/m to 32.7dS/m. These values are high and are typical of groundwater within Bringelly Shale. The high values reflect the marine depositional environment of the Wianamatta formation.

The conductivity in the deep shale piezometers varied from 18.7dS/m to 32.7dS/m. Those in the shallow clay soils piezometers varied from 1.9dS/m to 25.0dS/m. The single low value of 1.9dS/m probably reflects a relatively fresh groundwater recharge condition at P3S compared to the remainder of the results which vary from 21.1dS/m to 25.0dS/m.

Total dissolved solids (TDS) analyses were undertaken on samples obtained during the second round of analyses. Concentrations in the deep shale piezometers ranged from 10,700mg/L to 20,200mg/L with an average concentration of 16,295mg/L. Those in the shallow clay soil piezometers varied from 15,770mg/L to 19,030mg/L with an average concentration of 17,175mg/L.

3.3.2 Chloride, Fluoride and Sulphate

The range of chloride, fluoride and sulphate laboratory test values together with typical values for groundwater in the Bringelly Shale are shown in the table below. Piezometer P3S is excluded from this data set as the water in this piezometer appears to be of recent origin when compared to all other samples. Values are presented in mg/L.

	Minimum Value	Maximum Value	Typical Value
Chloride	7,840	14,500	11,000
Fluoride	<0.5	1.1	<0.5
Sulphate	689	2,560	1,500

The chloride and fluoride levels in the groundwater are typical of the Bringelly Shale formation, however the sulphate values are considered to be elevated. Concrete of appropriate durability for the given soil and groundwater conditions should be used in the proposed development, based on Technical Note TN57, produced by the Cement and Concrete Association of Australia, 1989.

3.3.3 Alkalinity, Carbonate Alkalinity

The alkalinity values ranged from non-detectable to 1,560mg/L. Values were typically several hundred mg/L. The carbonate alkalinity was zero in all cases. The measured values are considered to be within the range expected for groundwater resident within the Bringelly Shale formation and reflect the measured calcium and magnesium concentrations.

3.3.4 Calcium, Magnesium and Potassium

Calcium (Ca) levels varied from 63mg/L to 250mg/L (with the exception of P3S at 7.7mg/L). Magnesium (Mg) values ranged from 588mg/L to 1,280mg/L. Potassium values varied from 2.6mg/L to 50mg/L. The results are considered to be within the expected range for the given shale conditions.

3.3.5 TKN, Ammonia

Total nitrogen levels varied up to 1.9mg/L. Ammonia-N values varied up to 1.6mg/L but were typically below the analysis method detection limits. These values are considered to be relatively low.

3.3.6 Sodium

Sodium levels ranged from 5,000mg/L to 7,600mg/L (with the exception of P3S with a concentration of 390mg/L reflecting the waters recent origin). The sodium levels are not unusual for the Bringelly Shale formation.

3.4 Geotechnical Laboratory Test Results

3.4.1 Atterberg Limit Tests

Atterberg Limit tests were undertaken on samples typically obtained at a depth of 0.5m to 0.95m from the boreholes drilled for the groundwater piezometer installation. The samples were obtained from the standard penetration test (SPT) sampler and the soil moisture content was also measured. The results are presented in Table 5 and are summarised in Figure 3.

Soils of high plasticity were typically encountered in the south and generally lower section of the site and in the north-east corner with liquid limits varying from 52% to 68%. The Plasticity Index of these soils varied from 36 to 52. The linear shrinkage varied from 15.5% to 18.0%, and moisture content varied from 14% to 31%. The Plastic Limit varied from 10% to 16%. The *in-situ* soil moisture content was mostly above the Plastic Limit.

Soils of low to medium plasticity were encountered in the generally higher, north-west section of the site with liquid limits varying from 31% to 36%. The plasticity Index of these soil varied from 18 to 27. The Linear Shrinkage varied from 9% to 12%, and moisture content varied from 11% to 20%. The plastic limit varied from 10% to 13%. The *in-situ* soil moisture content was about equal to or above the Plastic Limit.

The lower plasticity soils were generally encountered in the more elevated areas proposed for residential development and the high plasticity soils were located in the region of the proposed wetlands. The higher areas of the site with generally lower plasticity soils are expected to provide a more favourable classification on a residential lot basis than in the lower areas.

3.4.2 SPT Tests

SPT Tests were undertaken in selected boreholes drilled for groundwater piezometer installation. Tests were typically undertaken at depths of 0.5m to 0.95m, 1.5m to 1.95m and 3.0m to 3.45m. The results are shown on the borehole logs in Appendix A. At most locations the SPT values increased with depth.

The results at 0.5m depth varied from 4 to 15 with a typical value of 11. These results indicate the clayey soils to be of firm to very stiff, with a typically stiff consistency.

The results at 1.5m depth varied from 7 to 30 with a typical value of 15. These results indicate the clayey soil to be of stiff to hard, typically very stiff consistency.

The results at 3.0m depth varied from 10 to refusal with a typical value, where refusal was not encountered (ie in the shaly material), of about 25. The results typically indicate the clayey soil to be of very stiff to hard consistency.

Hand penetrometer strength tests were undertaken on most of the SPT samples. These tests give a more direct indication of the soil strength.

3.4.3 Permeability

Rising head permeability tests were undertaken where possible in the piezometers installed for the groundwater investigation. The results are presented in Table 7.

The piezometers installed in the clay overburden (PS series) gave permeability values of 0.00001m/day to 0.048m/day. The large range is attributed to the variable material type and remnant geological structure. The higher value was located in an area of higher ground compared to the remaining tests. Four of the piezometers were dry, indicating a lack of groundwater perched in the clay overlying the shale at the time on the measurements. The median value was in the order of 0.006m/day, which is typical of a silty soil.

The deeper piezometers installed in shale or sandstone (except P2D, terminated in silty gravelly clay) gave permeability values of 0.0007m/day to 0.05m/day. The large range of permeability is attributed to variable geologic structure in the bedrock. The median permeability was approximately 0.0016m/day, which is typical for shale of this origin.

4 DISCUSSION

4.1 Soil Conditions

The location of the soil sampling sites was designed to provide data in the following areas:

- General residential development area – 21 locations
- Drainage lines – 6 locations
- Proposed wetland locations – 6 locations with 3 common to the drainage lines.

Sample location details are shown in the table below.

Sample Location Areas

GENERAL AREA OF DEVELOPMENT		DRAINAGE LINE LOCATIONS	PROPOSED WETLANDS LOCATIONS AT TIME OF FIELDWORK (LATE 1999)
A1	TP14	TP3	TP4
A2	TP15	TP4	TP11
A3	TP17	TP8	TP16
TP1	TP18	TP9	TP21
TP2	TP19	TP11	TP22
TP5	TP20	TP16	TP25
TP6	TP23	C	-
TP7	TP24	-	-
TP10	A	-	-
TP12	B	-	-
TP13	-	-	-

In addition to the sample locations in the above table, 7 piezometers were installed at the wetland locations (P series) and 5 piezometers were installed in the general area of development (G series). Soil samples, principally for geotechnical testing purposes, were obtained from the boreholes drilled to install the piezometers.

4.1.1 Salinity

Soil salinity was evaluated at 31 test pit locations with typical sample depths of 0m to 0.1m, 0.3m and 7m. Sampling to a depth of 2m was also undertaken in areas where development may expose a deeper soil profile (wetland locations).

The salinity data has been adjusted for texture as outlined by Hazelton and Murphy (1992). This permits independent interpretation of the salinity data, regardless of the soil type. The adjustment factor for the given site soils varied from 7 to 14. The adjusted data is discussed as a saturated paste and is presented in Tables 1 and 2.

Salinity criteria was originally developed by the US Salinity Laboratory in 1954. This criteria has since been modified slightly to take into account Australian conditions (Northcote and Skene, 1972).

Salinity is usually assessed in terms of effects on crops. Salinity classes and plant response have been adapted from a review of Australian Soils by Shaw (1999), and are shown in the table below;

Salinity Classes and Response of Different Plant Types.

Salinity (Saturated extract) dS/m.	Soil salinity rating	Plant response (maximum salinity at which a 10% yield reduction occurs)
<0.95	Very low	Sensitive plants
0.95-1.9	Low	Moderately sensitive plants
1.9-4.5	Medium	Moderately tolerant plants
4.5-7.7	High	Tolerant plants
7.7-12.2	Very high	Very tolerant plants
>12.2	Extreme	Too high for most plants

(Source: Shaw, 1999).

Surface soils usually have the least salinity. Significant salinity was evident in the soils in TP4, TP18, TP25, Sites B and *C.* TP18 and Site B are located in the general area of site development and the remainder are located at the drainage and wetland locations. The salinity in TP18 and Site B correlated with the EMI survey data, where higher salinity was indicated. At these locations the salinity of the surface soils was considered to be low and would only affect moderately sensitive plants.

Knowledge of deeper soil salinity conditions is necessary in order to manage and minimise the potential for development of salinity problems as the proposed development will expose deeper profiles at specific locations. This information is also necessary for assessment and design to prevent the potential development of saline conditions at the toe of slopes associated with increased run-off due to urbanisation.

Salinity (corrected to saturated paste) at 0.3m ranged from 0.36 dS/m at TP16 (very low) to 4.86 dS/m at TP11 (high). Low to very low salinity (<1.9 dS/m) was encountered in the samples obtained at 0.3m depth at all locations except A2, *C,* TP3, TP11, TP14 and TP25. Site *C,* TP3, TP11 and TP25 are in lower parts of the landscape in drainage line and detention basin areas. Exposure of these soils should be minimised. This requirement should be incorporated into the planning process.

The soil salinity increased with depth at most locations sites. The table below shows that TP5, TP12 and TP24 are the only locations in the general development area of the site with very high salinity at a depth of 1.0m.

Soil Salinity Data at 1m Depth

Salinity (Saturated extract) dS/m.	**Soil salinity rating**	**General area of development**	**Drainage line areas or proposed wetlands**
<0.95	Very low	TP2,	TP4, TP16
0.95-1.9	Low	TP1	TP21, TP25,
1.9-4.5	Medium	TP14, TP17, TP20, A3,	
4.5-7.7	High	TP6, TP7, TP10, TP15, TP18, TP19, TP23, A2,	TP3, TP8, TP22
7.7-12.2	Very high	TP5, TP12, TP24	TP9, TP11,
>12.2	Extreme	Nil	Nil

Note: Data not available at 1m at TP13

The very high salinity ratings at sites TP12 and TP24 are consistent with the EMI survey. TP18, which lies between TP12 and TP24 has a high rating. These test pits are located in the south-west corner of the site adjacent to The Northern Road. Development in this area of the site will require specific planning to accommodate the saline nature of the subsurface soils. Excavation depths should be limited to 0.5m in this area where possible and subsoil drainage may be required to control and reduce the level of the groundwater table.

In summary, the surficial soil salinity conditions are considered to be satisfactory for the proposed development. Salinity becomes relatively high at a depth of approximately 1m and the development should be designed not to mobilise salinity from this depth to lower parts of the landscape. This can be achieved by limiting excavation depths, by reducing the volume of water entering the soil, and by the inclusion of surface and subsoil drains in areas where salinity may be mobilised.

4.1.2 pH

Bare soil can be eroded if the soil pH is outside of the desirable range. The criteria for soil pH is largely based on the effect on plant growth. The table below shows soils at TP11, TP15 and TP17 are highly acidic in the upper soil

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layer to a depth of approximately 0.3m. Five other locations show similar acidity at a depth of 1m.

Virtually all the soils show acidity at strong to very strong levels. Exceptions occur at TP5 and TP6 where soil pH conditions are optimal.

Effect of Soil pH on Plant Growth and Nutrient Availability
and pH Variation with Depth

pH (Ca Cl_2)	Locations with pH at surface	Locations with pH at 0.3m	Locations with pH at 1m	Effects
<4	TP17	TP11, TP15	TP1, TP15, TP17, TP23, TP24, A2	Extremely weathered soils, high Al toxicity
4-4.5	TP1, TP2, TP4, TP5, TP7, TP8, TP9, TP10, TP11, TP12, TP13, TP14, TP15, TP16, TP18, TP19, TP20, TP21, TP23, TP24, TP25, A1, A2, A3, A, C	TP1, TP3,TP4, TP8, TP9, TP10, TP12, TP13, TP14, TP16, TP17, TP18, TP19, TP20, TP21, TP23, TP24, TP25, B	TP2, TP4, TP6, TP9, TP10, TP11, TP12, TP14, TP16, TP18, TP19, TP20, TP22, A1 A3	Al and Mn toxicity, Reduced N transformation.
4.5-5.0	TP3, TP22, B	TP2, TP6, C	TP3, TP8, TP21	Potential Al and Mn toxicity.
5.0-6.5	TP6	TP5	TP5, TP7, TP25	Optimal for most plants and biological processes

Note: Data not available at 1m at TP13

Surface soil acidity is able to be adjusted relatively easily and economically by the addition of lime. Lime requirement analysis results presented in Table 2 indicate that up to 4.31 kg of lime/tonne of soil is needed. Assuming a soil bulk density of 1.75 tonnes/cubic metre and treatment for the surface 0.1m, the mass of lime required is up to approximately 7t/ha. The average application required is 2.9 t/ha. Present day costs including delivery and spreading are approximately $400/ha.

In summary, the acidic nature of the site soils is considered to be satisfactory for the proposed development, provided that adjustment is undertaken at appropriate times. Conventional treatment by the addition of lime is recommended.

4.1.3 Dispersivity

Soil dispersivity was assessed by performance of Emerson Aggregate Tests (EAT), dispersivity, cation exchange concentration and sodicity measurements on soil samples obtained from the test pits. These tests can be used to predict soil structural behaviour under various field conditions.

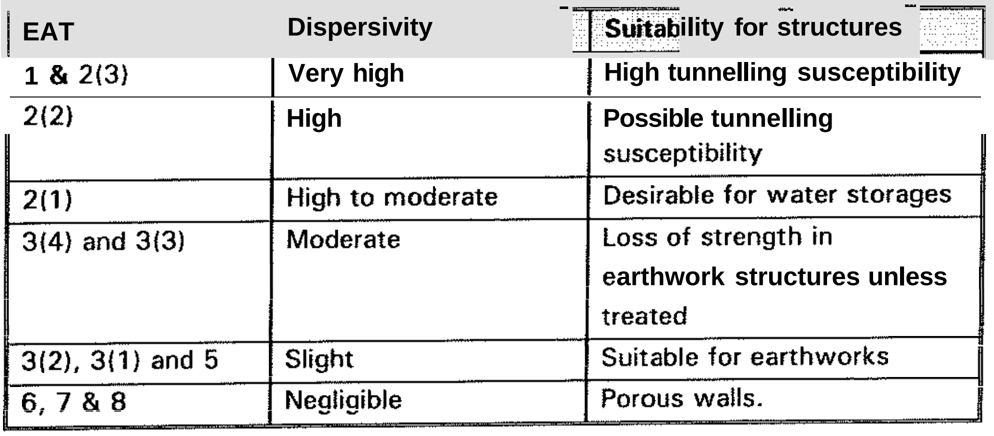
Dispersive soils are commonly associated with the following soil structure behaviour in urban development areas:

- Dispersion leading to sediment loss to streams;
- Susceptibility to tunnelling or piping through water retaining embankments;
- Leakage from detention ponds.
- Severe soil softening when saturated.

Desirable urban soil characteristics vary with the likely use. For example, an ideal pond base should be slightly dispersive to assist sealing of the pond base and to prevent water loss. Conversely a very stable soil is preferred on building sites.

Dispersibility criteria has been set out by **Charman (1978).** This is summarised in the table below;

Relationship Between Soil Dispersion and EAT
(Suitability for Water Holding Structures is also Shown)



EAT	Dispersivity	Suitability for structures
1 & 2(3)	Very high	High tunnelling susceptibility
2(2)	High	Possible tunnelling susceptibility
2(1)	High to moderate	Desirable for water storages
3(4) and 3(3)	Moderate	Loss of strength in earthwork structures unless treated
3(2), 3(1) and 5	Slight	Suitable for earthworks
6, 7 & 8	Negligible	Porous walls.

Bracketed figures are EAT assessments for remoulded (reworked) soil samples. (Source Charman, 1978, Crouch, 1991).

The dispersive nature on the soils at the various site locations are shown in the following table.

Soil Dispersibility Location Data

Location type and depth	**Dispersability**					
	Very high 1 & 2(3)	**High 2(2)**	**High to moderate 2(1)**	Moderate **3(4)** and **3(3)**	Slight **3(2), 3(1) and** 5	Negligible **6, 7 & 8**
Development-surface	-	-	-	TP6, TP7, *TP14*, *TP23*, A2, A3, *C*	TP1, TP2, TP5, TPIO, TP12, TP13, TP15, TP16, TP18, TP19, *TP20*, *TP24*, **A1,, A, B**	-
Development-0.3m	TP14, AI, A2, C	-	TP5, TP6, TP10, TP12, TP13, TP24, *C*	TP17, TP18, TP23,	TP1, TP2, TP15, TP19, TP20,	-
Drainage line area-surface	-	-	-	TP3, TP9, *C*	TP8	-
Drainage line area-0.3m	*TP3, C*	*TP8*	-	TP9	-	-
Wetland-surface	-	-	-	TP11, TP21,	TP4, TP16, TP25	-
Wetland-0.3m	-	TP11	TP21	*TP4,*	*TP16, TP25*	-
Wetland-1m	-	TP21	-	-	-	-

The table above shows that the surface soils in the general development areas have slight to moderate dispersibility, which is consistent with the occasional visual evidence of crusting of the surface soils. Dispersibility increases with depth. Soils at **TP14,** AI, A2 and *C* are very highly dispersive, and will require treatment in areas where the subsoil will be exposed by excavation to physical erosion processes.

The results in the drainage lines appear similar to those in the development areas, with low to moderate dispersibility in the surface soil. High to very high dispersibility occurs in the subsurface soil. The erosion potential of the highly dispersive soils is demonstrated by the slumping of exposed subsurface soils seen along drainage lines at the west precinct.

Site development will require exposure of subsoil. The use of conventional soil treatment methods to avoid soil dispersion is recommended in all such areas. A management plan will be required to ensure that potential soil dispersivity is effectively controlled and prevented. The table shown in Section 3.2.3 provides data on gypsum addition required to ameliorate potential soil dispersivity problems.

An initial application of up to 10tonnes/ha should be applied to the proposed development area (well in advance, to permit the gypsum to move through the soil profile). The indicative cost is on the order of $1,000/ha. Further applications of gypsum will be required during the development works, dependent on specific site conditions.

Wetland and detention ponds will require gypsum addition to the soils, both during and after construction, to prevent dispersion of clay into the stored water. The prevention of initial dispersion is critical, as control in detention/sediment ponds without the extensive use of potentially toxic chemicals is difficult.

In summary, provided that soil dispersivity is managed appropriately, the dispersive nature of the soils is not seen to be a limitation to the proposed site development.

4.1.4 Soil Erosion Potential

Site development will involve the exposure of areas of soil without vegetation cover. The main factors that affect potential soil erosion under these conditions are the erodibility of the soil, the slope gradient and the length of an uninterrupted slope. The soil erodibility is a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff. The soil erodibility (K) values in the table below have been calculated from measured soil properties including particle size analysis, organic carbon content, soil structure and profile permeability. Highly dispersive soils are also recognised to exhibit higher erodibility than soils with the same K value. The ***"Blue Book"*** (Department of Housing, 1998) suggests that the K value be increased by 20% for EAT Class 1 and 2 soils. In the table below these soils are denoted by ✓ in the column headed "High Dispersibility". The recommended 20% increase in K value is not shown in the table, but the "Erodibility Rating" (last column) has been adjusted accordingly.

Soil Erodibility Assessment

Location	**Sample Depth**	**K Value (from Table 3)**	**High Dispersibility**	**Adjusted Erodibility Rating**
TP1	0.8-1.0m	0.047		high
TP2	0.75-0.9m	0.040	✓	high
TP3	0.3-0.5m	0.060		high
TP4	2.0-2.1m	0.048		high
TP5	0.75-0.9m	0.052	✓	very high
TP6	0.75-0.9m	0.046	✓	high
TP7	0.75-0.95m	0.055		high
TP8	0.75-0.95m	0.064	✓	very high
TP9	0.3-0.5m	0.051		high
TP10	0.75-0.9m	0.044	✓	high
TP11	2.0m	0.064	✓	very high
TP12	0.3-0.45m	0.052	✓	very high
TP13	0.75m	0.049	✓	very high
TP14	0.3-0.5m	0.047	✓	high
TP15	0.3-0.45m	0.042		high
TP16	1.5-1.6m	0.059		high
TP17	0.75m	0.052		high
TP18	0.75-0.9m	0.057		high
TP19	0.75-0.9m	0.056		high
TP20	0.75-0.9m	0.048		high
TP21	2.0m	0.070	✓	very high
TP22	2.0-2.15m	0.060		very high
TP23	0.75-0.9m	0.045		high
TP24	0.75-0.9m	0.038	✓	high
TP25	2.0-2.1m	0.053		high

All analysed soils exhibit either high (K = 0.04 to 0.06) or very high (K > 0.06). The erodibility ratings indicate that effective erosion and sediment control measures will be required during the development process to manage and control sediment discharge from the site. The erosion and sediment control programme will need to remain in place during the development phase until dwelling construction is substantially complete.

In summary, provided that potential soil erosion is managed appropriately, the erosive nature of the soils is not seen to be a limitation to the proposed site development.

4.1.5 Soil Fertility and Stability

Soil Cation Exchange Concentration

The ability of a soil to retain nutrients is indicated by the soil Cation Exchange Concentration (CEC). The CEC plays important roles in soil fertility and stability and is a relatively stable attribute that can be slowly changed by reducing acidity or adding organic matter. The CEC is also a good indicator of soil dispersivity. In an urban development setting a low CEC indicates that leaching of nutrients to streams may occur.

The CEC was measured at all test pit locations. As in most Australian soils the CEC is lowest in the sandy topsoil and increases as the clay content increases with depth. TP1 shows this typical pattern. The surface CEC was 7.7 cmol(+)/kg. This increased to 17.8 at 0.3m with a slight further increase to 18.1 at 1m.

The variation of CEC over the site and CEC rating details are shown in the following table.

Cation Exchange Capacity at Investigation Locations

CEC	**Rating (assumes location is close to a drainage line. If not limitation is moderate to minimal)**	**CEC at surface**	**CEC at 0.3m**	**CEC at 1m**
<3	Severe limitation (low ability to retain nutrients or contaminants)	None	None	None
3-15	Moderate limitation	A, C, TP1, TP2, TP3, TP4, TP8, TP9, TP10, TP15, TP16, TP17, TP19, TP20, TP21, TP22, TP24	TP16, TP17, TP18, TP19, TP21, TP25	TP3
>15	Little limitation	B, TP5, TP6, TP7, TP11, TP12, TP13, TP14, TP18, TP23, TP25	A, C, TP1 to TP15, TP20, TP22, TP23, TP24	All apart from TP3

The CEC soil results vary from moderate to little limitation. None of the soils sampled indicated severe limitation due to low CEC. An east - west band of soils (TP18 to TP16) in the centre portion of the site indicated lower CEC than other areas. However, even at this location, the soils have adequate to high CEC at depth.

The CEC measurements indicate that the CEC is not likely to be a significant limitation to development of the site.

Exchangeable Sodium (Na)

Exchangeable Na plays a key role in the assessment of soil stability. Excessive Na leads to unstable soils, increased runoff, potential salinity, dispersivity and water logging problems. Normally the Na content is expressed as a percentage of the CEC as other cations can counteract the negative effects of the Na.

The effect of the exchangeable Na (Exchangeable Na percentage, ESP) varies with other soil factors such as the type of clay, the relative quantity of magnesium and the quantity of organic matter. A soil is considered sodic if the ESP exceeds 6%. An ESP greater than 15% indicates the soil to be severely sodic.

Sodicity at Investigation Locations

Exchangeable sodium Percentage (ESP)	Sodicity Rating	ESP at Surface	ESP at 0.3m	ESP at 1m
<6	Non sodic	All surface soils are non sodic	TP2, TP9, TP10, TP13, TP16, TP17, TP19, TP21	TP4
6-15	Sodic	None	B, C, TP1, TP4, TP5, TP6, TP7, TP8, TP11, TP12, TP14, TP15, TP18, TP20, TP23, TP24,	TP1, TP2, TP7, TP9, TP10, TP11, TP12, TP14, TP16, TP21
>15	Severely sodic		TP3, TP22	TP3, TP5, TP6, TP8, TP15, TP17, TP18, TP19, TP20, TP22, TP23, TP24

(Criterion Source: Soils: their Properties and Management. Charman and Murphy, 2000).

The above table indicates that all the surface soils are non-sodic. The sodicity increases with depth. The soils at a depth of 0.3m at TP3, TP22 and site C are severely sodic. Exposure will require treatment to prevent the creation of significant sediment yields. Treatment will typically involve the addition of gypsum. The amount of gypsum to be added will vary with the soil, but an indicative rate of up to 10 tlha (cost in the order of $1,000/ha) is a reasonable initial assumption.

Almost half the soils are severely sodic at 1.0m depth. The development should be designed to minimise exposure of the deeper soils.

Construction of detention ponds will involve the exposure of sodic soils. Gypsum should be applied to exposed surfaces during basin construction and site development phases to avoid de-flocculation of pond sediments (this would create an opaque suspension which would be difficult to treat and clarify). Lime stabilisation/modification and or gypsum application requirements for the detention ponds and the drainage lines should be assessed by site specific investigation.

Exchangeable Potassium

Exchangeable potassium ranged from 0.1 cmol(+)/kg at TP3 to 1.6 to 1.7 cmol(+)/kg in the subsoils at TP5 and TP14. Concentrations less than 0.2 cmol(+)/kg are considered low for pastures (Metson, 1961). Table 2 shows that TP3 and TP8 are the only locations with low potassium concentrations. Potassium deficiency can be readily corrected with fertiliser.

The potassium availability is generally considered to be at appropriate levels for the proposed development.

Exchangeable Calcium (Ca)

Exchangeable calcium concentrations are generally at levels considered suitable to maintain plant growth and soil structure associated with the proposed development. However, there are some locations where the exchangeable Ca concentrations are less than cmol(+)/kg, which are considered very low (Metson, 1961). This occurs in soils at TP1, TP8, TP15 and TP17. These soils lie in a north-south band at the central northern portion of the site. Ca deficiency in this band can be corrected via general application of gypsum and lime.

Exchangeable Magnesium (Mg)

The magnesium concentration is suitable for the proposed development. The soils have an average of 8.3 cmol(+)/kg, greater than the minimum desirable magnesium concentration of 1 cmol(+)/kg.

Magnesium is essential for plant growth, but too much relative to the quantity of Ca can result in loss of soil structure. Ideally there should be 4 to 6 times the amount of Ca to Mg (Eckert, 1987). Table 2 shows the ratio of Ca to Mg at the site to be typically 1:2.5. The relative deficiency in Ca can be corrected by the general application of gypsum and lime.

Exchangeable Aluminium (Al)

Soil conditions at the site in relation to aluminium are considered to be suitable for the proposed development provided that the application of lime required for pH adjustment is undertaken.

Soils usually contain large amounts of aluminium. The aluminium becomes exchangeable and potentially toxic when the pH is less than 4.5 ($CaCl_2$). Al toxicity is also related to Ca availability and if Ca is more than 4 cmol(+)/kg toxicity is unlikely (Cregan, 1980). Soils with $pH<4.5$ and low Ca require the addition of lime to reduce Al availability.

The conditions at many of the test pits require the addition of lime as outlined above. These are TP1, TP8, TP9, TP14, TP15, TP17, TP18, TP19, TP20, TP24 and A. Liming recommendations to counteract soils acidity are presented in the section dealing with soil pH (section 4.2.1).

4.1.6 Available Phosphorous

The addition of fertiliser to appropriate sections of the land is recommended to overcome a phosphorous (P) deficiency of the site soils.

The available P was extremely low in all soils tested with I mglkg the highest P concentrations in the test pit samples. Soils with less than 8 mg/kg are considered deficient (NSW Agriculture and Fisheries, 1989).

Low P concentrations reduce plant growth and affect revegetation rates of disturbed sites. The application of 40 kg/ha of elemental P to appropriate completed sections of the development is recommended (NB: the rate of fertiliser application will depend on the P concentration in the fertiliser mix). The application of P will be especially critical in areas where the subsoil has been exposed.

4.1.7 Summary

In summary, in common with typical Western Sydney soils, the soils at the site are, to a varying degree, acidic, unstable, erodible and have very low fertility. Salinity also occurs at depth. These characteristics can be readily overcome by a combination of amelioration and careful management involving standard methods.

The use of gypsum and lime will overcome aluminium toxicity, soil instability and acidity. **A** total of 10 tlha (2 to 3 t/ha of high grade agricultural lime and 7 to 8 tlha of gypsum) is recommended for the site in the proposed development area as soon as possible right up to the creek lines.

An effective application method is by a dual axle truck mounted spreader equipped with a hopper, vibrating feed and spinner. Such a unit should provide a 20m to 30m coverage per pass. The application should not involve any cultivation or ripping in order to minimise mobilisation of salinity from the subsurface soils.

All soils have a relatively high erodibility rating. An effective erosion and sediment control plan will be required during the development process in order to ensure that sediment discharge from the site is kept to acceptable levels.

Salinity at depth can be controlled by minimising the hydrological load on the site. This is discussed in Volume 1.

Phosphorus is needed to increase plant growth. In view of the generally low fertility of the site, a mix of N, P and K is recommended in selected areas of the site at an appropriate time. The mix should contain a minimum of 40 kg/ha of P and 100 kg/ha of K.

All design and work teams should be formerly inducted to the management strategies developed for the site in relation to the control of salinity and erosion. This will assist orderly development of the site with due consideration to the controls required for the range of soil conditions encountered.

4.2 Groundwater Conditions

Groundwater conditions were investigated at the site by the installation of two piezometers at each of the seven proposed wetland locations (P series piezometers). A further seven piezometers (G series piezometers) were installed up-slope of the wetlands adjacent to drainage lines (2 piezometers were located at G6 ie G6S and G6D). The up-slope piezometer locations were considered to be reasonably representative of the more elevated section of the site designated principally for residential development.

The depth to groundwater in the piezometers varied from 0.95m to 6.05m. There was no obvious correlation between the depth of the groundwater table at any particular location and other site features.

In the shallow clay soil piezometers (designated by S, eg P1S), the depth to groundwater varied in some cases to that in the deep shale piezometers (designated by D, eg P1D). The depth was virtually the same in P1, P4 and P5. In P3 and G6, the depth was shallower by up to 2.5m compared to the shale, indicating a possible perched aquifer condition. In P6 the depth was deeper by 0.54m indicating a possible sub-artesian condition. In P2S and P7S, the shallow clay piezometers installed to a depth of 4.4m and 4.05m respectively, did not intersect any groundwater.

The depth to the groundwater table appears to be affected by geologic structure including joints, faults, bedding and other discontinuities that can act as a flow path within the rock.

The groundwater table depth level was related to **AHD** datum and is plotted in Figures 4 and 5. The data has been contoured and the topographic features have been used as a guide to interpret the contours on the assumption that the groundwater table level is generally sympathetic with the topography. Interpreted groundwater flow directions are shown on the figures as arrow lines, orthogonal to the contours. The general flow direction was typically to the east, modified locally by the east-west striking ridgeline, with flow to the north-east on the north of the ridge and to the south-east on the south of the ridge.

The groundwater gradient typically varied from approximately 0.7% to 2.0% over the site and was generally higher in the area of the ridge in the central, north section of the site.

The formation conductivity (ie permeability) has been assessed by the performance of rising head tests in the piezometers, noting that most of the piezometers became dry during development and purging. The results were variable, and are described earlier in this report.

The flow across the site from the west to the east to the creek region was estimated to be approximately $3m^3$/day. This figure is based upon a typical groundwater gradient of approximately 1% at the site at the time of the investigation, medium shale permeability of 0.0016m/day and an aquifer thickness of 5m.

Localised flow would be expected to vary as much as the variation seen in the permeability results, ie by several orders of magnitude. The relatively small estimated flow indicates that significant changes in the groundwater table level can be expected to occur in areas with variable or potentially high recharge conditions.

Groundwater chemistry is discussed in Section 3.3.

4.3 Geotechnical Conditions

Single and double storey residential structures and similar infrastructure buildings will be founded typically on residual clayey soils that are generally dispersive, and moderately to highly reactive.

Detailed investigation will be required to assess individual or groups of sites in relation to lot classification and specific site preparation requirements. Due to the relatively deep clay profile (ie >2.0m) over most of the site, the moderately to highly reactive nature of the soils, as based on the Atterberg Limit results, most sites can be expected to classify as M to H in accordance with the AS2870 document. Detailed shrink/swell assessment may show the site soils to be less reactive than expected as the clay soils have a somewhat higher sand fraction than those typically encountered in the western areas of Sydney. Earthworks at the site will potentially change these classifications and technically where fill is greater than 0.4m thick the lots would be classified as P, unless the fill is tested to Level 1 certification, where a reclassification to Class M or H may be achieved.

Sites with trees located in areas of high potential clay shrinklswell behaviour will require special consideration as the time required for the development of equilibrium conditions after tree removal can be around 2 years depending on the rainfall. Detailed assessment should be undertaken in such instances to assess potential foundation movement conditions. If trees are to be cleared then preferentially this should be completed a year or more prior to the commencement of works associated with the development.

Roads fill may be constructed using the dispersive, moderate to high plasticity clay soils but precautions are required. Shale excavated from other infrastructure construction may be available for use as fill and should prove to be a better material, both to handle during earthworks and in relation to engineering properties. The dispersive clays will soften substantially on saturation and will have low California Bearing Ratio (CBR) values and resulting relatively thick pavements. Use of these soils as subgrade materials should be avoided if possible. Alternatively these soils could be improved by lime stabilisation/modification prior to use.

Roads located in potentially water logged areas should preferably be built up/down slope to minimise the damming effect of the roadway to the downhill flow of subsurface water. The need for subsoil drainage as part of road construction should be assessed on a case by case basis by the designer.

Site preparation should be based on conventional treatment including topsoil stripping and grubbing and treatment of soft spots etc. The effects of the dispersive and expansive nature of the clayey soils as well as low CBR values can be improved by conventional lime stabilisationlmodification of the soil during earthworks and construction. The amount of lime should be assessed from the results of CBR tests on stabilised samples. Compaction of fill should generally be at or just above Standard Optimum Moisture Content, to at least a density of between 100% and 104% of the Standard Maximum Dry Density to minimise future dispersion and softening.

All batter slopes in the relatively dispersive clayey soil will require stabilisation. Standard Blue Book stabilisation methods should be satisfactory to control erosion. The stabilisation works should be undertaken as soon as possible.

Development of the Western Precinct will involve construction of 7 major wetlands to depths up to approximately 3.0m. One of the ponds may extend down into the Bringelly shale. The base of the ponds may in some cases be below the groundwater table level. Seasonal fluctuation of the groundwater data must be expected and should be assessed by additional monitoring.

Leakage from the wetlands into the underlying clay or shale aquifer may be significant as the wetlands are to be maintained at a constant level where possible. Such leakage could be expected to lead to a localised rise in the groundwater table level due to the additional aquifer recharge, which may lead to the development of soil salinity problems.

Based on the available information, provision of a liner to the wetland facilities may be necessary. Conditions at each specific wetland location should be further investigated and assessed in relation to liner requirements and other design parameters. Assessment of special requirements for concrete in relation to sulphate attack should also be made.

Provision of a clay liner to the wetland facilities will reduce the loss of water from the wetlands through leakage. This is of benefit, as the ponds should be maintained at as constant a level as possible during dry weather periods. The thickness of the liner will be dependant on the availability of appropriate quality soils, and the construction method, together with operational methods of sediment removal from the wetlands. A liner thickness of approximately 0.5m to 1.0m is envisaged, based on the available information. The permeability of the stabilised material should be checked as lime stabilisation may increase the permeability of the soil.

Liners should be able to be constructed from on-site clayey soils, provided the dispersive behaviour is reduced by lime stabilisation of the soil during construction. A synthetic liner may be found to be more economical, especially where the possibility of the clay liner drying out exists. Good quality soils should be identified by sampling and testing during the wetland construction and such materials stockpiled during site earthworks for later use.

5 LIMITATIONS

This report has been prepared for the particular project described and no responsibility is accepted for the use of any part of this report in any other context or for any other purpose. J&K has used a degree of care, skill and diligence normally exercised by consulting engineers in similar circumstances and locality. No other warranty expressed or implied is made or intended. Subject to payment of all fees due for the investigation, the client alone shall have licence to use this report. The report shall not be reproduce except in full.

Should you have any questions regarding this report, please do not hesitate to contact the undersigned

Joanne Rosner	E H Fletcher
Environmental Scientist	Director

GLOSSARY[1]

AAS	Atomic Absorption Spectrometry
Acidity	The chemical activity of hydrogen ions in soil. Usually expressed in pH units
AHD	Australian Height Datum (metres)
Al	Aluminium
ANZECC	Australian and New Zealand Environment Conservation Council
Aquatic Macrophyte	A large plant capable of living in soils and sediments that are at least periodically flooded
BGL	Below Ground Level
BH	Borehole
BD	Bulk Density
C	Carbon
Ca	Calcium
$CaCO_3$	Calcium Carbonate
$Ca(OH)_2$	Lime (Calcium Hydroxide)
CBR	Californian Bearing Ratio
CEC	Cation Exchange Capacity: The total quantity of exchangeable cations that the soil can absorb. Includes Ca, Mg, Na, K, H and Al.
Crusting	The nearly horizontal orientation and packing of dispersed soil particles in the immediate surface layer of soil. This greatly reduces water penetration, encouraging run-off.
CSIRO	Commonwealth Scientific and Industrial Research Organisation
D%	Dispersion (percentage) The breakdown of soil particles into constituents such as clay, silt and sand via the process of deflocculation. Dispersion can lead to erosion, high rainfall run-off and turbid waters.
DUAP	Department of Urban Affairs and Planning (NSW)
EMI	Electromagnetic Induction Survey
EAT	Emerson Aggregate Test (Class number)
EC	Electrical Conductivity
Eh	REDOX Potential
EPA NSW	Environment Protection Authority, New South Wales
Erodibility	The susceptibility of soil to detachment and transport by water and wind (The K value in R-USLE)
GC-ECD	Gas Chromatograph-Electron Capture Detector
GC-FID	Gas Chromatograph-Flame lonisation Detector
GC-MS	Gas Chromatograph-Mass Spectrometer
G series	Piezometer series - upstream of wetland areas

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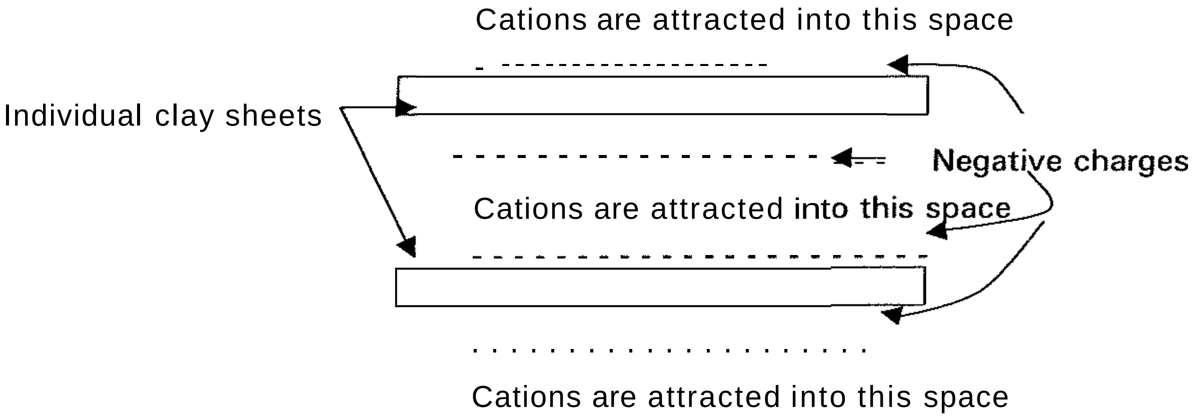
[1] Where possible definitions for industry based texts such as Wong et al (1998) have been used

ha	Hectare (1 ha = 100m*100m)
HCl	Hydrochloric Acid
K	Potassium
KL	Kilolitre (1000L) equivalent to 1 cubic metre of water
Mg	Magnesium
NATA	National Association of Testing Authorities, Australia
Na	Sodium
NHMRC	National Health and Medical Research Council
NH_4F	Ammonium Flouride
NO_3	Nitrate
OC%	Organic Carbon Percentage
P	Phosphorus
Percentile	The percentage
pH	A measure of acidity
PD series	Piezometer series - deep shale at wetland locations
PS series	Piezometer series - shallow clay at wetland locations
PO_4	Phosphate
PSA	Particle Size Analysis - soil fractionation based on grain size
RPD	Relative Percentage Difference
R-USLE	Revised Universal Soil Loss Equation - refer to Department of Housing "Blue Book" publication
R-USLE K Value	Soil Erodibility Rating
SAR	Sodium Absorption Ratio: A measure of the ratio of sodium to calcium plus magnesium. It is used in conjunction with salinity data to determine the stability of irrigation water.
Slaking	The partial breakdown of soil aggregates in water due to clay swelling and soil gas pressure
Sodic soil	A soil whose structure is degraded due to excess exchangeable sodium. Usually applies to soil where more than 6% of exchangeable cations are sodium. More than 15% indicates a strongly sodic soil.
SWL	Standing Water Level
t	Metric tonne (1000kg)
t/ha	Tonnes per hectare
TN 37	Technical Note: Cement and Concrete Association
TP	Test Pit
USEPA	United States Environmental Protection Agency
USLE K value	Soil erodibility rating - U
UV	Ultra Violet

Notes on the Roles of Clay Type and Cations – Effect on Soil Behaviour.

Clays are formed in soils from the weathering of rocks. The parent material determines the type of clay. Clays consist of sheets of cations (largely $Al^{3+}$and Si^{4+}) and anions (OH-and O^{2-}). Substitution of cations especially Mg^{2+}, Ca^{2+} for $Al^{3+}$and Si^{4}+, plus imperfections in the sheet result in the sheet surfaces having a net negative charge. This negative charge attracts cations such as H^{+}, Mg^{2}+, Ca^{2+}', Na^{+} and K^{+} (See below). This attraction is critical to soil structure. Without it the individual clay particles will not coalesce. The individual clay sheets are too small to settle via gravitational forces and therefore will remain in suspension forming a stable floc.



The distance between the clay surfaces is dependant on the equilibrium between the negative charges on the clay surface and the attractive forces of the cations. The attractive force of the cations is very dependant on the valance of the cations. For example, Ca^{2}+ has a much more attractive force for the clay layers than does Na^{+}. Additionally the attractive force is obviously dependant on the concentration of the cations. Thus adding gypsum (Calcium sulphate) has a two fold effect. It increases the proportion of cations that are divalent and it increases the total cation concentration of quantity of Ca^{2+}.

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TABLE 1
SUMMARY OF LABORATORY TEST DATA - SOILS
Urban Capability Data - Electrical Conductivity, pH, Organic Carbon, Dispersion (%) and EATs

Location	**Sample Depth**	**EC** (dS/m)	**EC Sat. Paste** (dS/m)	**pH** (CaCl2)	**OC** (%)	**D** (%)	**EAT**
TP 1	0.8-1.0m	0.24	2.16	3.90	0.14	87.0	2(3)
TP 2	0.75-0.9m	0.05	0.45	4.30	0.52	21.0	3(1)
TP 3	0.3-0.5m	0.06	0.54	4.80	0.49	68.0	2(3)
TP4	2.0-2.1m	0.09	0.72	4.80	0.11	29.0	5
TP5	0.75-0.9m	0.86	7.74	6.90	0.16	53.0	2(1)
TP6	0.75-0.9m	0.74	6.66	4.70	0.34	81.0	2(3)
TP7	0.75-0.95m	0.89	7.12	6.00	0.13	49.0	2(1)
TP8	0.75-0.95m	0.62	5.58	5.50	0.17	88.0	2(3)
TP9	0.3-0.5m	0.29	2.61	5.60	0.34	79.0	2(2)
TP10	0.75-0.9m	0.75	6.75	4.20	0.30	82.0	1
TP11	2.0m	0.91	8.19	4.70	0.09	61.0	2(2)
TP12	0.3-0.45m	0.09	0.81	4.40	0.39	51.0	2(1)
TP13	0.75m	0.10	0.90	4.50	0.56	62.0	2(1)
TP14	0.3-0.5m	0.25	2.25	4.30	0.45	71.0	2(2)
TP15	0.3-0.45m	0.32	2.56	4.00	0.29	38.0	3(2)
TP16	1.5-1.6m	0.14	1.26	4.40	0.08	81.0	2(3)
TP17	0.75m	0.22	1.76	4.10	0.29	33.0	2(1)
TP18	0.75-0.9m	0.79	6.32	4.00	0.23	0.0	6
TP19	0.75-0.9m	0.41	3.69	4.00	0.17	83.0	1
TP20	0.75-0.9m	0.64	5.12	4.00	0.21	34.0	3(1)
TP21	2.0m	0.58	5.80	4.20	0.15	62.0	6
TP22	2.0-2.15m	0.75	6.00	4.70	0.11	81.0	2(3)
TP23	0.75-0.9m	0.61	4.88	3.90	0.29	61.0	2(3)
TP24	0.75-0.9m	1.10	9.90	3.90	0.29	44.0	2(2)
TP25	2.0-2.1m	0.20	1.80	4.80	0.12	72.0	2(3)

Explanation of abbreviations
EC: Electrical Conductivity
OC: **Organic Carbon**
D: Dispersion
EAT: Emerson Aggregate Test

TABLE 2
SUMMARY OF LABORATORY TEST DATA - **SOILS**
Soil Chemisty - EATs, EC, pH, CEC, Available **Phosphorus**, Lime Requirements
Bulk Density, Exchangeable Sodium Percentage

Sample	EAT	EC	Corr for	EC Sat.	pH	CEC (cmol(+)/kg)						Available P	Lime Requirement	BD	ESP
		(dS/m)	Texture	Paste	($CaCl_2$)	CEC	Exch Na	Exch K	Exch Ca	Exch Mg	Exch Al	(mg/kg)	($CaCO_3$ kg/t)	(Mg/m3)	%
TP1 (0.0-0.12m)	3(1)	0.08	9	0.72	4.2	7.7	0.20	0.4	2	2.4	1.1	1.0			2.6
TP1 (0.3m)	3(1)	0.06	9	0.54	4.0	17.8	1.70	0.1	0.5	9	2		1.46		9.6
TP1 (1.0m)	-	0.21	9	1.89	3.8	18.1	2.40	0.3	0.7	8.1	2.1				13.3
TP2 (0.0-0.1m)	8/3(1)	0.06	9	0.54	4.4	12.4	0.10	0.4	3.7	5	0.2				0.8
TP2 (0.3m)	3(1)	0.09	9	0.81	4.7	15.0	0.30	0.3	7.8	4.1	nd		0.87		2.0
TP2 (1.0m)	-	0.08	9	0.72	4.3	27.8	1.70	0.6	7.8	12.6	0.2				6.1
TP3 (0.0-0.2m)	3(3)	0.05	9	0.45	4.6	11.5	0.50	0.1	3.1	5.3	nd			1.61	4.3
TP3 (0.4-0.5m)	1	0.29	9	2.61	4.3	17.5	2.90	0.1	0.9	9.3	nd		0.91		16.6
TP3 (1.0m)	-	0.79	9	7.11	4.7	14.9	2.80	0.2	1.6	6.7	nd				18.8
TP4 (0.0-0.03m)	3(2)	0.12	10	1.20	4.4	13.7	0.40	1	3.8	6.8	nd				2.9
TP4 (0.3m)	3(3)	0.12	9	1.08	4.2	17.8	1.20	0.3	5.1	7.9	0.4		1.41		6.7
TP4 (1.0m)	5	0.10	7	0.70	4.1	15.7	0.60	0.4	3.3	7.3	0.4				3.8
TP5 (0.0-0.06m)	8/3(2)	0.06	9	0.54	4.4	17.0	0.50	0.5	6.5	5.7	0.1				2.9
TP5(0.3m)	2(1)	0.15	9	1.35	5.2	23.7	2.70	0.4	8.5	8.8	nd				11.4
TP5 (1.0m)	-	0.97	9	8.73	6.0	37.0	6.60	16	9.1	15.3	nd				17.8
TP6 (0.0-0.07m)	3(3)	0.10	9	0.90	5.4	15.6	0.30	0.7	3.5	7.5	nd				1.9
TP6 (0.3m)	2(1)	0.16	9	1.44	4.7	18.9	1.20	0.4	2.4	9.9	0.5		1.74	1.82	6.3
TP6 (1.0m)	-	0.84	9	7.56	4.1	23.1	4.10	1.4	0.8	11.1	0.9				17.7
TP7 (0.0-0.2m)	8/3(3)	0.07	9	0.63	4.3	20.5	0.30	0.6	8.3	7.3	nd	<1.0			1.5
TP7 (0.75m)	-	0.82	9	7.38	5.2	28.5	3.30	0.7	10.2	10.3	nd				11.6
TP7 (1.0-1.1m)	-	0.92	7	6.44	5.5	26.2	2.80	0.6	9	9.2	nd				10.7
TP8 (0.0-0.08m)	8/3(1)	0.07	9	0.63	4.1	7.5	0.10	0.2	1.9	3.1	0.5		2.06		1.3
TP8 (0.3m)	2(2)	0.09	9	0.81	4.3	15.9	1.00	0.2	1.7	8.8	0.5		0.5	1.78	6.3
TP8 (1.0m)	-	0.72	9	6.48	4.7	18.8	3.60	0.3	1.4	9	nd				19.1
TP9 (0.0-0.16m)	3(3)	0.06	9	0.54	4.1	10.7	0.20	0.3	2.8	5.3	0.2				1.9
TP9 (0.3m)	3(3)	0.07	9	0.63	4.3	15.9	0.5	0.2	2.9	8.9	nd		0.41	1.68	3.1
TP9 (1.0m)	-	0.78	10	7.8	4.5	24.9	2.9	0.4	3.5	12.8	0.2				11.6
TP10 (0.0-0.08m)	8/3(1)	0.06	14	0.84	4.5	15.0	0.2	0.7	6.2	4.7	0.3	1			1.3
TP10 (0.3m)	2(1)	0.13	9	1.17	4.5	27.6	1.2	0.2	9.4	10.9	0.6		1.34	1.74	4.3
TP10 (1.0m)	-	0.85	9	7.65	4.1	27.8	3.3	0.9	3.3	11.2	2.7				11.9
TP11 (0.0-0.07m)	3(3)	0.08	9	0.72	4.3	16.7	0.3	0.5	4.9	7.1	0.1				1.8
TP11 (0.3m)	2(2)	0.54	9	4.86	3.9	22.0	1.9	0.2	1.9	10.6	2.3		2.58		8.6
TP11 (1.0m)	8/b	0.87	9	7.83	4.2	22.1	2.3	0.2	1.7	11.1	1.6				10.4
TP12 (0.0-0.1m)	3(2)	0.06	9	0.54	4.2	16.7	0.20	0.7	4.5	6.7	0.1	1.0			1.2
TP12 (0.3m)	2(1)	0.12	9	1.08	4.2	22.9	1.50	0.3	2.1	11.4	1.9		2.09		6.6
TP12 (1.0m)	-	1.07	9	9.63	4.2	25.6	3.60	0.7	1.8	12.8	1				14.1
TP13 (0.0-0.05m)	8/3(1)	0.10	9	0.90	4.3	16.4	0.20	1	5.2	6.1	0.2				1.2
TP13 (0.3m)	2(1)	0.09	7	0.63	4.5	23.0	1	0.5	3.1	13.2	0.2		1		4.3
TP14 (0.0-0.2m)	8/3(3)	0.06	9	0.54	4.3	22.7	0.4	0.9	3.8	12	0.3	1	2.65		1.8
TP14 (0.53-0.73m)	2(3)	0.36	9	3.24	4.1	24.2	3.1	1.2	1.2	12.4	1.9				12.8
TP14 (1.0m)	-	0.56	7	3.92	4.1	23.8	3.2	1.7	0.9	12.1	1.4				13.4
TP15 (0.0-0.14m)	8/3(2)	0.05	10	0.54	4.1	8.9	0.10	0.3	2.1	4	0.1				1.1
TP15 (0.3m)	3(1)	0.18	7	1.26	3.9	23.1	1.90	0.3	1.7	9.2	5.4		4.31		8.2
TP15 (0.9-1.0m)	-	0.69	7	4.83	3.9	22.7	4.20	0.9	1.1	10.3	2.4				18.5
TP16 (0.0-0.1m)	8/3(1)	0.06	10	0.60	4.4	9.4	0.10	0.3	3.8	2.7	0.1				1.1
TP16 (0.3m)	8/3(2)	0.04	9	0.36	4.4	6.6	0.10	0.2	1.7	2.5	0.1		0.34		1.5
TP16 (1.0m)	5	0.08	7	0.56	4.4	18.0	1.70	0.2	1.1	10.8	0.1				9.4
TP17 (0.0-0.17m)	3(2)	0.04	11	0.44	3.9	10.2	0.10	0.3	1.7	5.1	0.8	<1			1.0
TP17 (0.3m)	3(3)	0.04	10	0.40	4.3	7.9	0.30	0.1	2.1	3.2	0.2				3.8
TP17 (1.0m)	-	0.52	7	3.64	3.9	23.9	4.30	0.3	1.6	11.7	1.9				18.0
TP18 (0.0-0.05m)	8/3(1)	0.09	14	1.26	4.2	15.5	0.50	0.5	3.7	6.3	0.5				3.2
TP18 (0.3m)	3(3)	0.19	9	1.71	4.5	11.3	1.00	0.1	1.6	5.1	0.2		1.32	1.87	8.8
TP18 (1.0m)	-	0.92	7	6.44	4.2	23.5	4.10	0.1	1.6	12.1	0.5				17.4
TP19 (0.0-0.08m)	8/3(1)	0.09	10	0.90	4.1	11.6	0.20	0.6	2.7	4.4	0.1	1.0			1.7
TP19 (0.3m)	3(1)	0.07	9	0.63	4.1	10.3	0.20	0.2	1.7	5	0.3		2.23		1.9
TP19 (1.0m)	-	0.90	7	6.30	4.1	16.9	2.70	0.2	1.2	9.1	0.3				16.0
TP20 (0.0-0.12m)	3(2)	0.07	9	0.63	4.1	13.5	0.30	0.4	2.9	6.2	0.3				2.2
TP20 (0.3m)	3(2)	0.19	9	1.71	4.0	22.4	1.70	0.2	1.7	10.7	2.9		2.76		7.6
TP20 (1.0m)	-	0.54	7	3.78	4.1	23.1	4.10	0.4	1.2	11.5	1.2				17.7
TP21 (surface)	3(3)	0.06	10	0.60	4.4	14.7	0.10	0.5	3.9	6.2	0.1				0.7
TP21 (0.3m)	2(1)	0.08	10	0.80	4.5	14.7	0.60	0.2	2.9	6.7	0.1		0.34		4.1
TP21 (1.0m)	2(2)	0.14	10	1.40	4.6	16.3	2.10	0.2	1.6	8.6	nd				12.9
TP22 (0.0-0.2m)	8/3(1)	0.05	10	0.50	4.6	11.4	0.20	0.3	5	3.6	nd				1.8
TP22 (0.9-1.1m)	1	0.56	10	5.60	4.5	20.4	3.20	0.3	1.1	10.9	nd				15.7
TP22 (2.0-2.15m)	1	0.76	7	5.32	4.8	22.3	4.00	0.6	1.3	11.7	nd				17.9
TP23 (0.0-0.07m)	8/3(3)	0.07	10	0.70	4.5	21.2	0.40	0.7	6.1	8.5	0.2				1.9
TP23 (0.3m)	3(3)	0.12	9	1.08	4.4	23.4	1.5	0.3	4.9	10.7	1.1		1.42		6.4
TP23 (1.0m)	-	0.88	7	6.16	3.8	28.2	4.7	0.4	1	12.1	3.6				16.7
TP24 (0.0-0.08m)	3(1)	0.08	10	0.8	4.0	13.8	0.2	0.6	2.9	5	1.2	1			1.4
TP24 (0.3m)	2(1)	0.19	9	1.71	4.0	19.0	1.4	0.3	1.7	9.1	0.2		2.37	1.81	7.4
TP24 (1.0m)	1	1.08	9	9.72	3.9	30.0	5.4	0.7	1.1	13.9	2.3				18.0
TP25 (0.0-0.06m)	8/3(1)	0.5	10	5	4.5	18.7	0.9	0.4	5	7.7	0.1				4.8
TP25 (0.3m)	5	0.23	9	2.07	4.2	8.3	0.4	0.2	1.1	4.8	0.7		1.75		4.8
TP25 (1.0m)	-	0.17	9	1.53	5.0	16.2	2.7	0.3	0.8	10.9	nd				16.7
A1 (0.0-0.2m)	8/3(1)	0.05	9	0.45	4.2	7.3	0.2	0.2	2	3.2	nd				2.7
A1 (0.7-0.8m)	1	0.19	9	1.71	4.5	11.8	2.4	0.4	0.5	7.4	nd		0.34		20.3
A2 (0.0-0.2m)	8/3(3)	0.07	10	0.7	4.3	14.2	0.7	0.6	3.1	8.4	0.6				4.9
A2 (0.65-0.75m)	2(3)	0.72	9	6.48	3.9	28.3	3.8	0.9	0.9	16.7	2.7		3.24		13.4
A3 (0.0-0.2m)	3(3)	0.07	10	0.7	4.2	14.2	0.3	1.1	5.2	5.2	0.2				2.1
A3 (0.8m)	-	0.46	9	4.4	4.4	23.8	1.9	0.9	7	12.2	nd				8.0
A *(surface)*	8/3(2)	0.04	10	0.4	4.3	7.3	0.1	0.5	1.6	3.4	0.1				1.4
B (surface)	8/3(2)	0.1	10	1	4.7	18.9	0.2	1.3	6.2	7.5	0.1				1.1
B (0.3m)	2(1)	0.2	9	1.8	4.2	20.7	1.2	0.3	2.4	11.5	1				5.8
C (surface)	3(3)	0.1	10	1	4.5	12.9	0.3	0.5	3.4	5.7	0.1				2.3
C (0.3m)	2(3)	0.31	9	2.79	4.7	17.6	2.3	0.2	1.9	9.1	nd				13.1

Explanation to abbreviations

EAT: Emerson Aggregate Test
EC: Electrical Conductivity
P:Phosphorus
BD: Bulk Density

Lime Requirement: Application necessary for adjustment to pH 6.5
CEC: Cation Exchange Concentration
Exch Na: Exchangeable Sodium
Exch Ca: Exchangeable Calcium

ESP% : Exchangeable Sodium Percentage (Exch Na/CEC)
Exch K: Exchangeable Potassium
Exch Al: Exchangeable Aluminium
Exch Mg: Exchangeable Magnesium

TABLE 3
SUMMARY OF LABORATORY TEST DATA - SOILS
Soil Erodibility Test for USLE (K)

Location	Sample Depth	K		K		Adjusted
		1st Approx	*Rating*	*SS&PP*	*Rating*	*Rating*
TP 1	0.8-1.0m	0.029	moderate	0.047	high	high
TP 2	0.75-0.9m	0.030	moderate	0.040	high	high
TP 3	0.3-0.5m	0.041	high	0.060	high	high
TP4	2.0-2.1m	0.037	moderate	0.048	high	high
TP5	0.75-0.9m	0.034	moderate	0.052	high	very high
TP6	0.75-0.9m	0.027	moderate	0.046	high	high
TP7	0.75-0.95m	0.037	moderate	0.055	high	high
TP8	0.75-0.95m	0.046	high	0.064	very high	very high
TP9	0.3-0.5m	0.033	moderate	0.051	high	high
TP10	0.75-0.9m	0.025	moderate	0.044	high	high
TP11	2.0m	0.045	high	0.064	very high	very high
TP12	0.3-0.45m	0.033	moderate	0.052	high	very high
TP13	0.75m	0.031	moderate	0.049	high	very high
TP14	0.3-0.5m	0.028	moderate	0.047	high	high
TP15	0.3-0.45m	0.031	moderate	0.042	high	high
TP16	1.5-1.6m	0.040	high	0.059	high	high
TP17	0.75m	0.037	moderate	0.052	high	high
TP18	0.75-0.9m	0.046	high	0.057	high	high
TP19	0.75-0.9m	0.038	moderate	0.056	high	high
TP20	0.75-0.9m	0.033	moderate	0.048	high	high
TP21	2.0m	0.055	high	0.070	very high	very high
TP22	2.0-2.15m	0.042	high	0.060	very high	very high
TP23	0.75-0.9m	0.027	moderate	0.045	high	high
TP24	0.75-0.9m	0.023	moderate	0.038	moderate	high
TP25	2.0-2.1m	0.035	moderate	0.053	high	high

The first approximation of K is calculated from the laboratory data. PSA-mechanical dispersion and organic carbon (OC)
The second value of K is derived from the 1st approximation of K, soil structure (SS) and profile permeability (PP)
Adjusted rating is based on the "Blue Book" suggestion that k values for be increased by 20% for EAT class 1 or 2 soils.

The ratings are as follows:
Low: less than 0.02
Moderate: 0.02 to 0.04
High: 0.04 to 0.06
Very High: greater than 0.06

This interpretation is based on:
1. The samples supplied being representative;
2. Literature guidelines.

TABLE 4
SUMMARY OF LABORATORY TEST DATA - SOILS
Particle Size Distribution Analysis

Location	Sample Depth	PARTICLE SIZE ANALYSIS (%) - hydrometer							PARTICLE SIZE ANALYSIS - MECHANICAL DISPERSION (%)						
		CLAY	SILT	VERY FINE SAND	COARSE FINE SAND	COARSE SAND	TOTAL SAND	GRAVEL	CLAY	SILT	FINE SAND	COARSE FINE SAND	COARSE SAND	TOTAL SAND	GRAVEL
TP1	0.8-1.0m	**41**	**23**	**21**	8	6	**35**	1	**37**	**23**	**23**	**9**	**7**	**39**	**1**
TP2	0.75-0.9m	**33**	**13**	24	12	15	**51**	**3**	**24**	**15**	26	13	19	**58**	2
TP3	0.3-0.5m	**34**	**23**	27	13	3	**43**	**<1**	**27**	**25**	32	12	4	**48**	**<1**
TP4	2.0-2.1m	**44**	**16**	24	13	3	**40**	**<1**	**29**	**18**	33	16	4	**53**	**<1**
TP5	0.75-0.9m	**41**	**33**	8	3	6	**17**	**9**	**32**	**38**	11	2	8	**21**	**9**
TP6	0.75-0.9m	**49**	**27**	15	6	2	**23**	**1**	**42**	**32**	17	6	2	**25**	**1**
TP7	0.75-0.95m	**39**	**17**	29	14	1	**44**	**<1**	**30**	**22**	29	18	1	**48**	**<1**
TP8	0.75-0.95m	**34**	**30**	25	10	1	**36**	**0**	**28**	**34**	27	10	1	**38**	**0**
TP9	0.3-0.5m	**47**	**28**	18	6	1	**25**	**<1**	**37**	**34**	19	8	2	**29**	**<1**
TP10	0.75-0.9m	**53**	**27**	13	5	2	**20**	**<1**	**44**	**32**	15	6	3	**24**	**<1**
TP11	2.0m	**32**	**19**	31	16	2	**49**	**<1**	**25**	**21**	36	15	3	**54**	**<1**
TP12	0.3-0.45m	**31**	**18**	26	13	6	**45**	**6**	**26**	**19**	27	15	7	**49**	**6**
TP13	0.75m	**39**	**16**	25	13	4	**42**	**3**	**32**	**19**	29	13	4	**46**	**3**
TP14	0.3-0.5m	**44**	**27**	15	6	5	**26**	**3**	**38**	**31**	17	5	6	**28**	**3**
TP15	0.3-0.45m	**49**	**11**	22	12	2	**36**	**4**	**34**	**23**	25	11	3	**39**	**4**
TP16	1.5-1.6m	**37**	**25**	24	11	3	**38**	**0**	**31**	**29**	27	9	4	**40**	**0**
TP17	0.75m	**49**	**10**	24	13	4	**41**	**<1**	**30**	**25**	27	15	3	**45**	**<1**
TP18	0.75-0.9m	**57**	**13**	18	7	3	**28**	**2**	**28**	**42**	19	6	3	**28**	**2**
TP19	0.75-0.9m	**38**	**21**	27	12	2	**41**	**<1**	**32**	**21**	33	12	2	**47**	**<1**
TP20	0.75-0.9m	**54**	**17**	15	6	5	**26**	**3**	**35**	**32**	19	6	5	**30**	**3**
TP21	2.0m	**23**	**14**	38	19	6	**63**	**<1**	**13**	**20**	39	22	6	**67**	**<1**
TP22	2.0-2.15m	**42**	**21**	24	11	2	**37**	**<1**	**30**	**29**	28	10	3	**41**	**<1**
TP23	0.75-0.9m	**55**	**18**	16	7	3	**26**	**1**	**41**	**25**	22	9	2	**33**	**1**
TP24	0.75-0.9m	**49**	**20**	12	5	3	**20**	**11**	**41**	**27**	14	4	3	**21**	**11**
TP25	2.0-2.1m	**36**	**13**	27	13	9	**49**	**2**	**27**	**15**	32	15	9	**56**	**2**

Explanation

clay, particle size <0.002mm
silt: particle size = 0 002-0.02mm
very fine sand: particle sire = 0.02-0 1mm
course fine sand. particle size = 0.1-0.2mm
course sand particle size = 0.2-2.0mm
ravel: particle size >2mm

TABLE 5
SUMMARY OF LABORATORY TEST DATA - SOILS
Piezometer Soil Samples - Engineering Tests - Atterberg Limits, EATs

Location	Sample Depth (m)	Moisture Content%	Liquid Limit%	Plastic Limit %	Plasticity index%	Linear Shrinkage%	EAT No.
BH P1D	0.5-0.95	16.5	31	13	18	8.5	2
BHP2D	0.75-0.95	15.8	52	16	36	16.5	1
BHP4D	0.5-0.95	23.4	55	11	44	45.5	1
BHP5D	0.5-0.95	31	60	15	45	18	1
BHP6D	0.6-0.95	23.4	57	10	47	16.5	2
BHP7D	0.5-0.95	16.5	57	11	46	16	2
BHG1	0.5-0.95	23	68	16	52	14.5	1
BHG2	0.5-0.95	11.8	36	13	23	12	2
BHG4	0.5-0.95	20	36	13	23	11	1
BHG5	0.5-0.95	10.8	37	10	27	11.5	1
BHG6	0.5-0.95	14.1	52	14	38	15.5	1

TABLE *6*
SUMMARY OF LABORATORY TEST DATA - SOILS
Piezometer Soil Samples - Electrical Conductivity, pH Chloride and Sodium

Sample	**Depth**	**EC (mS/cm)**	**pH ($CaCl_2$)**	**Chloride mg/kg**	**Sodium mg/kg**
BH P1D	0.0-0.2	0.225	4.52	241.0	390.0
BH P1D	0.2-0.5	0.275	4.57	285.0	245.0
BH P1D	1.0-1.5	1.147	5.86	na	na
BH P1D	4.0-4.5	1.076	6.43	na	na
BH P1D	4.5-5.0	1.119	6.98	na	na
BH P1D	5.5-6.0	1.059	7.25	na	na
BH P1D	6.5-7.0	1.181	8.14	na	na
BH P1D	7.5-8.0	0.950	7.66	na	na
BH P1D	8.5-9.0	0.965	7.96	na	na
BHP2D	0.0-0.25	0.695	5.48	2170.0	890.0
BHP2D	0.25-0.5	0.657	5.31	899.0	1500.0
BHP2D	1.0-1.5	0.596	3.84	1030.0	2580.0
BHP2D	2.5-3.0	0.591	4.03	na	na
BHP2D	3.0-3.45	0.568	4.63	na	na
BHP2D	4.0-4.5	0.561	4.11	na	na
BHP2D	5.0-5.5	0.802	4.79	na	na
BHP2D	6.0-6.5	1.082	5.69	na	na
BHP2D	6.5-7.0	1.174	5.25	na	na
BHP2D	7.5-8.0	1.269	5.61	na	na
BHP2D	8.5-9.0	2.090	5.43	na	na
BHP3D	0.0-0.1	0.317	6.22	416.0	190.0
BHP3D	0.3-0.5	0.258	6.54	328.0	220.0
BHP3D	1.0-1.5	0.885	4.44	899.0	1130.0
BHP3D	2.5-3.0	0.652	4.30	na	na
BHP3D	3.0-3.5	0.474	4.53	na	na
BHP3D	4.0-4.5	0.497	4.72	na	na
BHP3D	5.0-5.5	1.198	5.25	na	na
BHP3D	6.0-6.5	1.357	5.16	na	na
BHP3D	8.5-9.0	0.718	6.82	na	na
BHP4D	0.0-0.2	0.221	4.94	241.0	115.0
BHP4D	0.2-0.5	0.399	6.20	635.0	1030.0
BHP4D	1.0-1.5	1.155	4.38	1644.0	4000.0
BHP4D	3.0-3.45	1.510	4.33	na	na
BHP4D	4.0-4.5	1.590	5.12	na	na
BHP4D	5.0-5.5	2.150	6.17	na	na
BHP4D	7.0-7.5	2.000	7.29	na	na
BHP5D	0.0-0.2	0.224	4.42	197.0	100.0
BHP5D	0.2-0.5	0.220	4.22	241.0	150.0
BHP5D	1.0-1.5	0.851	3.95	1293.0	1550.0
BHP5D	1.5-1.95	1.035	4.39	na	na
BHP5D	2.0-2.5	1.125	4.66	na	na
BHP5D	2.5-2.95	0.966	4.60	na	na
BHP5D	3.0-3.5	1.100	4.89	na	na
BHP5D	4.0-4.5	1.125	5.30	na	na
BHP5D	5.0-5.5	1.372	6.75	na	na
BHP6D	0.0-0.1	0.189	4.52	197.0	105.0
BHP6D	0.2-0.5	0.213	4.31	241.0	175.0
BHP6D	1.0-1.5	1.212	4.03	1732.0	3800.0
BHP6D	2.5-3.0	1.096	4.30	na	na
BHP6D	3.0-3.45	1.644	4.07	na	na
BHP6D	3.5-4.0	1.014	4.61	na	na
BHP6D	4.5-5.0	1.349	6.08	na	na
BHP6D	5.5-6.0	1.119	8.07	na	na
BHP6D	7.58-8.0	1.342	7.85	na	na

note: EC units mS/cm are equivalent to dS/m.

CONTINUED OVER PAGE

TABLE 6 Continued
Piezometer Soil Samples

Sample	Depth	EC (mS/cm)	pH ($CaCl_2$)	Chloride mg/kg	Sodium mg/kg
BHP7D	0.0-0.1	0.290	4.14	328.0	90.0
BHP7D	0.3-0.5	0.318	3.96	328.0	105.0
BHP7D	1.3-1.5	0.962	4.28	1030.0	2080.0
BHP7D	2.5-2.7	0.800	4.80	na	na
BHP7D	2.7-3.0	0.918	5.02	na	na
BHP7D	3.0-3.45	0.783	6.38	na	na
BHP7D	4.0-4.3	0.749	6.64	na	na
BHP7D	5.0-5.3	1.500	7.78	na	na
BHP7D	6.0-6.3	1.921	8.17	na	na
BHP7D	7.0-7.3	1.792	8.06	na	na
BHG1	0.0-0.25	0.350	4.16	241.0	380.0
BHG1	0.25-0.5	0.400	3.96	372.0	515.0
BHG1	1.0-1.5	0.601	3.86	942.0	2100.0
BHG1	2.0-2.5	0.672	7.92	na	na
BHG1	3.0-3.5	0.415	7.85	na	na
BHG1	5.5-6.0	0.535	8.52	na	na
BHG2	0.0-0.2	0.279	4.49	372	230
BHG2	0.2-0.5	0.262	4.48	285	265
BHG2	1.0-1.5	0.648	6.07	1074	2000
BHG2	2.5-3.0	0.790	7.57	na	na
BHG2	3.0-3.45	0.841	5.85	na	na
BHG2	3.5-4.0	0.407	5.79	na	na
BHG2	4.5-5.0	0.372	7.38	na	na
BHG2	5.5-6.0	0.543	8.77	na	na
BHG3	0.0-0.2	0.451	4.13	592.0	130.0
BHG3	0.3-0.5	0.337	3.58	504.0	200.0
BHG3	1.0-1.5	0.512	3.53	899.0	700.0
BHG3	2.0-2.5	0.788	4.48	na	na
BHG3	2.5-3.0	0.692	4.95	na	na
BHG3	3.5-4.0	0.725	4.53	na	na
BHG3	4.7-5.0	0.424	5.60	na	na
BHG3	5.8-6.0	0.519	5.96	na	na
BHG3	6.8-7.0	0.381	6.18	na	na
BHG3	7.6-7.8	0.574	7.01	na	na
BHG4	0.0-0.1	1.027	4.57	1293.0	3500.0
BHG4	0.2-0.5	1.161	4.51	1732.0	2500.0
BHG4	1.0-1.5	0.901	5.42	1337.0	1700.0
BHG4	2.5-3.0	1.026	4.93	na	na
BHG4	3.0-3.45	0.878	6.20	na	na
BHG4	4.0-4.5	1.125	6.05	na	na
BHG4	5.5-6.0	1.134	6.75	na	na
BHG4	6.0-6.5	1.111	6.76	na	na
BHG4	7.0-7.5	0.827	8.01	na	na
BHG4	8.5-9.0	1.920	7.94	na	na
BHG5	0.0-0.1	0.163	4.41	153.0	100.0
BHG5	0.2-0.5	0.180	4.38	197.0	100.0
BHG5	1.0-1.5	0.642	4.71	942.0	1400.0
BHG5	2.5-3.0	0.700	4.42	na	na
BHG5	3.0-3.45	0.850	4.40	na	na
BHG5	4.0-4.5	0.734	4.11	na	na
BHG5	5.0-5.5	0.384	5.50	na	na
BHG5	7.5-8.0	0.441	7.99	na	na
BHG6	0.0-0.1	0.172	3.99	197	65
BHG6	0.3-0.5	0.486	3.79	592	625
BHG6	1.0-1.5	0.880	4.02	1030	2180
BHG6	2.5-3.0	1.378	6.23	na	na
BHG6	3.0-3.45	1.487	5.90	na	na
BHG6	3.8-4.0	0.922	4.56	na	na
BHG6	4.8-5.0	0.784	4.41	na	na
BHG6	5.3-5.5	0.783	4.90	na	na
BHG6	5.8-6.0	0.460	5.81	na	na
BHG6	5.8-7.0	0.597	6.40	na	na
BHG6	7.8-8.0	0.775	6.95	na	na
BHG6	8.3-8.5	0.562	8.26	na	na

note: EC units mS/cm are equivalent to dS/m.

TABLE 7A
SUMMARY OF LABORATORY TEST DATA - GROUNDWATER
Groundwater Chemisty - Round 1 Sampling 16-17 November 1999

Test	PQL	P1D	P1S	P2D	P2S	P3D	P3S	P4D	P4S	P5D	P5S	P6D	P6S	P7D	P7S
Groundwater Level AHD (m)		27.38	28.39	15.89	Piezometer 'Dry'	16.87	19.67	23.81	24.07	26.9	26.95	37.14	34.74	32.79	Piezometer 'Dry'
pH		6.9	6.9	6.25	na	6.27	6.23	6.44	5.69	7.58	5.66	6.7	Insufficient	6.79	na
Conductivity (mS/cm)	0.000001	24.3	24.1	23.3	na	26.9	1.944	23.9	23.5	21.8	21.1	32.7	Sample	30	na
Carbonate Alkalinity	0	0	0	0	na	0	0	0	0	0	0	0	for	0	na
Total Alkalinity	<20	1560	140	146	na	203	114	224	78	494	73	634	Analysis	494	na
Sulphate	<1	1378	1181	1132	na	1698	93	1526	1649	1501	1554	2116	na	1625	na
Ammonia-N	<0.5	<0.5	<0.5	<0.5	na	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	1.6	na	<0.5	na
Fluoride	<0.5	0.5	<0.5	<0.5	na	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	na	<0.5	na
Chloride	<1	9600	11300	9970	na	13000	462	11900	11300	9450	9320	12700	na	13200	na
Total Kjeldahl Nitrogen	<0.5	1.9	0.6	<0.5	na	1.2	0.8	1.4	1.6	0.5	1	0.8	na	0.9	na
Calcium	<0.1	170	120	190	na	250	7.7	170	75	110	81	170	na	160	na
Sodium	<0.1	6800	6700	6200	na	7300	390	7000	6600	5400	5800	7600	na	6700	na
Potassium	<0.1	8.9	3.9	10.4	na	16.3	0.64	11.7	2.7	6.0	5.2	21.8	na	16.1	na
Magnesium	<0.1	897	920	805	na	1170	6.7	871	742	729	778	1070	na	805	na

Test	G1	G2	G3	G4	G5	G6D
Groundwater Level AHD (m)	23.04	Piezometer 'Dry'	23.91	36.64	26.9	41.51
pH	7.39		6.88	6.71	6.87	6.35
Conductivity (mS/cm)	3		18.7	29.1	25.1	18.9
Carbonate Alkalinity	0		0	0	0	0
Total Alkalinity	1264		728	806	130	286
Sulphate	1132		689	1748	1525	1082
Ammonia-N	<0.5		<0.5	<0.5	<0.5	<0.5
Fluoride	<0.5		<0.5	<0.5	0.5	0.6
Chloride	11900		8420	9500	11700	7840
Total Kjeldahl Nitrogen	1.5		<0.5	1.2	1	1.5
Calcium	250		160	120	140	95
Sodium	580		5000	6300	7400	5000
Potassium	50		21	21	30.8	20.4
Magnesium	1180		588	903	1031	539

Explanation:
PQL : Practical Quantitation Limit
NSL : No set limit
na : Not Analysed
Units are mg/L unless otherwise shown

TABLE 7B
SUMMARY OF LABORATORY TEST DATA - GROUNDWATER
Groundwater Chemisty - Round 2 Sampling 12, 13 and 17 January 2000

Test	PQL	P1D	P1S	P2D	P2S	P3D	P3S	P4D	P4S	P5D	P5S	P6D	P6S	P7D	P7S
Groundwater Level AHD (m)		28.01	297.96	15.99	Piezometer 'Dry'	16.73	17.94	23.86	23.91	26.75	26.8	37.25	36.71	32.64	30.75
pH		7.53	7.12	5.85	na	6.69	na	6.6	5.29	6.45	5.52	6.53	4.29	6.66	na
Conductivity (mS/cm)	0.000001	22.5	23.4	24.3	na	26800	na	25.4	24.2	22.2	22.6	27.9	28.5	25.7	na
Carbonate Alkalinity	0	na	na	na	na	na	na	na	na	na	na	na	0	na	na
Total Dissolved Solids	<20	15510	15770	17600	na	20200	na	17200	17100	17000	16800	18100	19030	19520	na
Total Alkalinity	<20	na	na	189	na	na	na	na	53	na	na	na	<20	na	na
Sulphate	<1	na	na	na	na	1680	na	na	na	na	na	na	2370	na	na
Ammonia-N	<0.5	na	na	na	na	na	na	na	na	<0.5	na	<0.5	<0.5	na	na
Fluoride	<0.5	0.5	na	na	na	na	na	na	na	na	na	na	<0.5	na	na
Chloride	<1	na	11750	na	na	15300	na	na	na	na	na	na	12070	na	na
Total Kjeldahl Nitrogen	<0.5	1.91	na	2.21	na	na	na	na	na	na	na	2.65	1.62	na	na
Calcium	<0.1	na	na	na	na	na	na	na	55	na	na	na	na	na	na
Sodium	<0.1	na	na	na	na	na	na	na	5800	na	na	na	na	na	na
Potassium	<0.1	na	na	na	na	na	na	na	2	na	na	na	na	na	na
Magnesium	<0.1	na	na	na	na	na	na	na	850	na	na	na	na	na	na

Test	G1	G2	G3	G4	G5	G6D	G6S
Groundwater Level AHD (m)	24.96	35.71	25.81	36.81	27.24	41.68	44.29
pH	7.16	7.45	7.24	6.75	6.28	6.35	4.03
Conductivity (mS/cm)	16.98	19.74	20.4	21.9	24.5	18.9	10730
Carbonate Alkalinity	na	na	na	na	0	0	0
Total Dissolved Solids	10700	13600	14300	13800	18000	na	7200
Total Alkalinity	874	na	na	na	307	286	<20
Sulphate	na	na	na	na	1730	1082	760
Ammonia-N	na	na	na	na	<0.5	<0.5	0.6
Fluoride	na	0.6	<0.5	na	0.5	0.6	0.6
Chloride	na	na	na	na	12270	7840	3570
Total Kjeldahl Nitrogen	na	na	0.74	na	1.47	1.5	2.5
Calcium	210	na	150	na	90	95	na
Sodium	4500	na	5000	na	7150	5000	na
Potassium	26	na	15	na	18	20.4	na
Magnesium	57	na	890	na	1080	539	na

Explanation:
PQL : Practical Quantitation Limit
NSL : No set limit
na : Not Analysed
Units are mg/L unless otherwise shown

TABLE 8: SUMMARY OF FIELD AND TEST DATA - GROUNDWATER
Groundwater depth, volume and permeability test details

	Piezometer Elevation Details					Sampling Details						Permeability Test Details				
Piezometer	Depth BGL (m)	Depth to Shale (m)	AHD Ground Level (m)	Casing above ground level	AHD elevation Top of Casing	SWL AHD 1st round	Volume Purged	SWL AHD 2nd round	Depth SWL BGL	Volume Purged	Start Depth BGL (m)	Recovery Depth BGL (m)	Time (min)	K		
														α		10^{-x}
P1D	8.70	6.20	29.43	0.40	29.83	27.38	16.0	28.01	1.42	36.0*	8.41	4.58	30	-10	1.7	-2
P1S	5 90	-	29.39	0 50	29 89	28.39	14.0*	27.96	1.43	24.0*	[illegible]	1.70	75	-10	4.8	-2
	9 23	>9.0	22 04	0.53	22 57	15.89	125	15.99	6.05	31.0*	6.85	6.53	42	-1	2.3	-3
[illegible]	4 40		22 02	0.40	2242	-	0.0	-		0.0		Permeability Test Not Undertaken				
P2D	858	850	21 97	0.45	22.42	18.87	12.0*	16.73	5.24	11.0*	8.66	8 28	50	-5	1.8	-3
P2S	4.13	-	22.02	0.42	22.44	19.67	6.0*	17.94	4.08	0.2	Permeability Test Not Undertaken					
P3D	9.05	5.00	25.46	0.52	25.98	23.81	11.0	23.86	1.60	25.0*	9.01	7.48	90	-3	3	-4
P4S	5.15	-	25.57	0.63	26.20	24.07	21.0	23.91	1.66	53.0	2.45	1.76	63	-1	8	-3
P5D	8.55	5.70	28.70	0.35	29.05	26.90	42.0*	26.75	1.95	39.0*	5.17	3.95	14.5	-1	1.4	-3
P5S	5.70	-	28.75	0.32	29.07	26.95	13.0*	26.80	1.95	10.0*	5.13	3.47	43	-2	4.2	-3
P6D	7.50	3.80	38.19	0.70	38.89	37.14	45.0*	37.25	0.94	51.0*	6.67	2.66	35	-10	2.4	-2
P6S	4.20	-	38.19	0.65	38.84	34.74	3.0*	36.71	1.48	19.0*	Permeability Test Not Undertaken					
P7D	7.50	2.50	34.44	0.55	34.99	32.79	70.0	32.64	1.80	70.0	2.42	2.04	25	-1	1.8	-3
P7S	4.05	2.50	34.50	0.52	35.02	-	0.0	-	-	0.0	Permeability Test Not Undertaken					
G1	6.30	2.00	28.54	0.67	29.21	23.04	2.0*	24.96	3.58	6.0*	5.61	5.47	76.00	-1	4.8	-5
G2	5.66	3.50	40.84	0.57	41.41	-	0.0	35.71	5.13	1.5*	Permeability Test Not Undertaken					
G3	8.20	4.35	30.46	0.58	31.04	23.91	9.0*	25.81	4.65	8.0*	8.05	7.76	56	-1	6.4	-5
G4	8.70	3.60	38.24	0.60	38.84	36.64	13.0	36.81	1.43	40.0	5.60	3.18	25	-3	5.2	-2
G5	8.10	3.80	31.90	0.64	32.54	26.90	10.0*	27.24	4.66	11.0*	7.88	7.19	80	-1	2.1	-4
G6D	8.50	5.80	47.06	0.67	47.73	41.51	8.0*	41.68	5.38	7.0*	8.43	8.20	60	-4	6.9	-4
G6S	4.85	-	47.19	0.60	47.79	-	0.0	44.29	2.90	6.5*	4.80	4.69	94	-1	1	-5

Explanation of symbols and abbreviations
*: Denotes Purged Dry
SWL: Standing Water Level
BGL: Below Ground Level

All recorded heights are measured in metres (m)
All recorded volumes are measured in Litres (L)

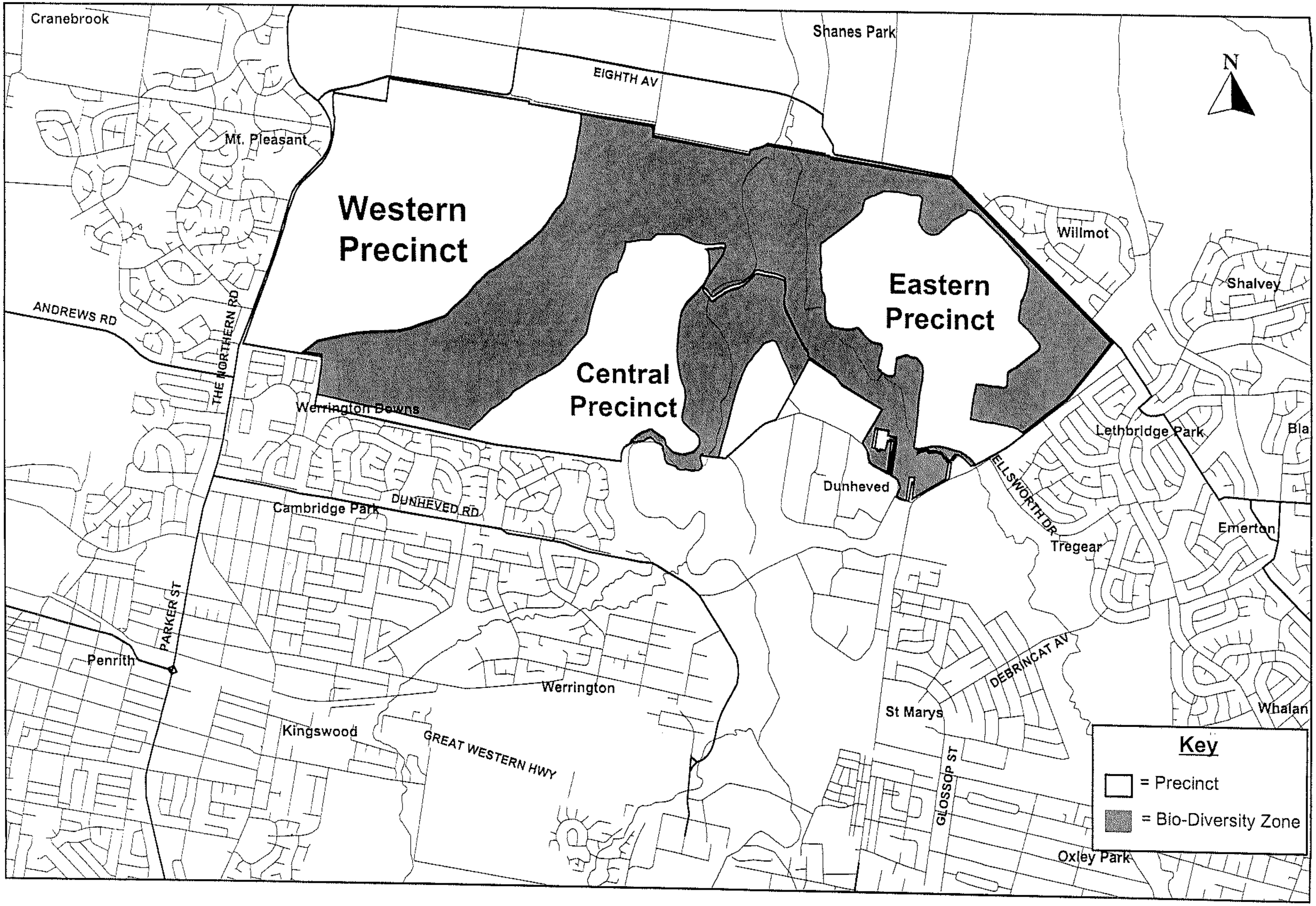
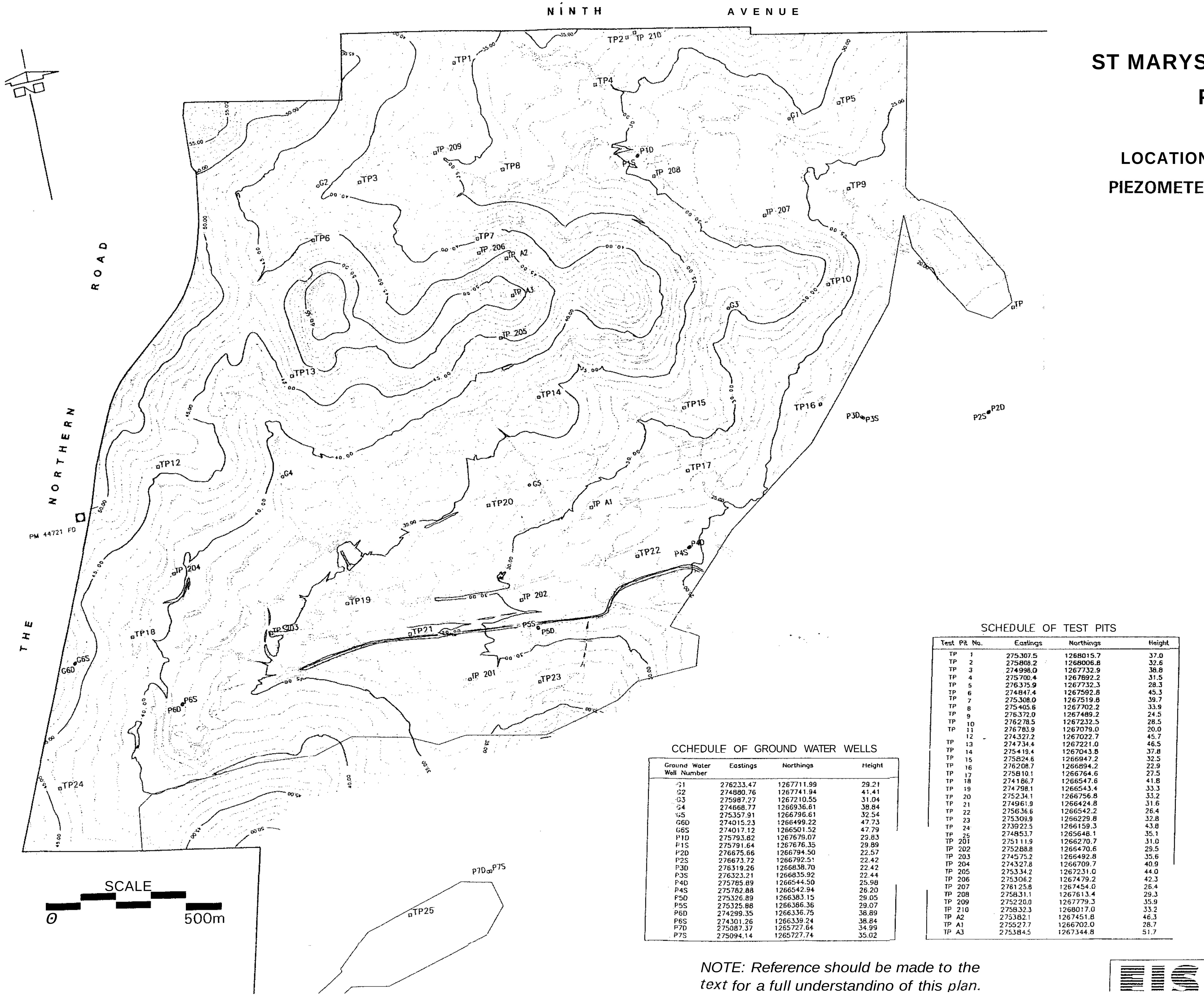


Figure 1: Locality Plan

ST MARYS REDEVELOPMENT PROJECT

LOCATION OF TEST PITS AND PIEZOMETERS ON THE WESTERN PRECINCT



CCHEDULE OF GROUND WATER WELLS

Ground Water Well Number	Eastings	Northings	Height
G1	276233.47	1267711.99	29.21
G2	274880.76	1267741.94	41.41
G3	275987.27	1267210.55	31.04
G4	274668.77	1266936.61	38.84
G5	275357.91	1266796.61	32.54
G6D	274015.23	1266499.22	47.73
G6S	274017.12	1266501.52	47.79
P1D	275793.82	1267679.07	29.83
P1S	275791.64	1267676.35	29.89
P2D	276675.66	1266794.50	22.57
P2S	276673.72	1266792.51	22.42
P3D	276319.26	1266838.70	22.42
P3S	276323.21	1266835.92	22.44
P4D	275785.89	1266544.50	25.98
P4S	275782.88	1266542.94	26.20
P5D	275326.89	1266383.15	29.05
P5S	275325.88	1266386.36	29.07
P6D	274299.35	1266336.75	38.89
P6S	274301.26	1266339.24	38.84
P7D	275087.37	1265727.64	34.99
P7S	275094.14	1265727.74	35.02

SCHEDULE OF TEST PITS

Test Pit No.	Eastings	Northings	Height
TP 1	275307.5	1268015.7	37.0
TP 2	275808.2	1268006.8	32.6
TP 3	274998.0	1267732.9	38.8
TP 4	275700.4	1267892.2	31.5
TP 5	276375.9	1267732.3	28.3
TP 6	274847.4	1267592.8	45.3
TP 7	275308.0	1267519.8	39.7
TP 8	275405.6	1267702.2	33.9
TP 9	276372.0	1267489.2	24.5
TP 10	276278.5	1267232.5	28.5
TP 11	276783.9	1267079.0	20.0
12	274327.2	1267022.7	45.7
TP 13	274734.4	1267221.0	46.5
TP 14	275419.4	1267043.8	37.8
TP 15	275824.6	1266947.2	32.5
TP 16	276208.7	1266894.2	22.9
TP 17	275810.1	1266764.6	27.5
TP 18	274186.7	1266547.6	41.8
TP 19	274798.1	1266543.4	33.3
TP 20	275234.1	1266756.8	33.2
TP 21	274961.9	1266424.8	31.6
TP 22	275636.6	1266542.2	26.4
TP 23	275309.9	1266229.8	32.8
TP 24	273922.5	1266159.3	43.8
TP 25	274853.7	1265648.1	35.1
TP 201	275111.9	1266270.7	31.0
TP 202	275288.8	1266470.6	29.5
TP 203	274575.2	1266492.8	35.6
TP 204	274327.8	1266709.7	40.9
TP 205	275334.2	1267231.0	44.0
TP 206	275306.2	1267479.2	42.3
TP 207	276125.8	1267454.0	26.4
TP 208	275831.1	1267613.4	29.3
TP 209	275220.0	1267779.3	35.9
TP 210	275832.3	1268017.0	33.2
TP A2	275382.1	1267451.8	46.3
TP A1	275527.7	1266702.0	28.7
TP A3	275384.5	1267344.8	51.7

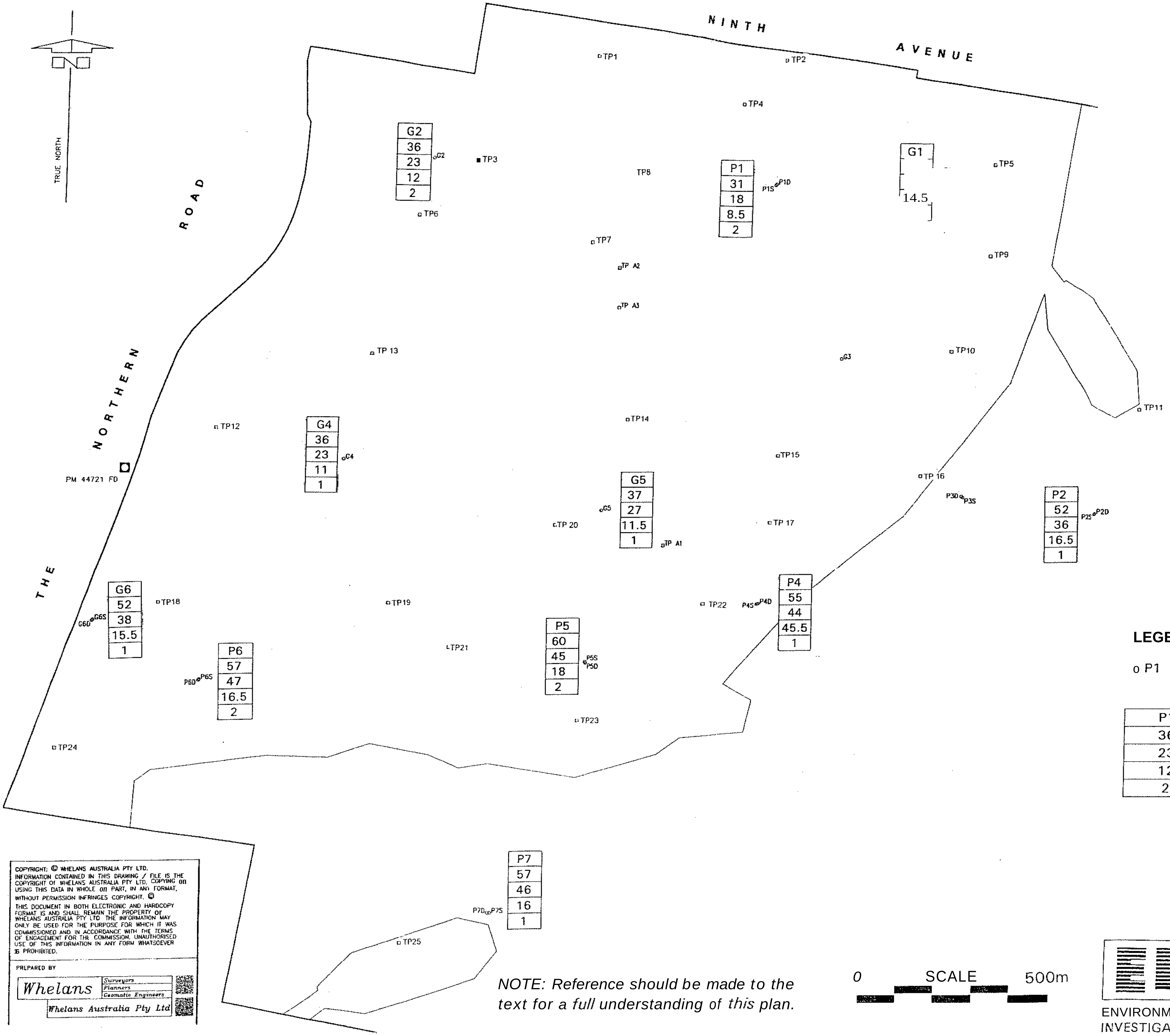
NOTE: Reference should be made to the text for a full understandino of this plan.

EIS

Report No. E13431F
Figure No. 2

ST MARYS DEVELOPMENT
PROJECT

BOREHOLE PIEZOMETER LOCATION PLA
AND
ATTERBERG LIMIT DATA



NOTE: Reference should be made to the text for a full understanding of this plan.

LEGEND:

o P1 PIEZOMETER BOREHOLE LOCATION

P1	SAMPLE LOCATION
36	LIQUID LIMIT %
23	PLASTICITY INDEX %
12	LINEAR SHRINKAGE %
2	EMERSON (EAT) CLASS NUMBER

PREPARED BY

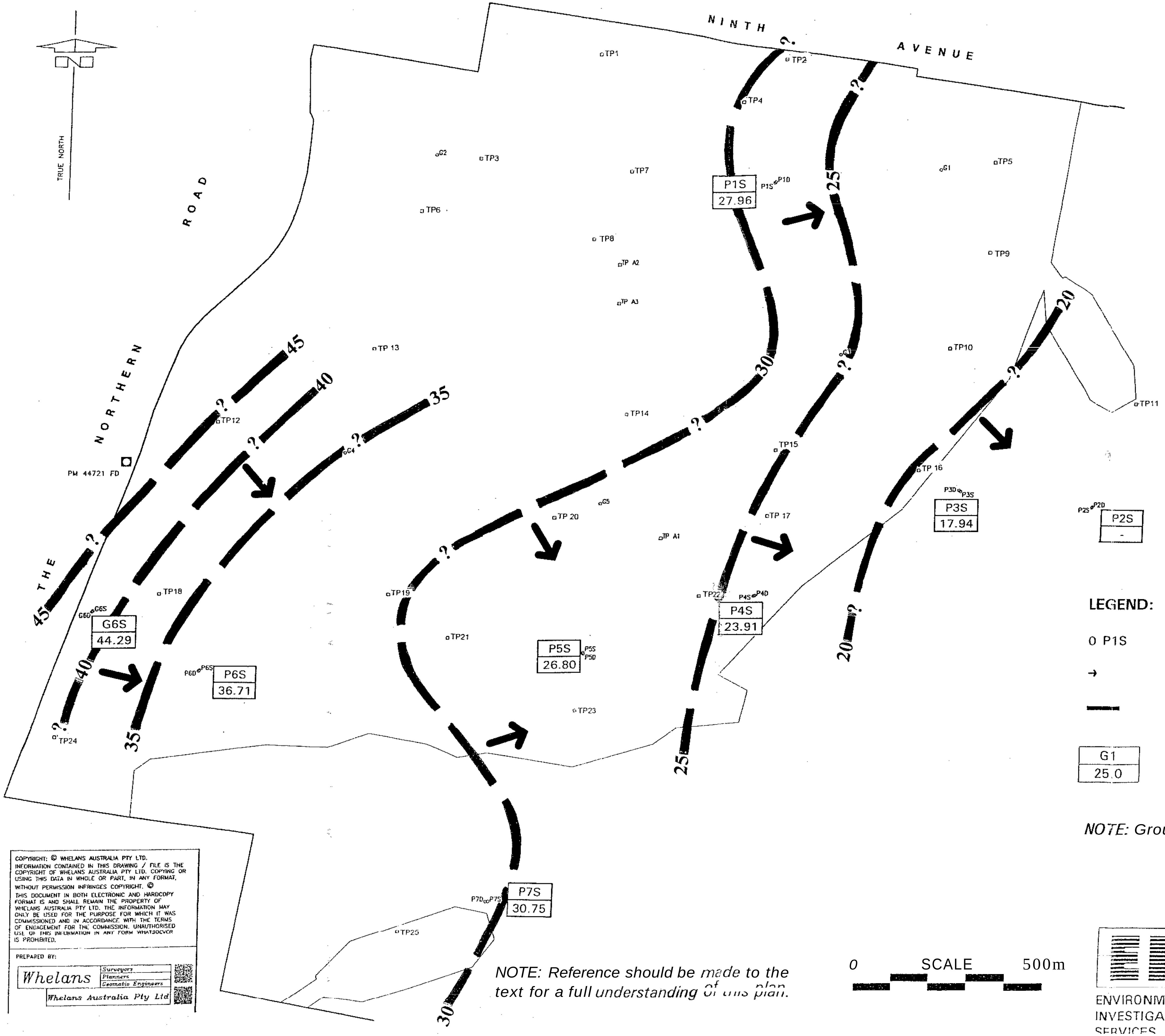
Whelans
Surveyors
Planners
Geomatic Engineers
Whelans Australia Pty Ltd

0 SCALE 500m

EIS
ENVIRONMENTAL
INVESTIGATION

Report No E13431F

Figure No 3



ST MARYS DEVELOPMENT PROJECT

PIEZOMETER LOCATION PLAN
GROUNDWATER LEVEL DATA
AND
AHD GROUNDWATER CONTOURS
SHALLOW CLAY AQUIFER

LEGEND:

0 P1S	PIEZOMETER LOCATION AND NUMBER
→	INDICATED GROUNDWATER FLOW DIRECTION
▬	GROUNDWATER CONTOURS (5 METRE INTERVALS)
G1 25.0	PIEZOMETER LOCATION AHD GROUNDWATER LEVEL (METRES)

NOTE: Groundwater contours are judgemental.

NOTE: Reference should be made to the text for a full understanding of this plan.

0 SCALE 500m

PREPARED BY:
Whelans
Surveyors
Planners
Geomatic Engineers
Whelans Australia Pty Ltd

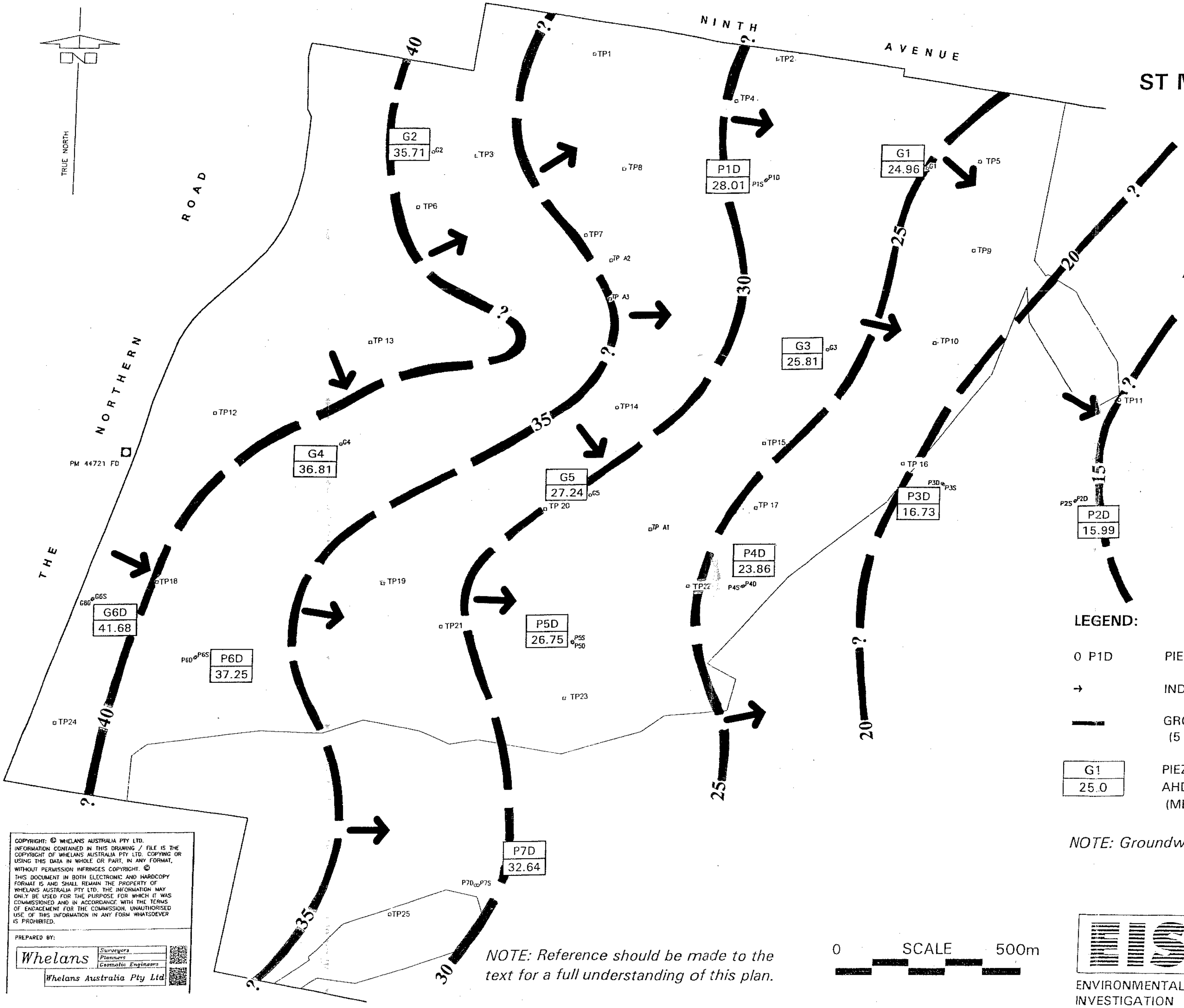
EIS
ENVIRONMENTAL INVESTIGATION SERVICES

Reporr No. E13431F
Figure No. 4

ST MARYS REDEVELOPMEN PROJECT

PIEZOMETER LOCATION PLAN
GROUNDWATER LEVEL DATA
AND
AHD GROUNDWATER CONTOURS

DEEP SHALE AQUIFER



LEGEND:

0 P1D	PIEZOMETER LOCATION AND NUMBER
→	INDICATED GROUNDWATER FLOW DIRECTION
▬	GROUNDWATER CONTOURS (5 METRE INTERVALS)
G1 25.0	PIEZOMETER LOCATION AHD GROUNDWATER LEVEL (METRES)

NOTE: Groundwater contours are judgemental.

NOTE: Reference should be made to the text for a full understanding of this plan.

0 SCALE 500m

PREPARED BY:
Whelans
Surveyors
Planners
Geomatic Engineers
Whelans Australia Pty Ltd

EIS
ENVIRONMENTAL INVESTIGATION SERVICES

Report No. E13431F

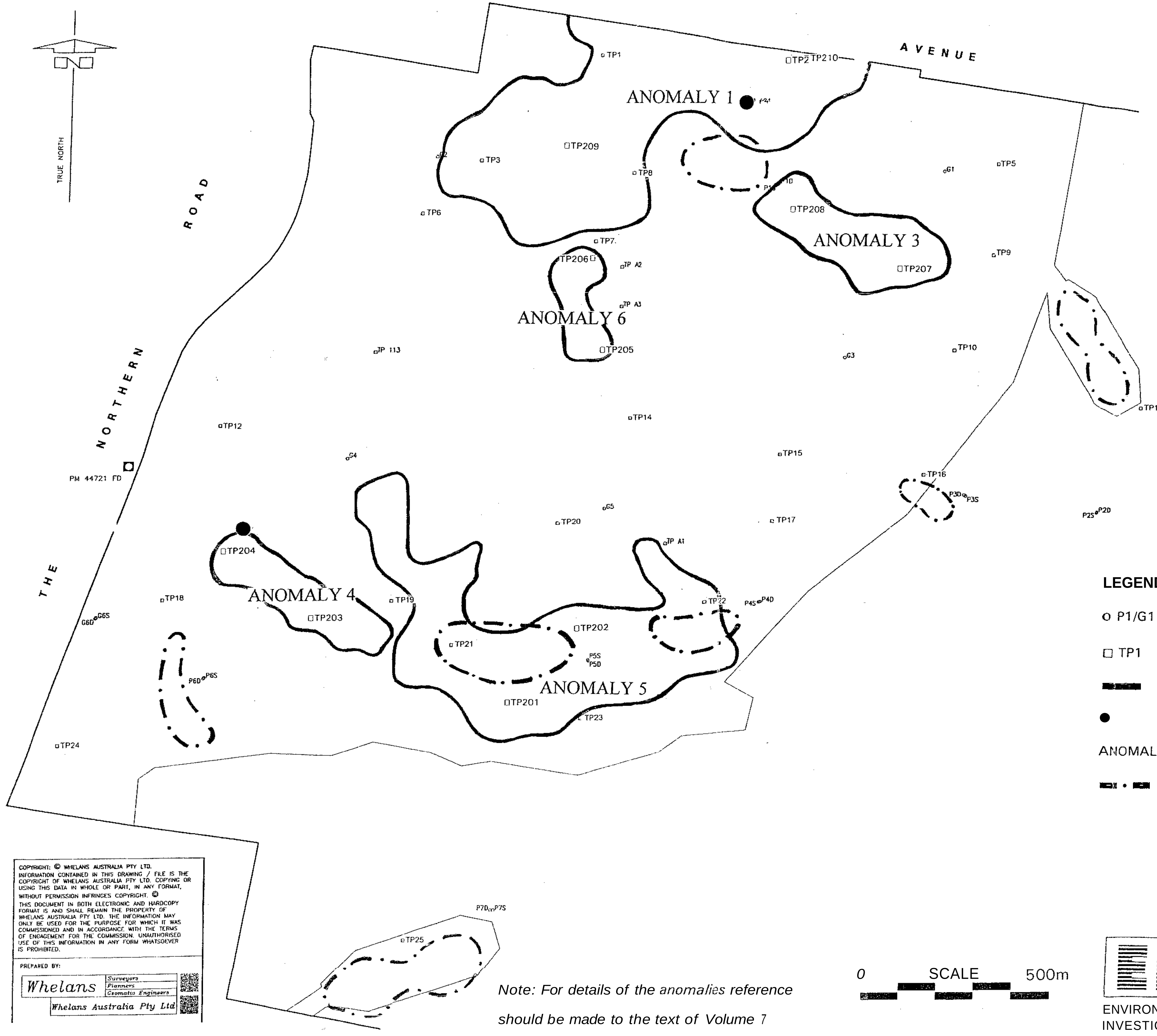
Figure No. 5

ST MARYS REDEVELOPMEN

PROJECT

ELECTROMAGNETIC INDUCTION SURVEY

AMOMALOUS AREAS



Note: For details of the anomalies reference should be made to the text of Volume 7

LEGEND:

○ P1/G1	PIEZOMETER LOCATION AND NUMBER
□ TP1	TESTPIT LOCATION AND NUMBER
▬	ANOMALOUS ZONE BOUNDARY
●	SURFACE WATER SAMPLE POINT
ANOMALY 1	ANOMALOUS AREA NUMBER
▬ • ▬	PROPOSED WETLAND LOCATIONS

PREPARED BY:
Whelans
Surveyors
Planners
Geomatic Engineers
Whelans Australia Pty Ltd

EIS
ENVIRONMENTAL
INVESTIGATION

Report No. E13431F

Figure No. 6

APPENDIX A

BOREHOLE LOG

Borehole No.
P1D 1/2

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS, NSW.

Job No. E13431F
Date: 5-11-99
Method: SPIRAL AUGER INTERTECH 550
R.L. Surface: N/A
Datum:
Logged/Checked by: J.R./ɛl.

Groundwater Record	SAMPLES ES U50 DB DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	**Remarks**
			0		ML/CL	CLAYEY SILT/SILTY CLAY: low plasticity, brown, with a trace of rootlets.	MC<PL	St		
		N = 7 2,3,4	1		CL	SILTY SANDY CLAY: medium plasticity, brawn mottled dark gray. fine to medium grained sand. with fine to medium grained ironstone gravel.	MC>PL	St–VSt	120 140 200	
						as above, but brown mottled pale grey and dark grey.				
		N = 10 3,5,5	2		CH	as above. but high plasticity, pole grey mottled yellow brown.		VSt	230 270 280	
		N = 20 7,9,11	3 4		CL–CH	SILTY GRAVELLY CLAY: medium to high plasticity, orange brown mottled grey. with bands of fine to coarse grained ironstone gravel and fine to medium grained sand.		VSt–H	360 400 350	
			5		CH	SILTY SANDY CLAY: high plasticity, orange brown mottled grey, fine to medium grained sand, with fine to medium grained ironstone gravel.				
▶			6			or above. but high plasticity, brawn mottled grey.	MC=PL			
			7		–	SHALE: pole grey.	XW	VL	–	LOW 'TC' BIT RESISTANCE VERY LOW TO LOW RESISTANCE

BOREHOLE LOG

Borehole No.
P1D 2/2

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 5-11-99
Method: SPIRAL AUGER INTERTECH 550
R.L. Surface: N/A
Datum:
Logged/Checked by: J.R./

Groundwater Record	SAMPLES				Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength / Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
	ES	U50	DB	DS									
				■		7	▤		SHALE: pole grey.	XW	VL		VERY LOW TO LOW RESISTANCE
				■		8	▤				VL-L		LOW TO MODERATE RESISTANCE
						9			END OF BOREHOLE AT 9.0m				PIEZOMETER INSTALLED TO 9.0m, SLOTTED PVC 9.0-6.0m, UNSLOTTED 6.0m TO SURFACE, 2mm COARSE GRAINED SAND PACK 9.0-5.0m, BENTONITE SEAL 5.0-4.2m, BACKFILLED WITH SHALE CUTTINGS TO SURFACE, FITTED WITH 0.5m LOCKABLE STEEL STANDPIPE
						10							
						11							
						12							
						13							

CONSULTING ENVIRONMENTAL ENGINEERS

BOREHOLE LOG

Borehole No. P1S 1/1

Client: LEND LEASE DEVELOPMENT

Project: SOIL AND GROUNDWATER INVESTIGATION

Location: COMLAND, ST MARYS. NSW

Job No. E13431F

Date: 5-11-99

Method: SPIRAL AUGER
INTERTECH 550

R.L. Surface: N/A

Datum:

Logged/Checked by: J.R./gf

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
						0		CL	SILTY CLAY: low to medium plasticity, brown. with a trace of rootlets.	MC>PL	(St-VSt)		
								CL-CH	SILTY SANDY CLAY: medium to high plasticity, pale grey mottled orange brown. with fine to medium grained sand.				
						1							
						2			as above, but orange brown mottled grey. with a trace of fine to medium grained ironstone gravel.				
						3							
						4							PIEZOMETER INSTALLED TO A DEPTH OF 6.0m, SLOTTED PVC 6.0-3.0m, UNSLOTTED FROM 3.0m TO SURFACE, 2mm COARSE GRAINED SAND PACK 6.0-2.0m AND 1.2m TO SURFACE, BENTONITE SEAL FROM 2.0-1.2m FITTED WITH 0.5m LOCKABLE STEEL STANDPIPE
						5							
▶													
						6			END OF BOREHOLE AT 6.0m				
						7							

BOREHOLE LOG

Borehole No.
P2D 1/2

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 5-11-99
Method: SPIRAL AUGER INTERTECH 550
R.L. Surface: N/A
Datum:
Logged/Checked by: J.R./

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
						0			FILL: Silty sandy clay, low to medium plasticity, brown, with fine to medium grained igneous gravel and concrete fragments and fine to medium grained sand.				
					N = 14 5,6,8			CH	SILTY CLAY: high plasticity, pole grey mottled red brown. with fine to medium grained sand.	MC<PL	H	510 530	–
						1							
					N = 30 8,14,16				as above, but with bands of iron indurated, fine to medium grained gravel.			550 >600 >600	
						2							
					N > 29 10,14, >15/ 100mm R	3						>600 >600 >600	
						4							
									or above, but medium to high plasticity, pale grey mottled red and yellow brown.				
						5							
						6							
						7							

BOREHOLE LOG

Borehole No. P2D 2/2

Client: LEND LEASE DEVELOPMENT

Project: SOIL AND GROUNDWATER INVESTIGATION

Location: COMLAND, ST MARYS. NSW

Job No. E13431F

Date: 5-11-99

Method: SPIRAL AUGER INTERTECH 550

R.L. Surface: N/A

Datum:

Logged/Checked by: J.R./

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
						7	▨	CH	SILTY SANDY CLAY: high plasticity. orange brown mottled red and pale grey, with fine to medium grained ironstone gravel.	MC>PL			
▶				■			▨	CL-CH	SILTY GRAVELLY CLAY: medium to high plasticity. brown. with fine to medium grained ironstone gravel and a trace of fine to medium grained sand.				
						8	▨						
				■			▨						
						9			END OF BOREHOLE AT 9.0m				PIEZOMETER INSTALLED TO A DEPTH OF 9.0m, SLOTTED 50mm DIA. PVC PIPE 9.0-6.0m, UNSLOTTED PVC 6.0m TO SURFACE. 2mm COARSE GRAINED SANDPACK FROM 9.0-5.0m AND 4.5m TO SURFACE. BENTONITE SEAL FROM 5.0-4.5m, FITTED WITH A 0.5m LOCKABLE STEEL STANDPIPE
						10							
						11							
						12							
						13							

BOREHOLE LOG

Borehole No.
P2S 1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 5-11-99
Method: SPIRAL AUGER INTERTECH 550
R.L. Surface: N/A
Datum:
Logged/Checked by: J.R./

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
						0	▩		FILL: Silty clay, low to medium plasticity, brown, with fine to medium grained igneous and ironstone gravel and concrete fragments, with a trace of fine to medium grained sand.	D			
						1	▨	CH	SILTY SANDY CLAY: high plasticity, pale grey mottled red with fine to medium grained sand.	MC<PL	(VSt)	–	–
						2 3 4	▨		as above, but pale grey mottled red and yellow brawn. with bands of fine to medium grained ironstone gravel.				
						5 6 7			END OF BOREHOLE AT 4.5m				PIEZOMETER INSTALLED TO 4.5m DEPTH, 50mm DIA. SLOTTED PVC PIPE FROM 4.5-1.5m, UNSLOTTED FROM 1.5m TO SURFACE. 2mm COARSE SAND PACK FROM 4.5-1 .0m, BENTONITE SEAL FROM 1.0m TO SURFACE. FITTED WITH 0.5m LOCKABLE STEEL STANDPIPE

BOREHOLE LOG

Borehole No.
P3D 1/2

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 3-11-99
Method: SPIRAL AUGER INTERTECH 550
R.L. Surface: N/A
Datum:
Logged/Checked by: J.R./

Groundwater Record	SAMPLES ES U50 DB DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
		N = 4 2,2,2	0			FILL: Silty gravelly clay, medium to high plasticity, brown. with a trace of fine to medium grained igneous and ironstone gravel and concrete fragments.	MC>PL			APPEARS POORLY COMPACTED
		N = 7 2,3,4	1			or above, but with fine to coarse grained igneous gravel, ash and fine to medium grained sand.	MC<PL			
			2		CL-CH	SILTY SANDY CLAY: medium to high plasticity, pale grey mottled orange brown.	MC≑PL	VSt	280 300	-
					CL	SILTY SANDY CLAY: low to medium plasticity, pale grey mottled orange brown, with a trace of fine to medium grained ironstone gravel and fine grained sand.	MC>PL			
		N = 10 3,5,5	3			as above. but with no ironstone gravel.		F	60 80 90	
			4		CL	SILTY SANDY CLAY: low plasticity, mottled grey and orange brawn., with fine to medium grained ironstone gravel.				
			5 6 7		CH	SILTY SANDY CLAY: high plasticity, brown mottled orange brown. with fine to medium grained ironstone gravel.				

BOREHOLE LOG

Borehole No.
P3D 2/2

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 3-11-99
Method: SPIRAL AUGER INTERTECH 550
R.L. Surface: N/A
Datum:
Logged/Checked by: J.R./

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
				■		7	▨	CH	SILTY SANDY **CLAY:** as above	MC<P			
						8	▨		SILTY CLAY: **high** plasticity. grey, with **bands of** silty sandy cloy, **orange brawn.**				
				■			▤	–	SHALE: **grey.**	DW	L		LOW 'TC' BIT RESISTANCE
						9			END OF BOREHOLE AT 9.0m				PIEZOMETER INSTALLED TO 9.0m DEPTH. SLOTTED PVC PIPE FROM 9.0-6.0m, UNSLOTTED PVC FROM 6.0m TO SURFACE. 2mm COARSE GRAINED SAND PACK FROM 9.0-5.5m AND FROM 4.75m TO SURFACE. BENTONITE SEAL FROM 5.5-4.75m, FITTED WITH A 0.5m LOCKABLE STEEL STANDPIPE
						10							
						11							
						12							
						13							

CONSULTING ENVIRONMENTAL ENGINEERS

BOREHOLE LOG

Borehole No.
P3S 1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 3-11-99
Method: SPIRAL AUGER
INTERTECH 550
R.L. Surface: N/A
Datum:
Logged/Checked by: J.R./

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
▶						0			**FILL:** Silty sandy grovel. fine to coarse grained igneous grovel, with a trace of fine to coarse grained **ironstone** gravel.	D-M			
						1		CL-CH	SILTY SANDY CLAY: medium to high **plasticity**, mottled **orange** brown **and** grey brawn. with a trace of fine to medium groined **ironstone** gravel.	MC>PL			
						2		CH	SILTY SANDY CLAY: high plasticity, pale grey mottled orange brown, with fine grained ironstone gravel				
						3							
						4							
						5			END OF BOREHOLE AT 4.5m				PIEZOMETER INSTALLED TO 4.5m DEPTH, 50mm OIA. SLOTTED PVC PIPE FROM 4.5-1 .5m, SAND PACK 4.5-1.0m, BENTONITE SEAL 1.0m TO SURFACE. FITTED WITH 0.5m LOCKABLE STEEL STANDPIPE
						6							
						7							

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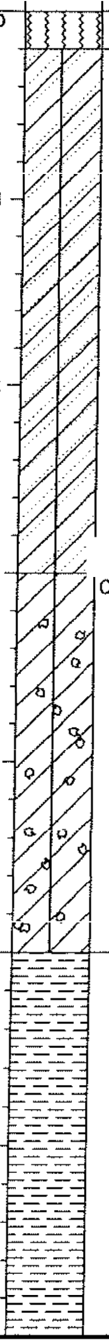
BOREHOLE LOG

Borehole No. P4D 1/2

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 3-11-99
Method: SPIRAL AUGER INTERTECH 550
R.L. Surface: N/A
Datum:
Logged/Checked by: K.T.N./



Groundwater Record	Field Tests	Depth (m)	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
		0		TOPSOIL: Silty clay, law to medium plasticity, dark brown. with a trace of rootlets.	MC>PL			GRASS COVER
			CH	SILTY SANDY CLAY: high plasticity. orange brown, with a face of fine medium grained ironstone gravel.	MC>PL	VSt		–
	N = 11 4,5,6						350 300 320	
		1						
	N = 11 4,5,6			as above, but pale grey mottled orange brown.			220 250 300	
		2						
	N = 19 7,8,11	3	CL-CH	GRAVELLY SILTY CLAY: medium to high plasticity, pole grey mottled orange, with a trace of fine to medium grained sand.			250 200	
▶								
		4		as above. but with ironstone bonds.				
		5	–	SHALE: pale grey mottled orange.	XW	EL		VERY LOW 'TC' BIT RESISTANCE
		6						
		7						

SAMPLES: ES U50 DB DS

BOREHOLE LOG

Borehole No.
P4D 2/2

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 3-11-99
Method: SPIRAL AUGER INTERTECH 550
R.L. Surface: N/A
Datum:
Logged/Checked by: K.T.N./

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
				■		7			SHALE: grey brown.	DW	L		LOW RESISTANCE
				■		8							
						9			END OF BOREHOLE AT 9.0m				PIEZOMETER INSTALLED TO 9.0m DEPTH, 50mm DIA. SLOTTED PVC PIPE FROM 9.0-6.0m, 2mm COARSE SAND PACK FROM 9.0-5.5m AND 4.75m TO SURFACE, BENTONITE SEAL 5.5-4.75m, FITTED WITH 0.5m LOCKABLE STEEL STANDPIPE
						10							
						11							
						12							
						13							

BOREHOLE LOG

Borehole No.
P4S 1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 3–11–99
Method: SPIRAL AUGER INTERTECH 550
R.L. Surface: N/A
Datum:

Logged/Checked by: K.T.N./

Groundwater Record	SAMPLES ES U50 DB DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
			0			TOPSOIL: Silty clay, low to medium plasticity, dark brown, with a trace of rootlets.	MC>PL			GRASS COVER
▶			1 2		CH	SILTY CLAY: high plasticity, orange brown.-with a trace of fine to medium grained ironstone gravel and fine to medium grained sand.	MC>PL	(VSt)		
			3 4		CL–CH	GRAVELLY SILTY CLAY: medium to high plasticity, pale grey mottled orange, with fine to medium grained ironstone gravel.				
			5 6 7			END OF BOREHOLE AT 5.0m				PIEZOMETER INSTALLED TO 5.0m DEPTH. SLOTTED 50mm DIA. PVC PIPE FROM 5.0–2.0m, UNSLOTTED 2.0m TO SURFACE. 2mm COARSE GRAINED SAND PACK FROM 5.0–1.0m, BENTONITE SEAL FROM 1.0m TO SURFACE. FITTED WITH LOCKABLE STEEL STANDPIPE

BOREHOLE LOG

Borehole No.
P5D 1/2

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 20-10-99
Method: SPIRAL AUGER
INTERTECH 550
R.L. Surface: N/A
Datum:
Logged/Checked by: K.T.N./

Groundwater Record	SAMPLES ES U50 DB DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Str ngth/ Rel. Densi.,	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION			0			TOPSOIL: Silty cloy. medium plasticity. dark brown. with a trace of rootlets.	MC>PL			GRASS COVER
		N = 14 6,6,8			CH	SILTY CLAY: high plasticity, red brown. with a trace of fine to medium grained ironstone grovel and fine to medium grained sand.	MC>PL	H	>600 >600 >600	
			1							
		N = 11 4,5,6,				as above, but pale grey mottled red brown, with bands of fine to medium grained iron indurated grovel.	MC≑PL	VSt	250 300 280	
			2							
		N = 23 5,10,13							300 320 350	
			3							
			4							
			5							
					-	SHALE: grey brown.	DW	L	-	LOW 'TC' BIT RESISTANCE
			6			REFER TO CORED BOREHOLE LOG				
			7							

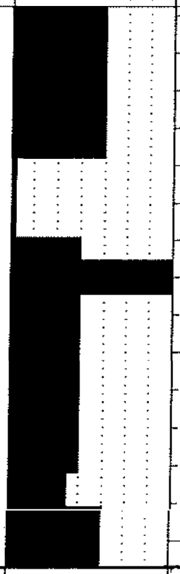
CORED BOREHOLE LOG

Borehole No. P5D 2/2

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 20– 10 – 99
Drill Type: INTERTECH 550
Core Size: NMLC
Inclination: VERTICAL
Bearing: –
R.L. Surface: N/A
Datum:
Logged/Checked by: K.T.N./

Water Loss/Level	Barrel Lift	Depth (m)	Graphic Log	CORE DESCRIPTION Rock Type. grain character-istics. colour. structure. minor components.	Weathering	Strength	POINT LOAD INDEX STRENGTH $I_s(50)$ EL VL L M H VH EH	DEFECT SPACING (mm) 500 300 100 50 30 10	DEFECT DETAILS DESCRIPTION Type, inclination, thickness. planarity. roughness, coating. Specific / General
		5							NOTE: DEFECTS NOT INDIVIDUALLY DESCRIBED ARE BEDDING PARTINGS 0°. PLANAR. SMOOTH
		6		START CORING AT 6.09m					
FULL RET-URN				CORE LOSS 0.06m					
				SHALE: grey brown.	OH	L			- XWSICS. 15mm.t.
		7		as above, but grey.	OW–SW	L–M			- XWSICS. 20mm.t. - XWSICS. 190mm.t. XWSICS. 50mm.t. XWSICS. 170mm.t
		8							
		9		END OF BOREHOLE AT 9.14m					PEIZOMETER INSTALLED TO 9.1m DEPTH, SLOTTED 50mm DIA. PVC PIPE FROM 9.1-6.1m, UNSLOTTED PVC, FROM 6.1m TO SURFACE, 2mm COARSE GRAINED SAND PACK FROM 9.1-5.5m AND FROM 4.8m TO SURFACE, BENTONITE SEAL FROM 5.5-4.8m, FITTED WITH 0.5m LOCKABLE STEEL STANDPIPE
		10							
		11							
		12							



BOREHOLE LOG

Borehole No.
P5S 1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 20-10-99
Method: SPIRAL AUGER INTERTECH 550
R.L. Surface: N/A
Datum:
Logged/Checked by: K.T.N./

Groundwater Record	SAMPLES				Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
	ES	U50	DB	DS									
						0			TOPSOIL: Silty cloy, medium plasticity, dark brown. with a trace of rootlets.	MC>PL			GRASS COVER
								CH	SILTY CLAY: high plasticity, red brown. with a trace of fine to medium groined ironstone gravel and fine to medium grained rand.	MC>PL	(VSt)	–	–
						1							
									as above. but mottled pole grey and red brown.	MC≑PL			
						2							
						3							
						4							PIEZOMETER INSTALLED, SLOTTED 5.7-2.7m, UNSLOTTEO 2.7m TO SURFACE. SAND PACK 5.7-2.5m AND 1.75m TO SURFACE. BENTONITE SEAL 2.5-2.75m, WITH LOCKABLE STEEL STANDPIPE
						5							
									END OF BOREHOLE AT 5.7m				'TC' BIT RESISTANCE ON INFERRED SHALE BEDROCK
						6							
						7							

BOREHOLE LOG

Borehole No.
P6D 1/2

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 29-10-99
Method: SPIRAL AUGER
INTERTECH 550
R.L. Surface: N/A
Datum:
Logged/Checked by: J.R./

Groundwater Record	Field Tests	Depth (m)	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION		0	CL	SILTY CLAY: low to medium plasticity, brown, with fine to medium grained ironstone gravel and fine to medium grained sand.	MC>PL	VSt		ROOTS
	N = 7 2,3,4						200 200 200	
			CH	SILTY SANDY CLAY: high plasticity, pale grey mottled yellow brown, with a trace of root fibres.				
		1						
	N = 12 2,5,7					St-VSt	160 210 210	
		2						
				as above, but medium to high plasticity, grey mottled red.	MC<PL			
	N = 24 8,9,15	3	–	INTERBEDDED SILTY CLAY: high plasticity, red mottled pole grey, and SHALE: pale grey, with bands of fine' grained iron indurated gravel.		H	400 450 450	
			–	SHALE: pale grey.	XW	VL	–	EXTREMELY LOW 'TC' BIT RESISTANCE
		4			DW	L		LOW RESISTANCE
		5						
		6						
▼ AFTER 5 MINS								
		7						

BOREHOLE LOG

Borehole No.
P6D 2/2

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 29-10-99
Method: PIRAL AUGER INTERTECH 550
R.L. Surface: N/A
Datum:
Logged/Checked by: J.R./

Groundwater Record	SAMPLES				Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
	ES	U50	DB	DS									
				■		7			SHALE: grey.	DW	L-M		LOW TO MODERATE RESISTANCE
						8 9 10 11 12 13			END OF BOREHOLE AT 7.5m				PIEZOMETER INSTALLED TO 7.5m DEPTH, SLOTTED 50mm PVC PIPE FROM 7.5-4.5m, UNSLOTTED FROM 4.5m TO SURFACE, 2mm COARSE GRAINED SAND PACK FROM 7.5-4.0m AND FROM 3.3m TO SURFACE, BENTONITE SEAL FROM 4.0-3.3m, FITTED WITH LOCKABLE STEEL STANDPIPE

BOREHOLE LOG

Borehole No.
P6S 1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 29-10- 99
Method: SPIRAL AUGER
INTERTECH 550
Logged/Checked by: J.R./
R.L. Surface: N/A
Datum:

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
						0		CL	SILTY SANDY CLAY: low to medium plasticity, red brown. with fine grained ironstone grovel.	MC>PL			
						1		CL-CH	as above, but medium to high plasticity. pale grey mottled yellow brown.				
						2			as above, but pale grey mottled red brown.				
						3							
									as above, but pole grey mottled yellow brown.				
						4			END OF BOREHOLE AT 4.0m				PIEZOMETER INSTALLED TO 4.0m DEPTH. SLOTTED 50mm. DIA. PVC PIPE FROM 4.0-1.0m, UNSLOTTED PVC FROM 1.0m TO SURFACE. 2mm DIA. COARSE GRAINED SAND PACK FROM 4.0-0.75m, BENTONITE SEAL FROM 0.75m TO SURFACE. FITTED WITH A 0.5m LOCKABLE STEEL STANDPIPE
						5							
						6							
						7							

BOREHOLE LOG

Borehole No.
P7D 1/2

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 29-10-99
Method: SPIRAL AUGER
INTERTECH 550
R.L. Surface: N/A
Datum:
Logged/Checked by: J.R./

Groundwater Record	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
		0	▨	CL	SILTY SANDY CLAY: medium plasticity. brown., with a trace of 'fine to medium grained ironstone gravel and rootlets.	MC>PL			
	N = 15 6,7,8	1	▨	CH	SILTY SANDY CLAY: high plasticity, red brown mottled grey, with a trace of medium to coarse grained ironstone grovel and fine rootlets.	MC>PL	H	>600 >600 >600	
	N = 11 3,5,6	2	▨	CH	SILTY SANDY CLAY: high plasticity, pole grey mottled red and yellow brown, with a trace of fine to medium grained ironstone grovel.	MC≑PL	St	170 180 180	
	N > 25 13,10, 15/70mm REFUSAL	3	☰	–	SHALE: grey, with occasional thin bands of high plasticity silty clay, grey.	XW	EL–VL	>600 >600 550	VERY LOW TO LOW 'TC' BIT RESISTANCE
		4	☰			DW	VL–L		LOW RESISTANCE
		5	☰						MODERATE RESISTANCE
▶		6 7	☰				M		MODERATE TO HIGH RESISTANCE

BOREHOLE LOG

Borehole No.
P7D 2/2

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 29-10-99
Method: SPIRAL AUGER
INTERTECH 550
Logged/Checked by: J.R./
R.L. Surface: N/A
Datum:

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
				■		7	▤		SHALE: pale grey.	DW	M		LOW TO MODERATE RESISTANCE
						8 9 10 11 12 13			END OF BOREHOLE AT 7.5m				PIEZOMETER INSTALLED TO 7.5m DEPTH, SLOTTED 50mm DIA. PVC PIPE FROM 7.5–4.5m, UNSLOTTED FROM 4.5m TO SURFACE, 2mm COARSE GRAINED SAND PACK FROM 7.5–4.0m AND FROM 3.3m TO SURFACE, BENTONITE SEAL 4.0–3.3m, FITTED WITH 0.5m LOCKABLE STEEL STANDPIPE

BOREHOLE LOG

Borehole No. P7S 1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 29-10-99
Method: SPIRAL AUGER INTERTECH 550
R.L. Surface: N/A
Datum:
Logged/Checked by: J.R./

Groundwater Record	SAMPLES ES U50 DB DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
			0			SILTY SANDY CLAY: brown. with a trace of fine grained sand and rootlets.				
					CL-CH	SILTY SANDY CLAY: medium to high plasticity, red brown mottled pale grey.	MC≑PL			
			1		CH	as above, but high plasticity.	MC>PL			
			2			as above, but red mottled pole grey. with medium to coarse grained ironstone grovel.				
			3		–	SHALE: pale grey.	XW	EL–VL		VERY LOW TO LOW 'TC' BIT RESISTANCE
			4			END OF BOREHOLE AT 4.0m				PIEZOMETER INSTALLED TO 4.0m DEPTH. SLOTTED PVC PIPE FROM 4.0-1.0m, UNSLOTTED PVC FROM 1.0m TO SURFACE. 2mm COARSE GRAINED SAND PACK FROM 4.0-0.5m, BENTONITE SEAL 0.5m TO SURFACE. FITTED WITH LOCKABLE 0.5m STEEL STANDPIPE
			5							
			6							
			7							

BOREHOLE LOG

Borehole No. G1 1/1

Client: LEND LEASE DEVELOPMENT

Project: SOIL AND GROUNDWATER INVESTIGATION

Location: COMLAND, ST MARYS. NSW

Job No. E13431F

Date: 3-11-99

Method: SPIRAL AUGER INTERTECH 550

R.L. Surface: N/A

Datum:

Logged/Checked by: J.R./

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
						0			TOPSOIL; Silty cloy. low to medium plasticity, brown. with rootlets.	MC>PL			
					N = 9 1,3,6			CH	SILTY SANDY CLAY: high plasticity, mottled orange brown and pole grey.	MC>PL	VSt	300 210	–
						1			SILTY SANDY CLAY: high plasticity, pale grey mottled red brown, with fine to coarse grained ironstone gravel	MC<PL	H	410	
					N = 22 7,8,14				as above, but interbedded with bonds of extremely weathered SHALE. pale grey.			>600 >600 >600	
						2		–	SHALE: pale brown grey.	XW	L–VL		VERY LOW 'TC' BIT RESISTANCE
						3			SHALE: dark grey.	DW	–M		LOW TO MODERATE RESISTANCE
						4							
						5							PIEZOMETER INSTALLED TO 6.0m DEPTH, SLOTTED 50mm DIA. PVC PIPE FROM 6.0–3.0m, UNSLOTTED FROM 3.0m TO SURFACE, 2mm COARSE GRAINED SAND PACK FROM 6.0–2.5m AND 2.0m TO SURFACE, BENTONITE SEAL 2.5–2.0m, FITTED WITH 0.5m LOCKABLE STEEL STANDPIPE
						6			END OF BOREHOLE AT 6.0m				
						7							

REHOLE LOG

Borehole No.
G2 1/1

nt: LEND LEASE DEVELOPMENT
ect: SOIL AND GROUNDWATER INVESTIGATION
ation: COMLAND, ST MARYS. NSW

No. E13431F
e: 5— 11— 99
Method: SPIRAL AUGER INTERTECH 550
R.L. Surface: N/A
Datum:
Logged/Checked by: J.R./

ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Densit,	Hand Penetrometer Readings (kPa.)	Remarks
					0			TOPSOIL: Silty cloy. low plasticity, dark brown, with a trace of fine grained ironstone gravel and roots.	MC>PL			
							CL		MC<PL			
				N = 17 2,7,10				SILTY CLAY: medium plasticity. red brown mottled grey, with fine to medium grained ironstone gravel and fine to medium grained.		H	>600 >600 >600	
					1		CL–CH	as above., but no gravel.	MC<PL	St		
				N = 12 3,6,6				SILTY SANOY CLAY: medium to high plasticity, mottled red brown and grey.			180 210 220	
					2			SILTY SANDY CLAY: medium to high plasticity, grey mottled orange brown.	MC<PL			
				N > 25 5,10, >15/ 100mm R	3			as above. but with bands of iron indurated siltstone.		VSt–H	350 410 400	
							–	SHALE: pale brown.	DW	VL		LOW 'TC' BIT RESISTANCE
					4							
								SHALE: pale brown.		VL–L		LOW TO MODERATE RESISTANCE
					5							HIGH RESISTANCE PIEZOMETER, SLOTTED 6.0–3.0m, UNSLOTTED 3.0m TO SURFACE, 2mm COARSE GRAINED SAND PACK 6.0–2.5m AND 2.0m TO SURFACE. BENTONIE SEAL 2.5–2.0m, AND STANDPIPE
					6			END OF BOREHOLE AT 6.0m				
					7							

BOREHOLE LOG

Borehole No.
G3 1/2

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 28-10-99
Method: SPIRAL AUGER INTERTECH 550
R.L. Surface: N/A
Datum:
Logged/Checked by: B.A./

Groundwater Record	SAMPLES				Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
	ES	U50	DB	DS									
						0		CL	TOPSOIL: Clayey silt. low plasticity, brown.	MC>PL	–	–	–
									SILTY SANDY CLAY: medium plasticity. brawn.				
					N = 14 3,5,9			CH	SILTY SANDY CLAY: high plasticity, mottled orange brown and light grey, with a trace of fine to medium grained ironstone gravel.	MC<PL	H	>400 >400 >400	
						1							
					N = 13 4,5,8				as above. with a trace of fine to medium grained ironstained gravel.			>400 >400 >400	
						2							
									SILTY CLAY: high plasticity, light grey mottled red brown. with occasional bands of ironstained shale fragments and fine to medium grained ironstone gravel.				
					N = 44 12,19,25	3						>400 >400 >400	
									SILTY SANDY CLAY: high plasticity, red brown, with extremely to distinctly weathered shale fragments and fine to medium grained ironstone gravel.				LOW 'TC' BIT RESISTANCE
						4							
									REFER TO CORED BOREHOLE LOG				
						5							
						6							

CORED BOREHOLE LOG

Borehole No.
G3 2/2

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 28–10–99
Drill Type: INTERTECH 550
Core Size: NMLC
Inclination: VERTICAL
Bearing: –
R.L. Surface: N/A
Datum:
Logged/Checked by: B.A./

ter Loss/Level	Barrel Lift	Depth (m)	Graphic og	CORE DESCRIPTION Rock Type, groin character-istics, colour, structure. minor components.	Weathering	Strength	POINT LOAD INDEX STRENGTH $I_s(50)$ EL VL L M H VH EH	DEFECT DETAILS DEFECT SPACING (mm) 500 300 100 50 30 10	DEFECT DETAILS DESCRIPTION Type, inclination, thickness, planarity, roughness, coating. Specific	General
		4		START CORING AT 4.35m						
FULL RET–URN		5 6 7		SANDSTONE: fine grained, light brown, with some siltstone interbedding, grey to brown grey.	DW	L–M M				
		8		SHALE: grey to light grey with brown grey bands.		–M				
		9 10 11		END OF BOREHOLE AT 8.1m					PIEZOMETER INSTALLED TO 8.1m DEPTH, SLOTTED PVC PIPE FROM 8.1-5.1m, UNSLOTTED PVC FROM 5. 1m TO SURFACE, 2mm COARSE GRAINED SAND PACK FROM 8.1-4.8m AND FROM 4.1m TO SURFACE, BENTONITE SEAL FROM 4.8-4.1m, FITTED WITH 0.5m LOCKABLE STEEL STANDPIPE	

CONSULTING ENVIRONMENTAL ENGINEERS

BOREHOLE LOG

Borehole No.
G4 1/2

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date:
Method: SPIRAL AUGER INTERTECH 550
R.L. Surface: N/A
Datum:
Logged/Checked by: J.R./

Groundwater Record	Samples ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
						0		CL/ML	SILTY CLAY/CLAYEY SILT: low plasticity. brown. with a trace of fine grained ironstone gravel.	MC>PL			
					N = 7 2,3,4			CL	SILTY SANDY CLAY: medium plasticity. brown mottled pale grey and yellow brown. with a trace of fine to medium grained ironstone gravel.		St	130 140 150	
						1		CL-CH	as above, but medium to high plasticity. red brawn, with fine to medium grained ironstone ravel.				
					N = 18 6,9,9				or above, but mottled pale grey, red and orange brawn. with medium to coarse grained ironstone gravel.		VSt-H	360 460 400	
						2							
					N = 26 5,10,16	3		CH	INTERBEDDED SILTY SANDY CLAY: high plasticity, grey, and SHALY CLAY: red mottled yellow brown, with fine to medium grained ironstone gravel.			590 540 260	
								–	SHALE: pale grey.	XW	EL-VL	–	VERY LOW TO LOW 'TC' BIT RESISTANCE
						4							
						5							
						6							
						7							

CONSULTING ENVIRONMENTAL ENGINEERS

BOREHOLE LOG

Borehole No.
G4 2/2

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date:
Method: SPIRAL AUGER
INTERTECH 55(
R.L. Surface: N/A
Datum:
Logged/Checked by: J.R./

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
						7	▤		SHALE: pole grey.				
▶							▤				VL-L		LOW RESISTANCE
						8	▤				VL		VERY LOW TO LOW RESISTANCE
						9			END OF BOREHOLE AT 9.0m				PIEZOMETER INSTALLED TO 9.0m DEPTH, SLOTTED 9.0-6.0m, UNSLOTTED 6.0m TO SURFACE, 2mm COARSE GRAINED SAND PACK FROM 9.0-5.4m AND 4.6m TO SURFACE, BENTONITE 5.4-4.6m, WITH LOCKABLE STEEL STANDPIPE
						10							
						11							
						12							
						13							

CONSULTING ENVIRONMENTAL ENGINEERS

BOREHOLE LOG

Borehole No.
G5 1/2

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 3-11-99
Method: SPIRAL AUGER
INTERTECH 550
R.L. Surface: N/A
Datum:
Logged/Checked by: J.R./

Groundwater Record	SAMPLES ES U50 DB DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
			0			TOPSOIL: Silty sandy clay/clayey sandy silt, brown, wtih trace of rootlets.	M/ MC>PL			–
					CL	SILTY SANDY CLAY: medium plasticity, orange brown mottled pale grey, with fine to medium ironstone gravel.	MC≑PL			
		N = 15 5,7,8						H	>600 >600 >600	
			1							
		N = 17 5,7,10					MC>PL		500 460 480	
			2							
					CL–CH	as above. but high plasticity, pale grey mottled red, with occasional bands of fine to coarse grained ironstone grovel.	MC<PL			
		N = 18 4,8,10	3					VSt	360 310 300	
					–	SHALE: pale brown, with silty clay bands, high plasticity, pale grey.	DW	VL	–	VERY LOW TO LOW 'TC' BIT RESISTANCE
			4							
						SHALE: pale grey.				
			5							
								–L		LOW RESISTANCE
			6							
								L		LOW TO MODERATE RESISTANCE
			7							

BOREHOLE LOG

Borehole No.
G5 2/2

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 3-11-99
Method: SPIRAL AUGER
INTERTECH 550
R.L. Surface: N/A
Datum:
Logged/Checked by: J.R./

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
						7			SHALE: grey.	DW	L		
											M		HIGH RESISTANCE
						8			END OF BOREHOLE AT 8.0m				PIEZOMETER INSTALLED TO 8.0m. SLOTTED PVC 8.0-5.0m, UNSLOTTED PVC FROM 5.0m TO SURFACE. 2mm COARSE GRAINED SAND PACK 8.0- 5.0m, BENTONITE SEAL 5.0-4.0m, SHALE CUTTINGS FROM 4.0m- SURFACE. FITTED WITH LOCKABLE STEEL STANDPIPE
						9							
						10							
						11							
						12							
						13							

BOREHOLE LOG

Borehole No.
G6 1/2

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 28-10-99
Method: SPIRAL AUGER
INTERTECH 550
R.L. Surface: N/A
Datum:
Logged/Checked by: B.A./

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
						0			TOPSOIL: Clayey silt, brown.	MC<PL			TRACE OF ROOT FIBRES
					N = 10 4,5,5			CH	SILTY CLAY: high plasticity. brown.	MC≑PL	H	>400 >400 >400	
						1		CL	SILTY SANDY CLAY: medium plasticity, brown mottled grey and black. with a trace of fine grained gravel.	MC<PL			
					N = 19 4,8,11			CL–CH	SILTY SANDY CLAY: medium to high plasticity, light grey.	MC≑PL	Vst–H	350 290 400	
						2		CH	SIITY SANDY CLAY: plasticity, mottled light grey and red brown				
					N = 29 8,12,17	3			as above. but with bonds of fine to medium grained iron indurated gravel.	MC<PL	H	>400 >400 >400	
						4							
						5		CL	SILTY SANDY CLAY: medium plasticity, brown, with a trace of extremely weathered shale fragments.				
						6			REFER TO CORED BOREHOLE LOG				
						7							

CORED BOREHOLE LOG

Borehole No.
G6 2/2

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 28-10-99
Drill Type: INTERTECH 550
Core Size: NMLC
Inclination: VERTICAL
Bearing: -
R.L. Surface: N/A
Datum:
Logged/Checked by: B.A./

Water Loss/Level	Barrel Lift	Depth (m)	Graphic Log	CORE DESCRIPTION Rock Type, grain characteristics, colour, structure, minor components.	Weathering	trength	POINT LOAD INDEX STRENGTH $I_s(50)$ EL L M H VH EH	DEFECT SPACING (mm) 500 300 100 50 30 10	DEFECT DETAILS DESCRIPTION Type. inclination, thickness, planarity. roughness. coating. Specific	General
		5								
				START CORING AT 5.68m						
		6		SHALE: grey with occasional brown bands.	DW	L				
						VL				
FULL RETURN		7								
		8								
				SHALE: dark grey.						
				END OF BOREHOLE AT 8.53m					PIEZOMETER INSTALLED TO 8.5m DEPTH, SLOTTED PVC PIPE FROM 8.5-3.5m, UNSLOTTED FROM 5.5m TO SURFACE, SAND PACK, FROM 8.5-5.0m AND FROM 4.3m TO SURFACE, BENTONITE SEAL 5.0-4.3m, FITTED WITH LOCKABLE STEEL STANDPIPE	
		9								
		10								
		11								
		12								

TEST PIT LOG

Test Pit No.
1
1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Method: BACKHOE
R.L. Surface: N/A
Date: 29-10-99
Datum:
Logged/Checked by: B.A./

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0	ML	CLAYEY SILT: low plasticity. brown.	MC<PL			ROOT FIBRES THROUGHOUT
							CL/ML	SILTY CLAY/CLAYEY SILT: low plasticity, brown.	MC≑PL	VSt	250 260	
				■			CH	SILTY SANDY CLAY: high plasticity. orange brown mottled yellow grey. with a trace of fine grained ironstone gravel.	MC>PL		280 220	OCCASIONAL ROOT FIBRES
						1		SILTY SANDY CLAY: high plasticity, light grey mottled orange brown and red brown.	MC<PL	H	240 250 280 >400	
						2		SILTY SANDY CLAY: high plasticity, mottled light grey and red brown. with fine to medium grained ironstone nodules.			>400 >400	IRONSTAINED GRAVELLY SEAM, 50mm.t.
								END OF TEST PIT AT 2.1m				
						3						
						4						
						5						
						6						
						7						

CONSULTING ENVIRONMENTAL ENGINEERS

TEST PIT LOG

Test Pit No.
2
1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Method: BACKHOE
R.L. Surface: N/A
Date: 29-10-99
Datum:
Logged/Checked by: B.A./

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0			**TOPSOIL:** Clayey silt, law plasticity. brown.	MC<PL	St	150	
									as above, but dark brown.	MC>PL	VSt	250	
				■				CL CL–CH	**SILTY SANDY CLAY:** medium plasticity, brown mottled black.	MC>Pl	VSt H	350 360	
						1			**SILTY SANDY CLAY:** medium to high plasticity. yellow brown mottled black. with fine grained ironstone gravel.			400	
								–	**SANDSTONE:** fine grained. brown.	DW	M	400	
									END OF TEST PIT AT 1.05m				
						2							
						3							
						4							
						5							
						6							
						7							

TEST PIT LOG

Test Pit No.
3
1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 29-10-99
Method: BACKHOE
R.L. Surface: N/A
Datum:
Logged/Checked by: B.A./

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0			TOPSOIL: Clayey silt, law plasticity, brown.	MC<PL MC>PL			ROOT FIBRES THROUGHOUT
				■				CL	SILTY CLAY: medium to law plasticity, grey and brown.	MC<PL	H	>400	
						1			SILTY CLAY: medium plasticity. brown mottled grey, with fine to medium grained sand grading to yellow brown.			>400 >400	
								CL	SILTY SANDY CLAY: medium plasticity, yellow brown mottled block., with fine to medium grained ironstone grovel.			>400	
						2		CL	GRAVELLY SILTY CLAY: medium plasticity, yellow brown mottled block, with fine to medium grained ironstone grovel.			>460	
									END OF TEST PIT AT 2.2m				
						3 4 5 6 7							

TEST PIT LOG

Test Pit No.
4
1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 8-11-99
Method: BACKHOE
R.L. Surface: N/A
Datum:
Logged/Checked by: B.A./

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0	▨	CL-CH	SILTY SANDY CLAY: medium to high plasticity, mottled brown, orange brown and grey.	MC<PL	(VSt)		BLOCKY IN NATURE
							▨	CL	SILTY SANDY CLAY: medium plasticity. brown and grey brown, with a trace of fine to coarse grained ironstone gravel.		H	>400 >400	
						1	▨		SILTY SANDY CLAY: medium plasticity, brown.	MC≑PL	VSt	280 330 360	
				■		2	▨		SILTY SANDY CLAY: medium plasticity, light grey mottled yellow brown, with a trace of fine to medium grained ironstone gravel.	MC>PL		320 330	SOME BLACK ROOT STAINING
									END OF TEST PIT AT 2.1m				
						3							
						4							
						5							
						6							
						7							

TEST PIT LOG

Test Pit No.
5
1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 29-10-99
Method: BACKHOE
R.L. Surface: N/A
Datum:
Logged/Checked by: B.A./

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0		CL	TOPSOIL: Clayey silt, low plasticity, brown.	MC<PL			ROOT FIBRES THROUGHOUT
									SILTY SANDY CLAY: medium plasticity, orange brown and yellow brown, grading to yellow brown, with a trace of fine to medium grained ironstone grovel.	MC>PL	VSt	350	
											H	400	
				■				CH				>400	
												>400	
						1			SILTY SANDY CLAY: high plasticity. light grey with yellow streaking.			>400	
									grading to light grey mottled red brown.				
						2							
									END OF TEST PIT AT 2.3m				
						3							
						4							
						5							
						6							
						7							

TEST PIT LOG

Test Pit No.
6
1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 8-11-99
Method: BACKHOE
R.L. Surface: N/A
Datum:
Logged/Checked by: B.A./M

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0		CL-CH	TOPSOIL: Clayey silt, brown, with a trace of fine grained sand.	MC>PL			ROOT FIBRES THROUGHOUT
									SILTY SANDY CLAY: medium to high plasticity, mottled light grey and yellow brown.	MC>PL	VSt	230 250 280	
				■				CH	as above, but grey mottled yellow brown.	MC<PL		300	
						1			SILTY SANDY CLAY: high plasticity, light grey mottled red brown, yellow brown and orange brown.			350 380	
								–	SANDSTONE: fine grained, brown.				
									END OF TEST PIT AT 1.25m				
						2							
						3							
						4							
						5							
						6							
						7							

TEST PIT LOG

Test Pit No. 7 1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F **Method:** BACKHOE **R.L. Surface:** N/A
Date: 29-10-99 **Datum:**
Logged/Checked by: B.A./Ø1

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	H P R rometer ngs (kPa.)	Remarks
DRY ON COMPLETION						0		CL	TOPSOIL: Clayey silt, low plasticity, brown, with fine to medium grained sand.	MC<PL MC>PL	VSt	300 300	ROOT FIBRES THROUGHOUT
								CH	SILTY SANDY CLAY: medium plasticity, brown mottled orange brown and black.			310	–
				■		1		CL	SILTY SANDY CLAY: high plasticity, light grey and yellow brown, with fine to medium grained ironstone gravel.	MC≑PL	H	>400 >400 >400	
								–	SILTY CLAY: medium plasticity, banded light grey and yellow brown, with a trace of fine grained sand.	DW	VL	–	–
									as above, but with fine grained sand.				
						2			SANDSTONE: fine grained, banded brown and light grey.				
									END OF BOREHOLE AT 1.4m				
						3							
						4							
						5							
						6							
						7							

TEST PIT LOG

Test Pit No. 8 1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Method: BACKHOE
R.L. Surface: N/A
Date: 8-11-99
Datum:
Logged/Checked by: B.A./

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0		ML/CL	TOPSOIL: Clayey silt, brown. with a trace of fine to medium grained sand.	MC<PL	VSt	230 250	ROOT FIBRES THROUGHOUT
								CL	CLAYEY SILT/SILTY CLAY: low plasticity, brown.	MC>PL	H	400	
				■					SILTY CLAY: medium plasticity, brown and orange brown, with trace of fine grained sand.			>400	
						1			SILTY CLAY: medium plasticity, orange brown. with fine grained sand.			>400	
											(H)		PATCHY BLACK STAINING - PROBABLY ROOT FIBRES
									SILTY CLAY: medium plasticity. brown, with fine grained sand.				
						2			SILTY CLAY: medium plasticity, mottled brown, yellow brown and grey brown, with fine grained sand.				
									END OF BOREHOLE AT 2.45m				
						3							
						4							
						5							
						6							
						7							

TEST PIT LOG

Test Pit No.
9
1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 29-10-99
Method: BACKHOE
R.L. Surface: N/A
Datum:
Logged/Checked by: B.A./

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0			TOPSOIL: Clayey silt, low plasticity, brown.	MC<PL			ROOT FIBRES THROUGHOUT
				■				CL	SILTY CLAY: medium plasticity. orange brown.	MC>PL	H	>400 >400	OCCASIONAL TREE ROOTS
								CH	SILTY CLAY: high plasticity. brown, with fine to medium grained sand.	MC<PL		>400	
						1						>400 >400	
								CL	SILTY SANDY CLAY: medium plasticity, yellow brawn.		(VSt)		
						2							
									as above. but yellow brawn mottled brown and black.	MC≑PL			
									END OF TEST PIT AT 2.5m				
						3							
						4							
						5							
						6							

TEST PIT LOG

Test Pit No.
10
1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Method: BACKHOE
R.L. Surface: N/A
Date: 29-10-99
Datum:
Logged/Checked by: B.A./

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0		SM	SILTY SAND: fine grained. brown.	M		400	ROOT FIBRES
								CH	SILTY CLAY: high plasticity. red brown mottled light grey, with fine to medium grained sand.	MC>PL	vst	250 280 320	
				■		1			SILTY SANDY CLAY: high plasticity, light grey mottled red brown.	MC≑PL	H	>400 >400	
									SILTY CLAY: high plasticity, with shale fragments. distinctly weathered, very low strength.				
									END OF TEST PIT AT 1.2m				
						2							
						3							
						4							
						5							
						6							
						7							

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TEST PIT LOG

Test Pit No. 11 1/1

Client: LEND LEASE DEVELOPMENT

Project: SOIL AND GROUNDWATER INVESTIGATION

Location: COMLAND, ST MARYS. NSW

Job No. E13431F **Method:** BACKHOE **R.L. Surface:** N/A

Date: 8-11-99 **Datum:**

Logged/Checked by: B.A./

Groundwater Record	SAMPLES				Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
	ES	U50	DB	DS									
DRY ON COMPLETION						0		ML/CL	INTERBEDDED SILT AND SILTY CLAY: low to medium plasticity, brown.	MC<<PL			
								CL	SILTY SANDY CLAY: medium plasticity, orange brown.		H	>400	OCCASIONAL TREE ROOTS HEAVILY BLACK STAINED – PROBABLY ROOT FIBRES
						1		CL-CH	SILTY SANDY CLAY: medium to high plasticity. yellow brown mottled brown.				
				■					SILTY SANDY CLAY: medium plasticity, yellow brown.	MC<PL			
									END OF BOREHOLE AT 1.8m				
						2							
						3							
						4							
						5							
						6							
						7							

TEST PIT LOG

Test Pit No.
12
1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 8-11-99
Method: BACKHOE
R.L. Surface: N/A
Datum:
Logged/Checked by: B.A./

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	epth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Stre gth/ Rel. Densit,	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0		CL–CH	TOPSOIL: Clayey silt, low plasticity, brown.	MC<PL	VSt	280	ROOT FIBRES THROUGHOUT
				■					SILTY SANDY CLAY: medium to high plasticity, brown and orange brown, with a trace of medium grained ironstone nodules.	MC>PL	H	280 >400	
								CH	SILTY GRAVELLY CLAY: high plasticity, light grey, with horizontal bands of fine to medium grained ironstone gravel.	MC≈PL		>400	
						1			END OF TEST PIT AT 1.24m				
						2							
						3							
						4							
						5							
						6							
						7							

TEST PIT LOG

Test Pit No.
13 1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 8–11–99
Method: BACKHOE
R.L. Surface: N/A
Datum:
Logged/Checked by: B.A./

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0		CH	TOPSOIL: Clayey silt, low plasticity, brown.	MC<PL			ROOT FIBRES THROUGHOUT
				■					SILTY CLAY: high plasticity, mottled orange brown and light grey, with a trace of root fibres and fine to medium grained sand.	MC>PL			
								–	SANDSTONE: fine grained,				
						1			END OF TEST PIT AT 0.52m				
						2							
						3							
						4							
						5							
						6							
						7							

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TEST PIT LOG

Test Pit No.
14
1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Method: BACKHOE
R.L. Surface: N/A
Date: 29-10-99
Datum:
Logged/Checked by: B.A./

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0			TOPSOIL: Clayey silt, law plasticity, brown, with a trace of fine grained sand.	MC<PL			ROOT FIBRES THROUGHOUT
				■				CH	SILTY CLAY: high plasticity. mottled light grey and orange brown, with a trace of fine to medium grained sand.	MC>PL	VSt	220 250	
								–	SHALE: brown.	DW	M	-	
						1		CH	SILTY SANDY CLAY: high plasticity. mottled light grey and orange brown.	MC>PL	H	400 >400 >400	
									SILTY CLAY: high plasticity, mottled light grey and red brown, with bonds of ironstained shale, distinctly weathered, very low strength.				
								–	SHALE: brown.	DW	VL	–	–
						2			END OF TEST PIT AT 1.65m				
						3							
						4							
						5							
						6							
						7							

TEST PIT LOG

Test Pit No.
15
1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 8-11-99
Method: BACKHOE
R.L. Surface: N/A
Datum:
Logged/Checked by: B.A./

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0		ML/CL	TOPSOIL: Clayey silt, brown, low plasticity, with a trace of fine grained sand.	MC<PL	–	–	ROOT FIBRES THROUGHOUT
				■				CH	CLAYEY SILT/SILTY CLAY: low plasticity, brown.	MC<PL	VSt	230	–
									SILTY SANDY CLAY: high plasticity, mottled orange brown and light grey.	MC>PL	H	250 >400	
						1			as above, but with ironstained shale fragments			>400	
									END OF TEST PIT AT 1.0m				
						2							
						3							
						4							
						5							
						6							

Test Pit No.
16
1/1

TEST PIT LOG

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 29-10-99
Method: BACKHOE
R.L. Surface: N/A
Datum:
Logged/Checked by: B.A./

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0			TOPSOIL: Clayey silt, low plorticity. brown.	MC<PL	VSt	220	ROOT FIBRES
								ML			H		–
								CL-CH	CLAYEY SILT: law plasticity, brown. with fine to medium grained ironstone gravel.	MC>PL		>400 >400	
								CL	SILTY SANDY CLAY: medium to high plasticity, yellow brawn.	MC≑PL		>400	
						1			SILTY SANDY CLAY: medium plasticity, yellow brown mottled black and orange brown, with a trace of fine grained ironstone gravel.			>400	
									END OF TEST PIT AT 1.6m				INCREASE IN PROPORTION OF BLACK STAINING; POSSIBLY INDURATED LAYER
						2							
						3							
						4							
						5							
						6							
						7							

TEST PIT LOG

Test Pit No. 17 1/1

Client: LEND LEASE DEVELOPMENT

Project: SOIL AND GROUNDWATER INVESTIGATION

Location: COMLAND, ST MARYS. NSW

Job **No.** E13431F

Method: BACKHOE

R.L. Surface: N/A

Date: 8-11-99

Datum:

Logged/Checked by: B.A./ℋ.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	oisture ondition/ eathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLE-TION						0		SP/SM	GRAVELLY SILTY SAND: fine grained. brown.	M		200	ROOT FIBRES THROUGHOUT
								SP		M			
								SM	SAND: fine grained, orange brown. with clay and silt.			240 280	
				■				CL	SILTY SAND: fine grained. grey, with a trace of cloy and fine grained ironstone gravel.		H	>400 >400	
						1		CH	SILTY CLAY: medium plasticity, mottled orange brown and grey, with a trace of fine to medium grained rood.		(H)	>400	
									SILTY CLAY: high plasticity. mottled orange brown and light grey, with fine to medium grained sand.				
						2		CL	as above, but with fine to medium grained ironstone gravel.				IRONSTAINED SANDSTONE FRAGMENTS INCREASING WITH DEPTH
									SILTY CLAY: medium plasticity, light grey mottled red brown, with fine grained sand and ironstained sandstone fragments.				
									END OF TEST PIT AT 2.2m				
						3							
						4							
						5							
						6							
						7							

TEST PIT LOG

Test Pit No.
18
1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Method: BACKHOE
R.L. Surface: N/A
Date: 8–11–99
Datum:
Logged/Checked by: B.A./

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0			TOPSOIL: Clayey silt. low plasticity, brawn.	MC<PL	H	400	ROOT FIBRES THROUGHOUT
								GP	SILTY GRAVEL: fine and medium grained.	MC>PL	VSt	>400	
				■				CL–CH	SILTY SANDY CLAY: medium to high plasticity, mottled brown and orange brown, with trace of medium grained ironstone grovel.			280 280 300	
						1		CH	SILTY CLAY: high plasticity. red brown mottled light grey.			300 280 280	
						2			SILTY SANDY CLAY: high plasticity, grey mottled red brown, with bands of fine to coarse grained ironstone gravel increasing with depth.		(VSt)	260	
						3 4 5 6 7			END OF TEST PIT AT 2.2m				

CONSULTING ENVIRONMENTAL ENGINEERS

Test Pit No.
19
1/1

TEST PIT LOG

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Method: BACKHOE
R.L. Surface: N/A
Date: 8 – 11 – 99
Datum:
Logged/Checked by: B.A./

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0	≀≀≀		TOPSOIL: Clayey silt, low plasticity, with a trace of fine grained ironstone gravel.	MC<PL			ROOT FIBRES THROUGHOUT
				■		1	▨	CL	SILTY SANDY CLAY: low to medium plasticity, mottled brown and yellow brown, with a trace of ironstone gravel.	MC>PL	VSt	220 230 240 220	
						2	▨	CL	SILTY CLAY: medium plasticity. mottled yellow brawn and light grey, with fine grained sand.		(VSt)	210	
									END OF TEST PIT AT 2.05m				
						3							
						4							
						5							
						6							
						7							

TEST PIT LOG

Test Pit No.
20 1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 8-11-99
Method: BACKHOE
R.L. Surface: N/A
Datum:
Logged/Checked by: B.A./Ef

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0			TOPSOIL: Clayey silt, brown.	MC≑PL			
								CL	SILTY SANDY CLAY: medium plasticity, mottled brown, light brown and orange brown.	MC>P	VSt	260	–
								CH	SILTY SANDY CLAY: high plasticity, red brown.			230 280 260	
				■		1 2			SILTY SANDY CLAY: high plasticity, light grey mottled red brown and orange brown, with a trace of fine to coarse grained ironstone gravel increasing with depth.		H	>400 >400	
						3 4 5 6			END OF TEST PIT AT 2.1m				

CONSULTING ENVIRONMENTAL ENGINEERS

TEST PIT LOG

Test Pit No.
21
1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 8-11-99
Method: BACKHOE
R.L. Surface: N/A
Datum:
Logged/Checked by: B.A./

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0		CL	SILTY SANDY CLAY: low plasticity, brown.	MC<PL	H	>400	ROOT FIBRES THROUGHOUT
									as above, but medium to law plasticity.			>400	
									as above. but mottled orange brown and brown.			>400	
						1			SILTY SANDY CLAY: medium plasticity, mottled brown and grey brown.			>400	
									as above, but mottled yellow brown and grey.				SAMPLE OBTAINED FROM ADJACENT CREEK EMBANKMENT
									END OF TEST PIT AT 1.5m				
						2							
						3							
						4							
						5							
						6							
						7							

TEST PIT LOG

Test Pit No. 22 1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Method: BACKHOE
R.L. Surface: N/A
Date: 29–10–99
Datum:
Logged/Checked by: B.A./

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
						0			TOPSOIL: Clayey silt. low plasticity, brown.	MC≑PL			ROOT FIBRES THROUGHOUT
								CL	SILTY CLAY: medium plasticity. mottled orange brown and light grey.	MC>PL	VSt	200 360	–
						1		CH	SILTY SANDY CLAY: high plasticity, mottled yellow brown and light grey, with a trace of fine to medium grained ironstone gravel.		H	390 400 >400 >400	
▶				■		2		CL	SILTY SANDY CLAY: medium plasticity, mottled yellow brown, orange brown and light grey, with a trace of fine to medium grained ironstone gravel.			>400	ROOT FIBRES
									SILTY SANDY CLAY: medium plasticity, with heavily ironstained shale.				POSSIBLY INDURATED CLAY
						3 4 5 6 7			END OF BOREHOLE AT 2.7m				

TEST PIT LOG

Test Pit No. 23 1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F **Method:** BACKHOE **R.L. Surface:** N/A
Date: 8-11-99 **Datum:**
Logged/Checked by: B.A./

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0		CL	TOPSOIL: Clayey silt, law trace a fine rained sand.	MC<PL	VSt	–	ROOT FIBRES THROUGHOUT
								CH	SILTY SANDY CLAY: medium plasticity, mottled brown and ,ellow brown.	MC>PL		>400	–
				■					SILTY SANDY CLAY: high plasticity, mottled brown and ,ellow brown.			>400	
						1			SILTY SANDY CLAY: high plasticity, light grey mottled orange brown.		(VSt)	>400	
									as above, but with medium to coarse grained ironstone grovel. increasing with depth.				
						2			END OF TEST PIT AT 1.8m				
						3							
						4							
						5							
						6							
						7							

ST PIT LOG

Test Pit No.
24
1/1

nt: LEND LEASE DEVELOPMENT
ect: SOIL AND GROUNDWATER INVESTIGATION
ation: COMLAND, ST MARYS. NSW

No. E13431F
Method: BACKHOE
R.L. Surface: N/A
: 24
Datum:
Logged/Checked by: B.A./

ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
					0		ML/CL	TOPSOIL: Clayey silt, low plasticity, brown.	MC<PL			ROOT FIBRES THROUGHOUT
							CL-CH	CLAYEY SILT/SILTY CLAY: low plasticity, brown.	MC>PL	St-VSt	200	–
			■				CH	SILTY SANDY CLAY: medium to high plasticity, mottled yellow brown and brown.			200 200	
					1			SILTY SANDY CLAY: high plasticity, mottled yellow brown and light grey, with a trace of medium to coarse grained ironstone gravel.		VSt	320 350 320	
								SILTY SANDY CLAY: high plasticity, light grey mottled red brown and orange brown, with fine to coarse grained ironstone gravel.				
					2			END OF TEST PIT AT 1.73m				
					3							
					4							
					5							
					6							
					7							

TEST PIT LOG

Test Pit No.
25
1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F **Method:** BACKHOE **R.L. Surface:** N/A
Date: 8–11–99 **Datum:**

Logged/Checked by: B.A./

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0		ML/CL	TOPSOIL: Clayey silt, low plasticity, brown.	MC>PL	St	150 160 150 150 180 180 200 180	ROOT FIBRES THROUGHOUT
								CH	CLAYEY SILT/SILTY CLAY: low plasticity, mottled brown and light brown, with a trace of fine grained sand.	MC>PL			
						1			SILTY SANDY CLAY: high plasticity, mottled orange brown and grey brown, with a trace of fine grained ironstone gravel.		(VSt)		
						2		CL–CH	SILTY SANDY CLAY: medium to high plasticity, with fine to coarse grained ironstone gravel.				
									END OF TEST PIT AT 2.1m				
						3							
						4							
						5							
						6							
						7							

TEST PIT LOG

Test Pit No.
A1 1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E13431F
Date: 29– 10– 99
Method: BACKHOE
R.L. Surface: N/A
Datum:
Logged/Checked by: B.A./

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0			TOPSOIL: Clayey silt, low plasticity, brown.	MC≑PL	VSt	280	ROOT FIBRES
								ML/CL	CLAYEY SILT/SILTY CLAY: low to medium plasticity, with a trace of fine to medium grained ironstone gravel.	MC>PL	VSt St	300 120 140	0.25–0.55m VISIBLE FREE WATER (POSSIBLE PERCHED WATER TABLE)
								CL	as above, but no gravel.	MC≑PL	VSt	380	
						1			SILTY SANDY CLAY: medium plasticity, orange brown mottled black.	MC>PL	H	400 >400 >400	
								GC	as above, but with a trace of fine and medium grained ironstone gravel.	M	(D)		
				■		2		CH	GRAVEL: fine and medium grained, mottled red brown, black and yellow, with silty clay.	MC>PL	H	>400 >400	
									SILTY SANDY CLAY: high plasticity, mottled red brown and light grey.				
									as above, but with fine to medium grained ironstone gravel.				
						3			END OF TEST PIT AT 2.1m				
						4							
						5							
						6							
						7							

TING ENVIRONMENTAL ENGINEERS

ST PIT LOG

Test Pit No.
A2 1/1

nt: LEND LEASE DEVELOPMENT
ect: SOIL AND GROUNDWATER INVESTIGATION
ation: COMLAND, ST MARYS. NSW

No. E13431F
e: 29-10-99

Method: BACKHOE

R.L. Surface: N/A
Datum:

Logged/Checked by: B.A./

ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
					0		CH	TOPSOIL: Clayey silt. low plasticity, brown.	MC<PL	H	>400	ROOT FIBRES
			■					SILTY CLAY: high planticity. mottled light grey. orange brown and red brown, with a trace of fine to medium grained ironstone grovel and fine to medium grained sand.	MC>PL	H VSt H	400 400 400	HORIZONTAL ROOTS AT 0.45m
					1			SILTY SANDY CLAY: high plasticity, light grey mottled red brown., with a trace of ironstained shale fragments, increasing with depth.			>400	HORIZONTAL SHALE SEAM. 50mm.t.. DISTINCTLY WEATHERED. VERY LOW STRENGTH.
					2			END OF TEST PIT AT 1.85m				
					3							
					4							
					5							
					6							
					7							

TEST PIT LOG

Test Pit No.
A3 1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS. NSW

Job No. E I 3431F
Method: BACKHOE
R.L. Surface: N/A
Date: 29-10-99
Datum:
Logged/Checked by: B.A./

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0			TOPSOIL: Clayey silt, low plasticity, brawn.	MC<PL	H		ROOT FIBRES
				■				CL-CH	SILTY CLAY: medium plasticity, mottled brown and orange brown, with a trace of fine to medium grained sand.	MC≑PL		>400 >400	A TRACE OF ROOT FIBRES
						1		CL	SILTY CLAY: high plasticity. orange brown mottled yellow brown, with a trace of fine to medium groined sand.	MC<PL		>400 >400	
									SILTY SANDY CLAY: medium plasticity. orange brown.				
								–	SANDSTONE: fine grained, brown.	DW	VL	–	–
									END OF TEST PIT AT 1.55m				
						2							
						3							
						4							
						5							
						6							
						7							

TEST PIT LOG

Test Pit No.
201 1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS, NSW.

Job No. E13431F **Method:** 4WD BACKHOE **R.L. Surface:** N/A
Date: 13-4-00 **Datum:**
Logged/Checked by: J.R./

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION				■		0	▨	CL	SILTY SANDY CLAY: low to medium plasticity. fine grained sand, brown.	MC>PL			ROOT FIBRES THROUGHOUT VISIBLE WATER SEEPAGE OCCURRING FROM 0.0-03m
				■		0.5	▨		as above. but medium plasticity, mottled red brown and grey.	MC>PL			
				■		1	▨		grading to grey mottled red yellow brawn, with a trace of fine grained ironstone grovel, increasing with depth.				
				■		1.5			END OF TEST PIT AT 1.5m				
						2							
						2.5							
						3							
						3.5							

CONSULTING **ENVIRONMENTAL** ENGINEERS

TEST PIT LOG

Test Pit No.
202 1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS, NSW.

Job No. E13431F
Method: 4WD BACKHOE
R.L. Surface: N/A
Date: 13- 4- 00
Datum:

Logged/Checked by: J.R./

Groundwater Record	ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION				■		0	▨		CLAYEY SILT/SILTY CLAY: low to medium plasticity, brown.	MC=PL			ROOT FIBRES THROUGHOUT
				■		0.5	▨	CL-CH	SILTY CLAY: medium to high plasticity. orange brawn mottled light brown. with a trace of root fibres, fine grained sand and fine grained ironstone gravel.				
				■ ■		1 1.5	▨		or above. but light brown mottled orange brown, pole grey and black, with a trace of fine grained sand.	MC>PL			INCREASING BLACK STAINING WITH DEPTH- POSSIBLY ROOT FIBRES.
						2 2.5 3			END OF TEST PIT AT 1.7m				

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TEST PIT LOG

Test Pit No.
203
1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS, NSW.

Job **No.** E13431F
Method: 4WD BACKHOE
R.L. Surface: N/A
Date: 13-4-00
Datum:
Logged/Checked by: J.R./

Groundwater Record	SAMPLES ES	 U50	 DB	 DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	**Remarks**
DRY ON COMPLETION				■		0	▨	CL	SILTY SANDY CLAY: low to medium plasticity. grey brown mottled orange and black, with fine grained sand.	MC<PL			ROOT FIBRES THROUGHOUT
				■		0.5	▨	CL-CH	SILTY CLAY: medium to high plasticity, orange brown mottled red brown and grey. with a trace of fine grained sand and root fibres.				
				■		1	▨	CL	SILTY CLAY: medium plasticity, mottled yellow and orange brown and pale grey, with fine grained rand.	MC>PL			BLACK STAINING APPARENT – POSSIBLY ROOT FIBRES.
				■		1.5	▨		as above. but no black staining.				
						2 2.5 3 3.5			END OF TEST PIT AT 1.6m				

TEST PIT LOG

Test Pit No.
204 1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS, NSW.

Job No. E13431F
Method: 4WD BACKHOE
R.L. Surface: N/A
Date: 13-4-00
Datum:
Logged/Checked by: J.R./

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0			TOPSOIL: Clayey silt, low to medium plasticity. dark brown. with a trace of fine grained sand.	MC=PL			ROOT FIBRES THROUGHOUT
								CL-CH	SILTY CLAY: medium to high plasticity, brown mottled red brown. with fine grained sand and a trace of rootlets.	MC>PL	–	–	
						0.5							
									as above, but grey mottled red and yellow brown, with fine grained sand and a trace of black staining.	MC<PL			
						1							
									as above. but with a trace of fine grained ironstone gravel, black staining increasing with depth.				
						1.5							
									END OF TETS PIT AT 1.6m				
						2							
						2.5							
						3							
						3.5							

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TEST PIT LOG

Test Pit No.
205 1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS, NSW.

Job No. E13431F
Method: 4WD BACKHOE
R.L. Surface: N/A
Date: 13-4-00
Datum:
Logged/Checked by: J.R./

Groundwater Record	SAMPLES ES U50 DB DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION			0			TOPSOIL: Clayey silt. low plasticity, brown.	MC>PL			ROOT FIBRES THROUGHOUT
					CH	SILTY CLAY: high plasticity. red brown mottled grey brown. with fine grained sand and a trace of rootlets and fine grained ironstone gravel.	MC>PL	–	–	–
			0.5			SILTY CLAY: high plasticity. gale grey mottled yellow rown, with bands of fine to coarse qrained ironstone grovel.	MC<PL			
			1			as above, but with bands of ironstained shale, distinctly weathered, increasing with depth.	MC<PL			
			1.5							
			2							
						END OF TETS PIT AT 2.2m				
			2.5							
			3							
			3.5							

TEST PIT LOG

Test Pit No.
206 1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS, NSW.

Job No. E13431F
Method: 4WD BACKHOE
R.L. Surface: N/A
Date: 13-4-00
Datum:

Logged/Checked by: J.R./

Groundwater Record	SAMPLES ES U50 DB DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION			0		SC	SILTY CLAYEY SAND: fine to medium grained, mottled red brown and yellow brown.	D			ROOT FIBRES THROUGHOUT
			0.5		CH	SILTY CLAY: high plasticity, red brown mottled grey and yellow brown, with fine grained sand and ironstone gravel and a trace of fine grained sand and rootlets	MC<PL			
			1			as above. but pale grey mottled red and yellow, with bands of ironstone grovel and fine grained sand.				PATCHY BLACK STAINING – POSSIBLY ROOT FIBRES.
			1.5			as above. but with bands of ironstained shale, distinctly weathered. increasing with depth.	MC<PL			
			2							
						END OF BOREHOLE AT 2.2m				
			2.5							
			3							
			3.5							

TEST PIT LOG

Test Pit No.
207 1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS, NSW.

Job No. E13431F
Method: 4WD BACKHOE
R.L. Surface: N/A
Date: 13-4-00
Datum:
Logged/Checked by: J.R./

Groundwater Record	SAMPLES ES U50 DB DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION			0			TOPSOIL: Clayey silt, low plasticity, brown.	MC<PL			ROOT FIBRES THROUGHOUT
			0.5		CL–CH	SILTY SANDY CLAY: medium to high plasticity, brown mottled red and orange brown, fine grained sand and a trace of fine to medium grained ironstone grovel and rootlets.	MC<<PL	–	–	PATCHES OF BLACK STAINING POSSIBLY ROOT FIBRES.
			1			as above. but yellow brown mottled brown and pale grey. with bands of iron indurated gravel and black staining.	MC=PL			
			1.5 2			as above. but no iron induration.				
			2.5			as above, but pole grey mottled yellow brown, with increasing black staining.	MC>PL			
			3 3.5			END OF TETS PIT AT 1.6m				

TEST PIT LOG

Test Pit No.
208 1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS, NSW.

Job No. E13431F
Method: 4WD BACKHOE
R.L. Surface: N/A
Date: 13-4-00
Datum:
Logged/Checked by: J.R./4

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0			FILL: Silty clay, medium to high plasticity, pale grey mottled red. orange and yellow brown. with a trace of ash.	MC=PL			
								CL-CH	SILTY CLAY: medium to high plasticity, mottled red brown. with fine grained sand and a trace of rootlets.	MC<PL	–	–	
						0.5							
									as above, but high plasticity, yellow brown mottled brown, with a trace of fine grained ironstone gravel	MC=PL			PATCHY BLACK STAINING – POSSIBLY ROOT FIBRES.
						1			as above, but mottled red brown yellow brown and grey, with black staining, a trace of fine to medium grained ironstone gravel and rootlets.	MC>PL			
						1.5		CL-CH	SILTY SANDY CLAY: medium to high plasticity, yellow brown. mottled red brown, with black staining, fine grained sand and a trace of fine to medium grained sandstone gravel.	MC>PL			
						2							
						2.5							
									END OF TEST PIT AT 2.8m				
						3							
						3.5							

TEST PIT LOG

Test Pit No.
209 1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS, NSW.

Job No. E13431F
Date: 13-4-00
Method: 4WD BACKHOE
R.L. Surface: N/A
Datum:
Logged/Checked by: J.R./

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0			TOPSOIL: Clayey silt, law plasticity, brown.	MC<PL			ROOT FIBRES THROUGHOUT
								CL-CH	SILTY SANDY CLAY: medium to high plasticity, mottled red and orange brown, with fine arained rand.	–	–	–	–
						0.5		CL	SILTY SANDY CLAY: medium plasticity, orange brown mottled red and ole brown, fine grained sand: with a trace of fine to medium grained ironstone gravel.	MC<PL			PATCHY BLACK STAINING – POSSIBLY ROOT FIBRES
						1			grading to SILTY SANDY CLAY: medium plasticity, mottled orange and red brown, fine to medium grained ironstained sand and ironstained sandstone fragments.	MC=PL			FISSURED CLAY BLOCKY IN NATURE. SANDSTONE FRAGMENTS INCREASING WITH DEPTH
						1.5		–	SANDSTONE: fine grained, light brown, with orange and red brawn mottling.	DW	–	–	
						2			END OF TEST PIT AT 2.0m				
						2.5							
						3							
						3.5							

TEST PIT LOG

Test Pit No.
210 1/1

Client: LEND LEASE DEVELOPMENT
Project: SOIL AND GROUNDWATER INVESTIGATION
Location: COMLAND, ST MARYS, NSW.

Job No. E13431F
Date: 13-4-00
Method: 4WD BACKHOE
Logged/Checked by: J.R./
R.L. Surface: N/A
Datum:

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0		SC	CLAYEY SANDY SILT: law plasticity, brown. fine grained rand.	MC<PL			
								CH	SILTY SANDY CLAY: high plasticity, red brown pale grey, fine grained sand, with a trace of fine grained ironstone gravel and rootlets.	MC=PL	–	–	–
						0.5			SILN SANDY CLAY: high plasticity, red brown mottled orange brown and pole grey.	MC<PL			
						1			as above, but with increasing bands of ironstained sandstone, distinctly weathered, fine grained.				
						1.5							
									END Of BOREHOLE AT 1.85m				
						2							
						2.5							
						3							
						3.5							

TABLE B
SUMMARY OF LABORATORY TEST DATA - SOILS
Particle Size Distribution Analysis

Location	Sample Depth	PARTICLE SIZE ANALYSIS (%) - hydrometer					
		CLAY	SILT	FINE SAND	COARSE SAND	TOTAL SAND	GRAVEL
TP202	0.5m	**33**	**15**	51	1	**52**	**0**
TP204	0.5m	**46**	**15**	35	2	**37**	**2**
TP206	0.5m	**56**	**21**	19	4	**23**	**<1**
TP207	0.5m	**37**	**17**	39	5	**44**	**2**
TP210	0.7m	**45**	**15**	39	1	**40**	**<1**

Explanation
clay: particle size <0.002mm
silt: particle size = 0.002-0.02mm
fine sand: particle size = 0.02-0.2mm
course sand: particle size = 0.2-2.0mm
gravel: particle size >2mm

TABLE C
SUMMARY OF LABORATORY TEST DATA - SOILS
Soil Chemisty -Cation Exchange Capacity and Dispersion%

Sample	D%	CEC (me/100g)					Exch Al
		CEC	Exch Na	Exch K	Exch Ca	Exch Mg	
TP202 (0.5m)	18	12.7	0.90	0.2	1.2	7.5	0.2
TP204(0.5m)	42	16.9	2.30	0.2	1.6	9.3	1.7
TP206(0.5m)	92	22.6	5.10	0.9	0.9	13.9	nd
TP207(0.5m)	40	12.5	1.30	0.2	1.3	7.2	0.6
TP210(0.7m)	83	26.4	5.80	0.5	0.9	15	1.7

Explanation to abbreviations

D%: Percentage Dispersion
CEC: Cation Exchange Concentration
Ca: Calcium
Mg: Magnesium
nd: Not detected
Na: Sodium
Al: Aluminium
me/100g: milliequivalents per 100g soil
K: Potassium

APPENDIX C

SOIL SERVICES
LAND AND WATER CONSERVATION

SOIL TEST REPORT

Scone Research Service Centre

REPORT NO: SCO99/547R1

REPORT TO:
J. Rosner
EIS-Environmental Investigation Services
39 Buffalo Road
GLADESVILLE 2111

REPORT ON: One Hundred and ten soil samples
Job No: E13431F

PRELIMINARY RESULTS ISSUED: 20 December, 1999

REPORT STATUS: Final

DATE REPORTED: 23 December, 1999

METHODS: Information on test procedures can be obtained from Scone Research Service Centre

TESTING CARRIED OUT ON SAMPLE AS RECENED.
THIS DOCUMENT MAY NOT BE REPRODUCED EXCEPT IN FULL.

GHolman

G. Holman
(Technical Officer)

Report No.: SCO99/547R1

Client Reference: J. Rosner
EIS-Environmental Investigation Services
39 Buffalo Road
GLADESVILLE 2111

Lab. No.	Method	C1A/4	C2B/3	C6A/2	P8A/2	P9B/2
	Sample Id.	EC (dS/m)	pH ($CaCl_2$)	OC (%)	D (%)	EAT
1.	E13431F TP 101 0.8-1m	0.24	3.9	0.14	87	2(3)
2.	E13431F TP 102 0.75-0.9m	0.05	4.3	0.52	21	3(1)
3.	E13431F TP 103 0.3-0.5m	0.06	4.8	0.49	68	2(3)
4.	E13431F TP 104 2.0-2.1m	0.09	4.8	0.11	29	5
5.	E13431F TP 105 0.75-0.9m	0.86	6.9	0.16	53	2(1)
6.	E13431F TP 106 0.75-0.9m	0.74	4.7	0.34	81	2(3)
7.	E13431F TP 107 0.75-0.95m	0.89	6.0	0.13	49	2(1)
8.	E13431F TP 108 0.75-0.9m	0.62	5.5	0.17	88	2(3)
9.	E13431F TP 109 0.3-0.5m	0.29	5.6	0.34	79	2(2)
10.	E13431F TP 110 0.75-0.9m	0.75	4.2	0.30	82	1
11.	E13431F TP 111 2m	0.91	4.7	0.09	61	2(2)
12.	E13431F TP 112 0.3-0.45m	0.09	4.4	0.39	51	2(1)
13.	E13431F TP 113 0.75m	0.10	4.5	0.56	62	2(1)
14.	E13431F TP 114 0.3-0.5m	0.25	4.3	0.45	71	2(2)
15.	E13431F TP 115 0.3-0.45m	0.32	4.0	0.29	38	3(2)
16.	E13431F TP 116 1.5-1.6m	0.14	4.4	0.08	81	2(3)
17.	E13431F TP 117 0.75m	0.22	4.1	0.29	33	2(1)
18.	E13431F TP 118 0.75-0.9m	0.79	4.0	0.23	0	6
19.	E13431F TP 119 0.75-0.9m	0.41	4.0	0.17	83	1
20.	E13431F TP 120 0.75-0.9m	0.64	4.0	0.21	34	3(1)
21.	E13431F TP 121 2m	0.58	4.2	0.15	62	6
22.	E13431F TP 122 2.0-2.15m	0.75	4.7	0.11	81	2(3)
23.	E13431F TP 123 0.75-0.9m	0.61	3.9	0.29	61	2(3)
24.	E13431F TP 124 0.75-0.9m	1.10	3.9	0.29	44	2(2)
25.	E13431F TP 125 2.0-2.1m	0.20	4.8	0.12	72	2(3)

GHolman

SOIL AND WATER TESTING LABORATORY
Scone Research Service Centre

Report No.: SCO99/547R1
Client Reference: J. Rosner
EIS-Environmental Investigation Services
39 Buffalo Road
GLADESVILLE 2111

Lab. No.	Method	P7B/1 Particle Size Analysis (%)						P7C/1 Particle Size Analysis (%) – Mechanical Dispersion					
	Sample Id.	c	s	vfs	cfs	cs	g	c	s	vfs	cfs	cs	g
1.	E13431F TP 101 0.8-1m	41	23	21	8	6	1	37	23	23	9	7	1
2.	E13431F TP 102 0.75-0.9m	33	13	24	12	15	3	24	15	26	13	19	3
3.	E13431F TP 103 0.3-0.5m	34	23	27	13	3	<1	27	25	32	12	4	<1
4.	E13431F TP 104 2.0-2.1m	44	16	24	13	3	<1	29	18	33	16	4	<1
5.	E13431F TP 105 0.75-0.9m	41	33	8	3	6	9	32	38	11	2	8	9
6.	E13431F TP 106 0.75-0.9m	49	27	15	6	2	1	42	32	17	6	2	1
7.	E13431F TP 107 0.75-0.95m	39	17	29	14	1	<1	30	22	29	18	1	<1
8.	E13431F TP 108 0.75-0.9m	34	30	25	10	1	0	28	34	27	10	1	0
9.	E13431F TP 109 0.3-0.5m	47	28	18	6	1	<1	37	34	19	8	2	<1
10.	E13431F TP 110 0.75-0.9m	53	27	13	5	2	<1	44	32	15	6	3	<1
11.	E13431F TP 111 2m	32	19	31	16	2	<1	25	21	36	15	3	<1
12.	E13431F TP 112 0.3-0.45m	31	18	26	13	6	6	26	19	27	15	7	6

GHolman.

Report No.: SCO99/547R1
Client Reference: J. Rosner
EIS-Environmental Investigation Services
39 Buffalo Road
GLADESVILLE 2111

Lab. No.	Method	P7B/1 Particle Size Analysis (%)						P7C/1 Particle Size Analysis (%) – Mechanical Dispersion					
	Sample Id.	c	s	vfs	cfs	cs	g	c	s	vfs	cfs	cs	g
13.	E13431F TP 113 0.75m	39	16	25	13	4	3	32	19	29	13	4	3
14.	E13431F TP 114 0.3-0.5m	44	27	15	6	5	3	38	31	17	5	6	3
15.	E13431F TP 115 0.3-0.45m	49	11	22	12	2	4	34	23	25	11	3	4
16.	E13431F TP 116 1.5-1.6m	37	25	24	11	3	0	31	29	27	9	4	0
17.	E13431F TP 117 0.75m	49	10	24	13	4	<1	30	25	27	15	3	<1
18.	E13431F TP 118 0.75-0.9m	57	13	18	7	3	2	28	42	19	6	3	2
19.	E13431F TP 119 0.75-0.9m	38	21	27	12	2	<1	32	21	33	12	2	<1
20.	E13431F TP 120 0.75-0.9m	54	17	15	6	5	3	35	32	19	6	5	3
21.	E13431F TP 121 2m	23	14	38	19	6	<1	13	20	39	22	6	<1
22.	E13431F TP 122 2.0-2.15m	42	21	24	11	2	<1	30	29	28	10	3	<1
23.	E13431F TP 123 0.75-0.9m	55	18	16	7	3	1	41	25	22	9	2	1
24.	E13431F TP 124 0.75-0.9m	49	20	12	5	3	11	41	27	14	4	3	11
25.	E13431F TP 125 2.0-2.1m	36	13	27	13	9	2	27	15	32	15	9	2

Report No.: SCO99/547R1

Client Reference: J. Rosner
EIS-Environmental Investigation Services
39 Buffalo Road
GLADESVILLE 2111

Lab. No.	Method	C1A/4	C2B/3	C5A/3 CEC & exch. cations (me/100g)						C8A/2	P9B/2
	Sample Id.	EC (dS/m)	pH $(CaCl_2)$	CEC	Na	K	Ca	Mg	Al	P (mg/kg)	EAT
26.	E13431F A surface	0.04	4.3	7.3	0.1	0.5	1.6	3.4	0.1	nt	8/3(2)
27.	E13431F B surface	0.10	4.7	18.9	0.2	1.3	6.2	7.5	0.1	nt	8/3(2)
28.	E13431F B 30cm	0.20	4.2	20.7	1.2	0.3	2.4	11.5	1.0	nt	2(1)
29.	E13431F C surface	0.10	4.5	12.9	0.3	0.5	3.4	5.7	0.1	nt	3(3)
30.	E13431F C 30cm	0.31	4.7	17.6	2.3	0.2	1.9	9.1	nd	nt	2(3)
31.	E13431F 101 0-12cm	0.08	4.2	7.7	0.2	0.4	2.0	2.4	1.1	1	3(1)
32.	E13431F 101 30cm	0.06	4.0	17.8	1.7	0.1	0.5	9.0	2.0	nt	3(1)
33.	E13431F 101 1m	0.21	3.8	18.1	2.4	0.3	0.7	8.1	2.1	nt	nt
34.	E13431F 102 0-10cm	0.06	4.4	12.4	0.1	0.4	3.7	5.0	0.2	nt	8/3(1)
35.	E13431F 102 30cm	0.09	4.7	15.0	0.3	0.3	7.8	4.1	nd	nt	3(1)
36.	E13431F 102 1m	0.08	4.3	27.8	1.7	0.6	7.8	12.6	0.2	nt	nt
37.	E13431F 103 0-20cm	0.05	4.6	11.5	0.5	0.1	3.1	5.3	nd	nt	3(3)

nd = not detected, nt = not tested

GHolman.

Report No.: SCO99/547R1
Client Reference: J. Rosner
EIS-Environmental Investigation Services
39 Buffalo Road
GLADESVILLE 2111

Lab. No.	Method	C1A/4	C2B/3	C5A/3 CEC & exch. cations (me/100g)						C8A/2	P9B/2
	Sample Id.	EC (dS/m)	pH ($CaCl_2$)	CEC	Na	K	Ca	Mg	Al	P (mg/kg)	EAT
38.	E13431F 103 40-50cm	0.29	4.3	17.5	2.9	0.1	0.9	9.3	nd	nt	1
39.	E13431F 103 1m	0.79	4.7	14.9	2.8	0.2	1.6	6.7	nd	nt	nt
40.	E13431F 104 0-3cm	0.12	4.4	13.7	0.4	1.0	3.8	6.8	nd	nt	3(2)
41.	E13431F 104 30cm	0.12	4.2	17.8	1.2	0.3	5.1	7.9	0.4	nt	3(3)
42.	E13431F 104 1m	0.10	4.1	15.7	0.6	0.4	3.3	7.3	0.4	nt	5
43.	E13431F 105 0-6cm	0.06	4.4	17.0	0.5	0.5	6.5	5.7	0.1	nt	8/3(2)
44.	E13431F 105 30cm	0.15	5.2	23.7	2.7	0.4	8.5	8.8	nd	nt	2(1)
45.	E13431F 105 1m	0.97	6.0	37.0	6.6	1.6	9.1	15.3	nd	nt	nt
46.	E13431F 106 0-7cm	0.10	5.4	15.6	0.3	0.7	3.5	7.5	nd	nt	3(3)
47.	E13431F 106 30cm	0.16	4.7	18.9	1.2	0.4	2.4	9.9	0.5	nt	2(1)
48.	E13431F 106 1m	0.84	4.1	23.1	4.1	1.4	0.8	11.1	0.9	nt	nt
49.	E13431F 107 0-20cm	0.07	4.3	20.5	0.3	0.6	8.3	7.3	nd	<1	8/3(3)

nd = not detected; nt = not tested

Report No.: SCO99/547R1

Client Reference: J. Rosner
EIS-Environmental Investigation Services
39 Buffalo Road
GLADESVILLE 2111

Lab. No.	Method	C1A/4	C2B/3	C5A/3 CEC & exch. cations (me/100g)						C8A/2	P9B/2
	Sample Id.	EC (dS/m)	pH (CaCl$_2$)	CEC	Na	K	Ca	Mg	Al	P (mg/kg)	EAT
50.	E13431F 107 75cm	0.82	5.2	28.5	3.3	0.7	10.2	10.3	nd	nt	nt
51.	E13431F 107 100-110cm	0.92	5.5	26.2	2.8	0.6	9.0	9.2	nd	nt	nt
52.	E13431F 108 0-8cm	0.07	4.1	7.5	0.1	0.2	1.9	3.1	0.5	nt	8/3(1)
53.	E13431F 108 30cm	0.09	4.3	15.9	1.0	0.2	1.7	8.8	0.5	nt	2(2)
54.	E13431F 108 100cm	0.72	4.7	18.8	3.6	0.3	1.4	9.0	nd	nt	nt
55.	E13431F 109 0-16cm	0.06	4.1	10.7	0.2	0.3	2.8	5.3	0.2	nt	3(3)
56.	E13431F 109 30cm	0.07	4.3	15.9	0.5	0.2	2.9	8.9	nd	nt	3(3)
57.	E13431F 109 1m	0.78	4.5	24.9	2.9	0.4	3.5	12.8	0.2	nt	nt
58.	E13431F 110 0-8cm	0.06	4.5	15.0	0.2	0.7	6.2	4.7	0.3	1	8/3(1)
59.	E13431F 110 30cm	0.13	4.5	27.6	1.2	0.2	9.4	10.9	0.6	nt	2(1)
60.	E13431F 110 1m	0.85	4.1	27.8	3.3	0.9	3.3	11.2	2.7	nt	nt
61.	E13431F 111 0-7cm	0.08	4.3	16.7	0.3	0.5	4.9	7.1	0.1	nt	3(3)

nd = not detected; nt = not tested

Report No.: SCO99/547R1

Client Reference: J. Rosner
EIS-Environmental Investigation Services
39 Buffalo Road
GLADESVILLE 2111

Lab. No.	Method	C1A/4	C2B/3	C5A/3 CEC & exch. cations (me/100g)						C8A/2	P9B/2
	Sample Id.	EC (dS/m)	pH $(CaCl_2)$	CEC	Na	K	Ca	Mg	Al	P (mg/kg)	EAT
62.	E13431F 111 30cm	0.54	3.9	22.0	1.9	0.2	1.9	10.6	2.3	nt	2(2)
63.	E13431F 111 1m	0.87	4.2	22.1	2.3	0.2	1.7	11.1	1.6	nt	8/6
64.	E13431F 112 0-10cm	0.06	4.2	16.7	0.2	0.7	4.5	6.7	0.1	1	3(2)
65.	E13431F 112 30cm	0.12	4.2	22.9	1.5	0.3	2.1	11.4	1.9	nt	2(1)
66.	E13431F 112 1m	1.07	4.2	25.6	3.6	0.7	1.8	12.8	1.0	nt	nt
67.	E13431F 113 0-5cm	0.10	4.3	16.4	0.2	1.0	5.2	6.1	0.2	nt	8/3(1)
68.	E13431F 113 30cm	0.09	4.5	23.0	1.0	0.5	3.1	13.2	0.2	nt	2(1)
69.	E13431F 114 0-20cm	0.06	4.3	22.7	0.4	0.9	3.8	12.0	0.3	1	8/3(3)
70.	E13431F 114 53-73cm	0.36	4.1	24.2	3.1	1.2	1.2	12.4	1.9	nt	2(3)
71.	E13431F 114 1m	0.56	4.1	23.8	3.2	1.7	0.9	12.1	1.4	nt	nt
72.	E13431F 115 0-14cm	0.05	4.1	8.9	0.1	0.3	2.1	4.0	0.1	nt	8/3(2)
73.	E13431F 115 30cm	0.18	3.9	23.1	1.9	0.3	1.7	9.2	5.4	nt	3(1)

nt = not tested

Report No.: SCO99/547R1
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39 Buffalo Road
GLADESVILLE 2111

Lab. No.	Method	C1A/4	C2B/3	C5A/3 CEC & exch. cations (me/100g)						C8A/2	P9B/2
	Sample Id.	EC (dS/m)	pH ($CaCl_2$)	CEC	Na	K	Ca	Mg	Al	P (mg/kg)	EAT
74.	E13431F 115 90-100cm	0.69	3.9	22.7	4.2	0.9	1.1	10.3	2.4	nt	nt
75.	E13431F 116 0-10cm	0.06	4.4	9.4	0.1	0.3	3.8	2.7	0.1	nt	8/3(1)
76.	E13431F 116 30cm	0.04	4.4	6.6	0.1	0.2	1.7	2.5	0.1	nt	8/3(2)
77.	E13431F 116 1m	0.08	4.4	18.0	1.7	0.2	1.1	10.8	0.1	nt	5
78.	E13431F 117 0-17cm	0.04	3.9	10.2	0.1	0.3	1.7	5.1	0.8	<1	3(2)
79.	E13431F 117 30cm	0.04	4.3	7.9	0.3	0.1	2.1	3.2	0.2	nt	3(3)
80.	E13431F 117 1m	0.52	3.9	23.9	4.3	0.3	1.6	11.7	1.9	nt	nt
81.	E13431F 118 0-5cm	0.09	4.2	15.5	0.5	0.5	3.7	6.3	0.5	nt	8/3(1)
82.	E13431F 118 30cm	0.19	4.5	11.3	1.0	0.1	1.6	5.1	0.2	nt	3(3)
83.	E13431F 118 1m	0.92	4.2	23.5	4.1	0.1	1.6	12.1	0.5	nt	nt
84.	E13431F 119 0-8cm	0.09	4.1	11.6	0.2	0.6	2.7	4.4	0.1	1	8/3(1)
85.	E13431F 119 30cm	0.07	4.1	10.3	0.2	0.2	1.7	5.0	0.3	nt	3(1)

nt = not tested

GHolman.

SOIL AND WATER TESTING LABORATORY
Scone Research Service Centre

Report No.: SCO99/547R1
Client Reference: J. Rosner
EIS-Environmental Investigation Services
39 Buffalo Road
GLADESVILLE 2111

Lab. No.	Method	C1A/4	C2B/3	C5A/3 CEC & exch. cations (me/100g)						C8A/2	P9B/2
	Sample Id.	EC (dS/m)	pH $(CaCl_2)$	CEC	Na	K	Ca	Mg	Al	P (mg/kg)	EAT
86.	E13431F 119 1m	0.90	4.1	16.9	2.7	0.2	1.2	9.1	0.3	nt	nt
87.	E13431F 120 0-12cm	0.07	4.1	13.5	0.3	0.4	2.9	6.2	0.3	nt	3(2)
88.	E13431F 120 30cm	0.19	4.0	22.4	1.7	0.2	1.7	10.7	2.9	nt	3(2)
89.	E13431F 120 1m	0.54	4.1	23.1	4.1	0.4	1.2	11.5	1.2	nt	nt
90.	E13431F 121 surface	0.06	4.4	14.7	0.1	0.5	3.9	6.2	0.1	nt	3(3)
91.	E13431F 121 30cm	0.08	4.5	14.7	0.6	0.2	2.9	6.7	0.1	nt	2(1)
92.	E13431F 121 1m	0.14	4.6	16.3	2.1	0.2	1.6	8.6	nd	nt	2(2)
93.	E13431F 122 0-20cm	0.05	4.6	11.4	0.2	0.3	5.0	3.6	nd	nt	8/3(1)
94.	E13431F 122 90-110cm	0.56	4.5	20.4	3.2	0.3	1.1	10.9	nd	nt	1
95.	E13431F 122 2-2.15m	0.76	4.8	22.3	4.0	0.6	1.3	11.7	nd	nt	1
96.	E13431F 123 0-7cm	0.07	4.5	21.2	0.4	0.7	6.1	8.5	0.2	nt	8/3(3)
97.	E13431F 123 30cm	0.12	4.4	23.4	1.5	0.3	4.9	10.7	1.1	nt	3(3)

nd = not detected; nt = not tested

GHolman

Report No.: SCO99/547R1
Client Reference: J. Rosner
EIS-Environmental Investigation Services
39 Buffalo Road
GLADESVILLE 2111

Lab. No	Method	C1A/4	C2B/3	C5A/3 CEC & exch cations (me/100g)						C8A/2	P9B/2
	Sample Id	EC (dS/m)	pH ($CaCl_2$)	CEC	Na	K	Ca	Mg	Al	P (mg/kg)	EAT
98.	E13431F 123 1m	0.88	3.8	28.2	4.7	0.4	1.0	12.1	3.6	nt	nt
99.	E13431F 124 0-8cm	0.08	4.0	13.8	0.2	0.6	2.9	5.0	1.2	1	3(1)
100.	E13431F 124 30cm	0.19	4.0	19.0	1.4	0.3	1.7	9.1	2.0	nt	2(1)
101.	E13431F 124 1m	1.08	3.9	30.0	5.4	0.7	1.1	13.9	2.3	nt	1
102.	E13431F 125 0-6cm	0.50	4.5	18.7	0.9	0.4	5.0	7.7	0.1	nt	8/3(1)
103.	E13431F 125 30cm	0.23	4.2	8.3	0.4	0.2	1.1	4.8	0.7	nt	5
104.	E13431F 125 1m	0.17	5.0	16.2	2.7	0.3	0.8	10.9	nd	nt	nt
105.	E13431F A1 0-20cm	0.05	4.2	7.3	0.2	0.2	2.0	3.2	nd	nt	8/3(1)
106.	E13431F A1 70-80cm	0.19	4.5	11.8	2.4	0.4	0.5	7.4	nd	nt	1
107.	E13431F A2 0-20cm	0.07	4.3	14.2	0.7	0.6	3.1	8.4	0.6	nt	8/3(3)
108.	E13431F A2 65-75cm	0.72	3.9	28.3	3.8	0.9	0.9	16.7	2.7	nt	2(3)
109	E13431F A3 0-20cm	0.07	4.2	14.2	0.3	1.1	5.2	5.2	0.2	nt	3(3)
110.	E13431F A3 80cm	0.46	4.4	23.8	1.9	0.9	7.0	12.2	nd	nt	nt

nd = not detected; nt = not tested

GHolman.

Report No.: SCO99/547R1
Client Reference: J. Rosner
EIS-Environmental Investigation Services
39 Buffalo Road
GLADESVILLE 2111

Lab. No.	Method	C3A/3	P14B/1
	Sample Id.	Lime Requ. to pH 6.5 ($CaCO_3$kg/t)	BD (Mg/m^3)
26.	E13431F A surface	2.15	nt
28.	E13431F B 30cm	3.44	nt
30.	E13431F C 30cm	na	nt
32.	E13431F 101 30cm	1.46	nt
35.	E13431F 102 30cm	0.87	nt
37.	E13431F 103 0-20cm	nt	1.61
38.	E13431F 103 40-50cm	0.91	nt
41.	E13431F 104 30cm	1.41	nt
47.	E13431F 106 30cm	1.74	1.82
52.	E13431F 108 0-8cm	2.06	nt
53.	E13431F 108 30cm	0.50	1.78
56.	E13431F 109 30cm	0.41	1.68
59.	E13431F 110 30cm	1.34	1.74
62.	E13431F 111 30cm	2.58	nt
65.	E13431F 112 30cm	2.09	nt
68.	E13431F 113 30cm	1.00	nt
69.	E13431F 114 0-20cm	2.65	nt

na = not applicable
nt = not tested

GHolman

Report No.: SCO99/547R1

Client Reference: J. Rosner
EIS-Environmental Investigation Services
39 Buffalo Road
GLADESVILLE 2111

Lab. No.	Method	C3A/3	P14B/1
	Sample Id.	Lime Requ. to pH 6.5 ($CaCO_3$kg/t)	BD (Mg/m^3)
'73.	E13431F 115 30cm	4.31	nt
76.	E13431F 116 30cm	0.34	nt
79.	E13431F 117 30cm	na	nt
82.	E13431F 118 30cm	1.32	1.87
85.	E13431F 119 30cm	2.23	na
88.	E13431F 120 30cm	2.76	nt
91.	E13431F 121 30cm	0.34	nt
97.	E13431F 123 30cm	1.42	nt
100.	E13431F 124 30cm	2.37	1.81
103.	E13431F 125 30cm	1.75	nt
106.	E13431F A1 70-80cm	0.34	nt
108.	E13431F A2 65-75cm	3.24	nt

na = not applicable
nt = not tested

GHolman.

END OF TEST REPORT

Department of Land and Water Conservation
Soil and Water Testing Laboratory

Laboratory No.: SCO99547/R1

Client: J. Rosner
EIS-Environmental Investigation Services
39 Buffalo Road
GLADESVILLE 2111

Job No: E13431F

Scope: Soil erodibilty

Interpretation:

Table 1. Soil erodility factor (K).

Lab. No.	Sample Id.	K		K	
		1st approx.	Rating	SS & PP	Rating
1.	E13431F TP 101 0.8-1m	0.029	moderate	0.047	high
2.	E13431F TP 102 0.75-0.9m	0.030	moderate	0.040	high
3.	E13431F TP 103 0.3-0.5m	0.041	high	0.060	high
4.	E13431F TP 104 2.0-2.1m	0.037	moderate	0.048	high
5.	E13431F TP 105 0.75-0.9m	0.034	moderate	0.052	high
6.	E13431F TP 106 0.75-0.9m	0.027	moderate	0.046	high
7.	E13431F TP 107 0.75-0.95m	0.037	moderate	0.055	high
8.	E13431F TP 108 0.75-0.9m	0.046	high	0.064	very high
9.	E13431F TP 109 0.3-0.5m	0.033	moderate	0.051	high
10.	E13431F TP 110 0.75-0.9m	0.025	moderate	0.044	high
11.	E13431F TP 111 2m	0.045	high	0.064	very high
12.	E13431F TP 112 0.3-0.45m	0.033	moderate	0.052	high
13.	E13431F TP 113 0.75m	0.031	moderate	0.049	high
14.	E13431F TP 114 0.3-0.5m	0.028	moderate	0.047	high
15.	E13431F TP 115 0.3-0.45m	0.031	moderate	0.042	high
16.	E13431F TP 116 1.5-1.6m	0.040	high	0.059	high
17.	E13431F TP 117 0.75m	0.037	moderate	0.052	high
18.	E13431F TP 118 0.75-0.9m	0.046	high	0.057	high
19.	E13431F TP 119 0.75-0.9m	0.038	moderate	0.056	high
20.	E13431F TP 120 0.75-0.9m	0.033	moderate	0.048	high
21.	E13431F TP 121 2m	0.055	high	0.070	very high
22.	E13431F TP 122 2.0-2.15m	0.042	high	0.060	very high
23.	E13431F TP 123 0.75-0.9m	0.027	moderate	0.045	high
24.	E13431F TP 124 0.75-0.9m	0.023	moderate	0.038	moderate
25.	E13431F TP 125 2.0-2.1m	0.035	moderate	0.053	high

Department of Land and Water Conservation
Soil and Water Testing Laboratory

The 1st approximation of K is calculated from the laboratory data, Particle size analysis – mechanical dispersion and organic carbon (OC).

The 2nd K value is derived from the 1" approximation of K, soil structure (SS) and profile permeability(PP).

The ratings are as follows -

Low: less than 0.02
Moderate: 0.02 to 0.04
High: 0.04 to 0.06
Very high: greater than 0.06

This interpretation is based on:

1. the samples supplied being representative,
2. literature guidelines.

SRYoung

Stephen Young
Laboratory **Manager**
Scone Research Service Centre
3 March, 2000

JF

SOIL SERVICES
LAND AND WATER CONSERVATION

SOIL TEST REPORT

Scone Research Service Centre

REPORT NO: SCO99/547R2

REPORT TO:
J. Rosner
EIS-Environmental Investigation Services
39 Buffalo Road
GLADESVILLE 2111

REPORT ON:
Six soil samples
Job No.: E13431F

PRELIMINARY RESULTS ISSUED: Not issued

REPORT STATUS: Final

DATE REPORTED: 9 February, 2000

METHODS: Information on test procedures can be obtained from Scone Research Service Centre

TESTING CARRIED OUT ON SAMPLE AS RECEIVED.
THIS DOCUMENT MAY NOT BE REPRODUCED EXCEPT IN FULL.

G Holman

G. Holman
(Technical Officer)

SOIL AND WATER TESTING LABORATORY
Scone Research Service Centre

Report No.: SCO99/547R2

Page 2 of 2

Client Reference: J. Rosner
EIS – Environmental Investigation Services
39 Buffalo Road
GLADESVILLE 2111

Lab. No.	Method	P19A/2 Gypsum Requirement			
	Sample Id.	0%	0.2%	0.3%	0.4%
44.	E13431F 105 30cm	50	29	29	18
47.	E13431F 106 30cm	71	40	18	nt
62	E13431F 111 30cm	36	2	nt	nt
70.	E13431F 114 53-73cm	71	50	42	2
82.	E13431F 118 30cm	23	4	nt	nt
97.	E13431F 123 30cm	45	24	2	nt

nt = not tested

G Holman.

END OF TEST REPORT

NSW DEPARTMENT OF LAND AND WATER CONSERVATION

LAND & WATER CONSERVATION

FACSIMILE

TO Joanne Roener

FROM Glenda Holman

DATE 10/5/00 PAGES (including this one) 3

Scone Research Service Centre Gundy Road Scone NSW 2337
Telephone (02) 65451666 Facsimile (02) 65452520

SCO 00/152R1 preliminary test results.

Job No: E13431F

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT
SCONE RESEARCH SERVICE CENTRE
SOIL AND WATER TESTING LABORATORY

Laboratory No.: SCO~~92/~~ 00|152R1
Client: Joanne Rosner
Attention: Environmental Investigation Services
39 Buffalo Road
Gladesville 2111

Lab. No.	Method	P7B/1 Particle Size analysis(%)					P8A/2	P9B/2	P5A/1	P6A/1	P13A/3	C2A/3	C1A/4	P2B/1	P3A/1	P19A/2 Gypsum Requirement		
	Sample Id.	clay	silt	f.sand	c.sand	gravel	D%	EAT	VE%	LS%	USCS	pH	EC (dS/m)	LL%	PL%	0.2%	0.5%	1%
1	E13431F TP 202 0.5m	33	15	51	1	0	18											
2	E13431F TP 204 0.5m	46	15	35	2	2	42											
3	E13431F TP 206 0.5m	56	21	19	4	<1	92											
4	E13431F TP 207 0.5m	37	17	39	5	2	40					5.4	0.06					
5	E13431F TP 210 0.7m	45	15	39	1	<1	83											

Data Transcription

Checked:
Checked:

Report No: SCO 00/152R1
Client Reference: Joanne Rosner

Environmental Investigation Services
39 Buffalo Road
Gladesville 2111

	G5A/3					
ample	CEC & exch cations (me/100g)					
	CEC	Na	K	Ca	Mg	Al
1	12.7	0.9	0.2	1.2	7.5	0.2
2.	16.9	2.3	0.2	1.6	9.3	1.7
3.	22.6	5.1	0.9	0.9	13.9	nd
4.	12.5	1.3	0.2	1.3	7.2	0.6
5.	26.4	5.8	0.5	0.9	15.0	1.7

nd = not detected

23 -

A Commitment to Quality

ETRS Pty LM
A.C.N. 006 353 046
11-13 Byrne Street
Auburn NSW 2144
PO Box 6124
Silverwater DC
NSW 1811 Australia

Fax (02) 9647 2341
Phone (02) 9647 1077

REPORT NUMBER:	NA99-2144 (Page 1 of 6)
DATE RECEIVED:	24 November 1999

Environmental Investigation Services
39 Buffalo Road
GLADESVILLE NSW **2111**

ORDER NUMBER:	Chain - of - Custody Records	24.11.99
CLIENT CONTACT:	Mr E. Fletcher	
DESCRIPTION:	Analysis of (120) soil samples and three duplicate soil samples identified as project E13431F, St Marys. Samples transported in plastic bags placed in an esky cooled by ice. Analysed "as received".	
TEST METHODS:	Refer Page 2	
TEST RESULTS:	Refer Pages 3, 4, 5 and 6.	

Dr Rama Bhat
Manager Environmental Services
15112199

ISO9001:1994
Licence No. 7944
NCS International Pty Ltd

...../2

EIS Project: E13431F, St Marys.

Tests	Preparation	Analysis
Chloride	Water Exrtaction	NSW AES.030
pH	Calcium Chloride extraction (1:5)	APHA 4500 - H^+ B
Conductivity	Water Extraction (1:5)	BCRI
Sodium (Soluble)	Water Extraction	AAS, APHA 3111 - B

EIS Project No: E13431F, St Marys

TEST RESULTS: Measurements in mg/kg dry weight, except pH and Conductivity.

Sample ID	**BHP1 0-0.2**	**BHP1 0.2-0.5**	**BHP1 1.0-1.5**	**BHP1 4.0-4.5**	**BHP1 4.5-5.0**	**BHP1 5.5-6.0**	**BHP1 6.5-7.0**	**BHP1 7.5-8.0**
Chloride	241	285	-.-	-.-	-.-	-.-	-.-	-.-
pH	4.52	4.57	5.86	6.43	6.98	7.25	8.14	7.66
Conductivity (μS/cm)	225	275	1147	1076	1119	1059	1181	950
Sodium	390	245	-.-	-.-	-.-	-.-	-.-	-.-

Sample ID	**BHP1 8.5-9.0**	**BHG1 0-0.25**	**BHG1 0.25-0.5**	**BHG1 1.0-1.5**	**BHG1 2.0-2.5**	**BHG1 3.0-3.5**	**BHG1 5.5-6.0**	**BHP2D 0-0.25**
Chloride	-.-	241	372	942	-.-	-.-	-.-	2170
pH	7.96	4.16	3.96	3.86	7.92	7.85	8.52	5.48
Conductivity (μS/cm)	965	350	400	601	672	415	535	695
Sodium	-.-	380	515	2100	-.-	-.-	-.-	890

Sample ID	**BHP2D 0.25-0.5**	**BHP2D 1.0-1.5**	**BHP2D 2.5-3.0**	**BHP2D 3.0-3.45**	**BHP2D 4.0-4.5**	**BHP2D 5.0-5.5**	**BHP2D 6.0-6.5**	**BHP2D 6.5-7.0**
Chloride	899	1030	-.-	-.-	-.-	-.-	-.-	-.-
pH	5.31	3.84	4.03	4.63	4.11	4.79	5.69	5.25
Conductivity (μS/cm)	657	596	591	568	561	802	1082	1174
Sodium	1500	2580	-.-	-.-	-.-	-.-	-.-	-.-

Sample ID	**BHP2D 7.5-8.0**	**BHP2D 8.5-9.0**	**BHG2 0-0.2**	**BHG2 0.2-0.5**	**BHG2 1.0-1.5**	**BHG2 2.5-3.0**	**BHG2 3.0-3.45**	**BHG2 3.5-4.0**
Chloride	- -	- -	372	285	1074	- -	- -	- -
pH	5.61	5.43	4.49	4.48	6.07	7.57	5.85	5.79
Conductivity (μS/cm)	1269	2090	279	262	648	790	841	407
Sodium	- -	- -	230	265	2000	- -	- -	- -

NOTE: (a) Sampler will be disposed of thirty days after issue of this report unless otherwise notified.
(b) < Denotes 'less than'. -.-means tests not requested.

EIS Project No: E13431F, St Marys

TEST RESULTS: Measurements in mg/kg dry weight, except pH and Conductivity

Sample ID	BHG2 4.5-5.0	BHG2 5.5-6.0	BHP3D 0-0.1	BHP3D 0.3-0.5	BHP3D 1.0-1.5	BHP3D 2.5-3.0	BHP3D 3.0-3.5	BHP3D 4.0-4.5
Chloride	-.-	-.-	416	328	899	-.-	-.-	-.-
pH	7.38	8.77	6.22	6.54	4.44	4.30	4.53	4.72
Conductivity (μS/cm)	372	543	317	258	885	652	474	497
Sodium	-.-	-.-	190	220	1130	-.-	-.-	-.-

Sample ID	BHP3D 5.0-5.5	BHP3D 6.0-6.5	BHP3D 8.5-9.0	BHG3 0-0.2	BHG3 0.3-0.5	BHG3 1.0-1.5	BHG3 2.0-2.5	BHG3 2.5-3.0
Chloride	-.-	-.-	-.-	592	504	899	-.-	-.-
pH	5.25	5.16	6.82	4.13	3.58	3.53	4.48	4.95
Conductivity (μS/cm)	1198	1357	718	451	337	512	788	692
Sodium	-.-	-.-	-.-	130	200	700	-.-	-.-

Sample ID	BHG3 3.5-4.0	BHG3 4.7-5.0	BHG3 5.8-6.0	BHG3 6.8-7.0	BHG3 7.6-7.8	BHP4D 0-0.2	BHP4D 0.2-0.5	BHP4D 1.0-1.5
Chloride	-.-	-.-	-.-	-.-	-.-	241	635	1644
pH	4.53	5.60	5.96	6.18	7.01	4.94	6.20	4.38
Conductivity (μS/cm)	725	424	519	381	574	221	399	1155
Sodium	-.-	-.-	-.-	-.-	-.-	115	1030	4000

Sample ID	BHP4D 3.0-3.45	BHP4D 4.0-4.5	BHP4D 5.0-5.5	BHP4D 7.0-7.5	BHG4 0-0.1	BHG4 0.2-0.5	BHG4 1.0-1.5	BHG4 2.5-3.0
Chloride	-.-	-.-	-.-	-.-	1293	1732	1337	-.-
pH	4.33	5.12	6.17	7.29	4.57	4.51	5.42	4.93
Conductivity (μS/cm)	1510	1590	2150	2000	1027	1161	901	1026
Sodium	-.-	-.-	-.-	-.-	3500	2500	1700	-.-

NOTE:	(a)	Samples will be disposed of thirty days after issue of this report unless otherwise notified.
	(b)	< Denotes 'less than'. -.-means tests not requested.

EIS Project No: E13431F, St Marys

TEST RESULTS: Measurements in mg/kg dry weight, except pH and Conductivity

Sample ID	**BHG4 3.0-3.45**	**BHG4 4.0-4.5**	**BHG4 5.5-6.0**	**BHG4 6.0-6.5**	**BHG4 7.0-7.5**	**BHG4 8.5-9.0**	**BHP5D 0-0.2**	**BHP5D 0.2-0.5**
Chloride	-.-	-.-	-.-	-.-	-.-	-.-	197	241
pH	6.20	6.05	6.75	6.76	8.01	7.94	4.42	4.22
Conductivity (μS/cm)	878	1125	1134	1111	827	1920	224	220
Sodium	-.-	-.-	-.-	-.-	-.-	-.-	100	150

Sample ID	**BHP5D 1.0-1.5**	**BHP5D 1.5-1.95**	**BHP5D 2.0-2.5**	**BHP5D 2.5-2.95**	**BHP5D 3.0-3.5**	**BHP5D 4.0-4.5**	**BHP5D 5.0-5.5**	**BHG5 0-0.1**
Chloride	1293	-.-	-.-	-.-	-.-	-.-	-.-	153
pH	3.95	4.39	4.66	4.60	4.89	5.30	6.75	4.41
Conductivity (μS/cm)	851	1035	1125	966	1100	1125	1372	163
Sodium	1550	-.-	-.-	-.-	-.-	-.-	-.-	100

Sample ID	**BHG5 0.2-0.5**	**BHG5 1.0-1.5**	**BHG5 2.5-3.0**	**BHG5 3.0-3.45**	**BHG5 4.0-4.5**	**BHG5 5.0-5.5**	**BHG5 7.5-8.0**	**BHP6D 0-0.1**
Chloride	197	942	-.-	-.-	-.-	-.-	-.-	197
pH	4.38	4.71	4.42	4.40	4.11	5.50	7.99	4.52
Conductivity (μS/cm)	180	642	700	850	734	384	441	189
Sodium	100	1400	-.-	-.-	-.-	-.-	-.-	105

Sample ID	**BHP6D 0.2-0.5**	**BHP6D 1.0-1.5**	**BHP6D 2.5-3.0**	**BHP6D 3.0-3.45**	**BHP6D 3.5-4.0**	**BHP6D 4.5-5.0**	**BHP6D 5.5-6.0**	**BHP6D 7.5-8.0**
Chloride	241	1732	-.-	-.-	-.-	-.-	-.-	-.-
pH	4.31	4.03	4.30	4.07	4.61	6.08	8.07	7.85
Conductivity (μS/cm)	213	1212	1096	1644	1014	1349	1119	1342
Sodium	175	3800	-.-	-.-	-.-	-.-	-.-	--.

NOTE: (a) Samples will be disposed of thirty days after issue of this report unless otherwise notified.
(b) < Denotes less than', -.- means tests not requested.

REPORT NUMBER: NA99-2144
(Page 6 of 6)

EIS Project No: E13431F, St Marys

TEST RESULTS: Measurements in mg/kg dry weight, except pH and Conductivity.

Sample ID	**BHG6 0-0.1**	**BHG6 0.3-0.5**	**BHG6 1.0-1.5**	**BHG6 2.5-3.0**	**BHG6 3.0-3.45**	**BHG6 3.8-4.0**	**BHG6 4.8-5.0**	**BHG6 5.3-5.5**
Chloride	197	592	1030	-.-	-.-	-.-	-.-	-.-
pH	3.99	3.79	4.02	6.23	5.90	4.56	4.41	4.90
Conductivity (μS/cm)	172	486	880	1378	1487	922	784	783
Sodium	65	625	2180	-.-	-.-	-.-	-.-	-.-

Sample ID	**BHG6 5.8-6.0**	**BHG6 6.8-7.0**	**BHG6 7.8-8.0**	**BHG6 8.3-8.5**	**BHP7D 0-0.1**	**BHP7D 0.3-0.5**	**BHP7D 1.3-1.5**	**BHP7D 2.5-2.7**
Chloride	-.-	-.-	-.-	-.-	328	328	1030	-.-
pH	5.81	6.40	6.95	8.26	4.14	3.96	4.28	4.80
Conductivity (μS/cm)	460	597	775	562	290	318	962	800
Sodium	-.-	-.-	-.	-.-	90	105	2080	-.-

Sample ID	**BHP7D 2.7-3.0**	**BHP7D 3.0-3.45**	**BHP7D 4.0-4.3**	**BHP7D 5.0-5.3**	**BHP7D 6.0-6.3**	**BHP7D 7.0-7.3**	**BHP1 2.5-3.0**	**BHP1 3.0-3.45**
Chloride	-.-	-.-	-.-	-.-	-.-	-.-	-.-	-.-
pH	5.02	6.38	6.64	7.78	8.17	8.06	6.76	6.31
Conductivity (μS/cm)	918	783	749	1500	1921	1792	1503	1442
Sodium	-.-	-.-	-.-	-.-	-.-	-.-	-.-	-.-

Sample ID	**BHPZD dup 4.0-4.5**	**BHG6 dup 2.5-3.0**	**BHG6 dup 3.0-3.45**
Chloride	-.-	-.-	-.-
pH	4.74	4.25	4.13
Conductivity (μS/cm)	719	863	1004
Sodium	-.-	-.-	-.-

NOTE: (a) Samples will be disposed of thirty days after issue of this report unless otherwise notified.
(b) < Denotes 'less than', -.- means tests not requested.

Dr Rama Bhat
Manager Environmental Services
15/12/99

Ref No : E13431F
Table A: Page 1 of 1

TABLE A
SUMMARY OF LABORATORY TEST RESULTS

AS 1289	TEST METHOD	2.1.1	3.1.2	3.2.1	3.3.1	3.4.1
BOREHOLE NUMBER	SAMPLE DEPTH m	MOISTURE CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	PLASTICITY INDEX %	LINEAR SHRINKAGE %
BH G1	0.50 - 0.95	23.0	68	16	52	14½
BH G2	0.50 - 0.95	11.8	36	13	23	12
BH G4	0.50 - 0.95	20.0	36	13	23	11
BH G5	0.50 - 0.95	10.8	37	10	27	11½
BH G6	0.50 - 0.80	14.1	52	14	38	15½
BH P1D	0.50 - 0.95	16.5	31	13	18	8½
BH P2D	0.75 - 0.95	15.8	52	16	36	16½
BH P4D	0.50 - 0.95	23.4	55	11	44	15½
BH P5D	0.50 - 0.95	31.0	60	15	45	18
BH P6D	0.60 - 0.95	23.4	57	10	47	16½
BH P7D	0.50 - 0.95	16.5	57	11	46	16

Jeffery and Katauskas Pty Ltd
39 BUFFALO ROAD GLADESVILLE NSW 2111
LAB No. 1327

24/12/99
Authorised Signature

Ref NO : E13431F
Table B: Page 1 of 3

TABLE B
SUMMARY OF EMERSON CLASS NUMBER TEST RESULTS

BOREHOLE	DEPTH (m)	Air dried soil crumbs in water	Remoulded soil samples in water	Contact with hydrochloric acid	1:5 Soil/water suspension	Emerson class number
BH G1	0.50 - 0.95	Slaking Strong dispersion	NA	NA	NA	1
BH G2	0.50 - 0.95	Slaking Moderate dispersion	NA	NA	NA	2
BH G4	0.50 - 0.95	Slaking Strong dispersion	NA	NA	NA	1
BH G5	0.50 - 0.95	Slaking Strong dispersion	NA	NA	NA	1
BH G6	0.50 - 0.80	Slaking Strong dispersion	NA	NA	NA	1

24/12/99
Authorised Signature

TABLE B
SUMMARY OF EMERSON CLASS NUMBER TEST RESULTS

BOREHOLE	DEPTH (m)	Air dried soil crumbs in water	Remoulded soil samples in water	Contact with hydrochloric acid	1:5 Soil/water suspension	Emerson class number
BH P1D	0.50 - 0.95	Slaking Moderate dispersion	NA	NA	NA	2
BH P2D	0.75 - 0.95	Slaking Strong dispersion	NA	NA	NA	1
BH P3D	0.30 - 0.50	Slaking Strong dispersion	NA	NA	NA	1
BH P4D	0.50 - 0.95	Slaking Strong dispersion	NA	NA	NA	1
BH P5D	0.50 - 0.95	Slaking Slight dispersion	NA	NA	NA	2
BH P6D	0.65 - 0.95	Slaking Slight dispersion	NA	NA	NA	2

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TABLE B
SUMMARY OF EMERSON CLASS NUMBER TEST RESULTS

BOREHOLE	DEPTH (m)	Air dried soil crumbs in water	Remoulded soil samples in water	Contact with hydrochloric acid	1:5 Soil/water suspension	Emerson class number
BH P7D	0.00 - 0.20	Slaking Strong dispersion	NA	NA	NA	1
BH P7D	0.50 - 0.95	Slaking Strong dispersion	NA	NA	NA	1

NOTES:
- The lowest Emerson Class Number refers to the highest dispersion potential (Range: Class 1 to Class 8).
- The determination of the Emerson Class Number of a soil was completed in accordance with AS1289 3.8.11997.
- All contact water was distilled water; water temperature was 23°C.
- Water contact time was greater than 5 minutes for all test stages.
- Refer to the appropriate Borehole logs for soil descriptions.
- NA = Not Applicable.

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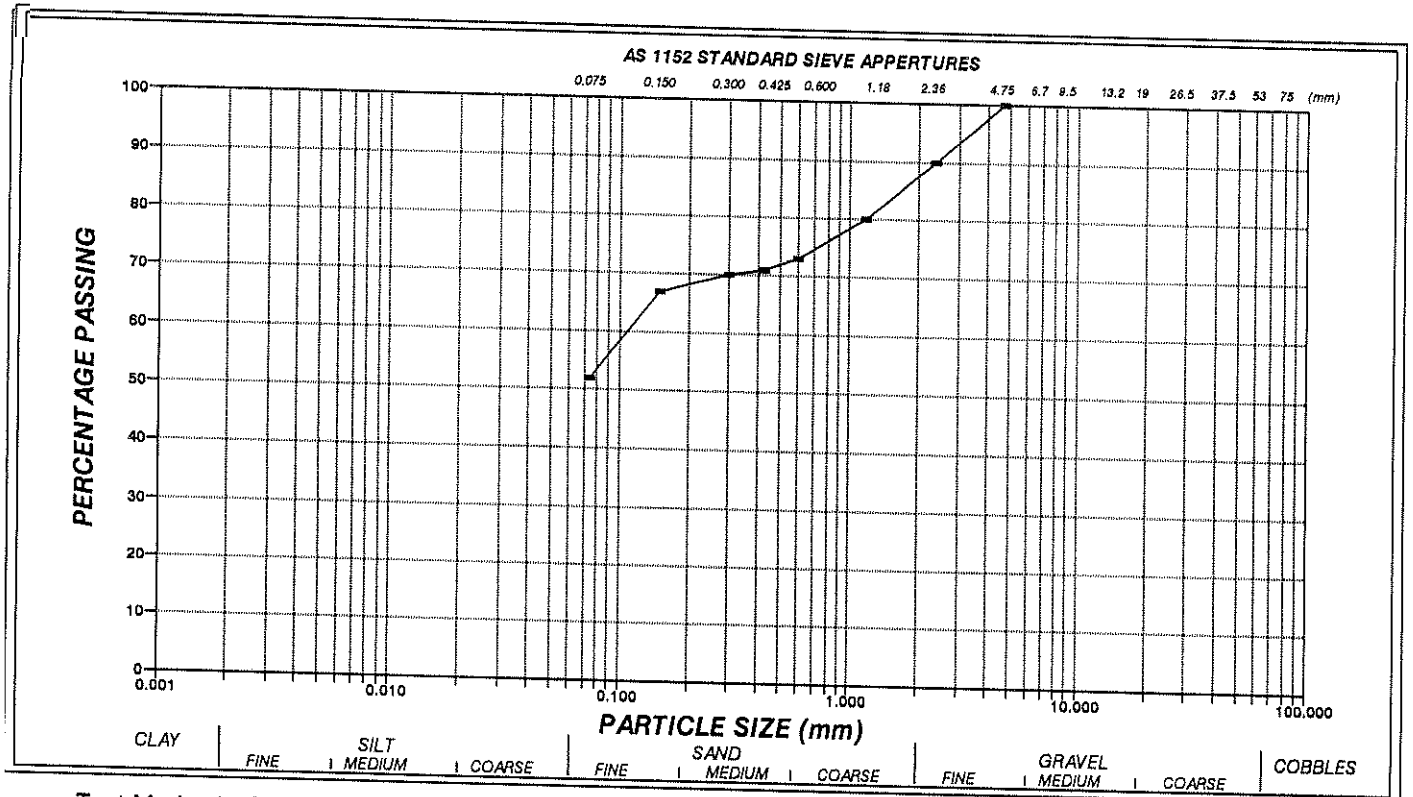

Test Method AS1289.3.6.1 Wet Sieve

PARTICLE SIZE DISTRIBUTION CURVE

SIEVE ANALYSIS RESULTS

SIEVE SIZE	% PASSING
4.75 mm	100
2.36 mm	90
1.18 mm	80
0.600 mm	73
0.425 mm	71
0.300 mm	70
0.150 mm	67
0.075 mm	52

JOB No: E13431F
BOREHOLE: BH 102
DEPTH: 0.75-0.90m

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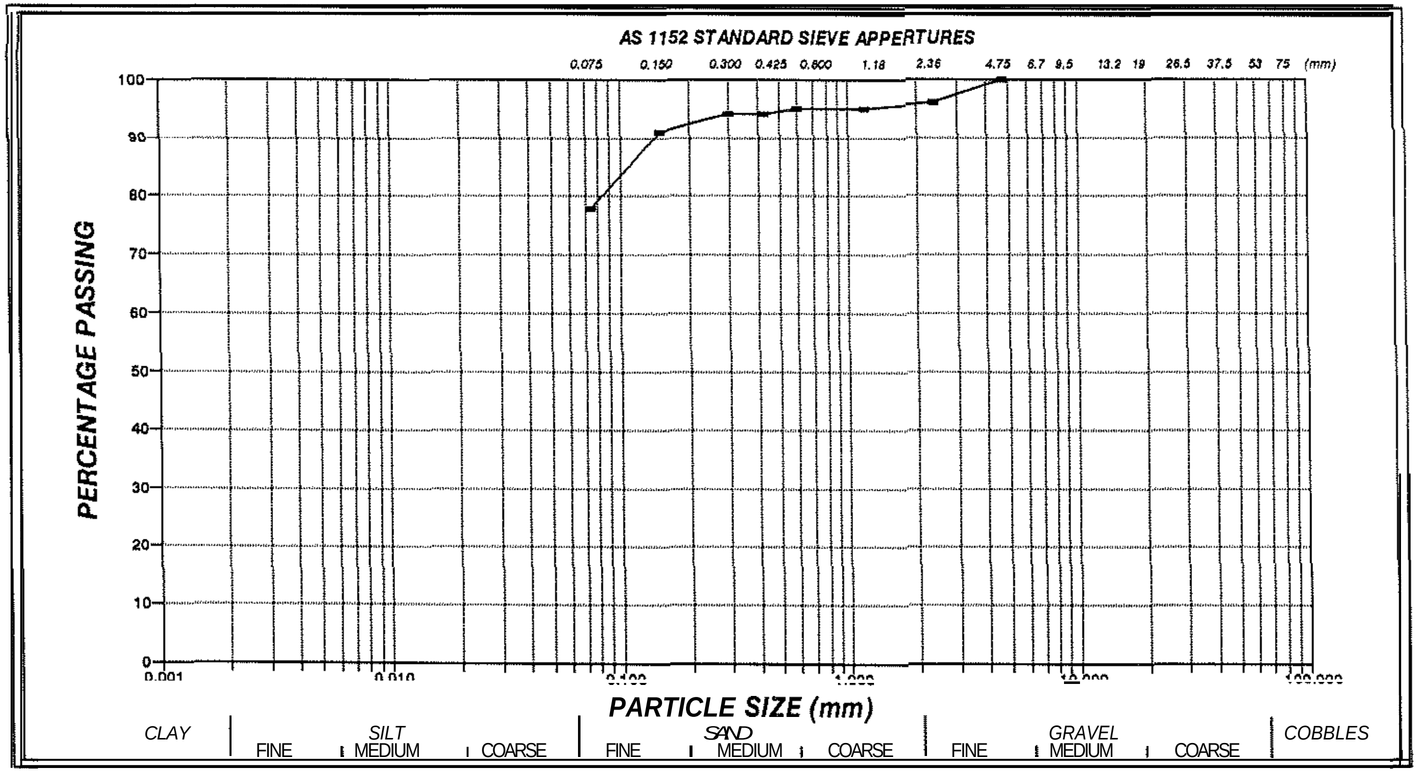

Test Method AS1289.3.6.1 *Wet Sieve*

PARTICLE SIZE DISTRIBUTION CURVE

SIEVE ANALYSIS RESULTS

SIEVE SIZE	% PASSING
4.75 mm	100
2.36 mm	96
1.18 mm	95
0.600 mm	95
0.425 mm	94
0.300 mm	94
0.150 mm	91
0.075 mm	78

JOB No: E13431F
TEST PIT: *TP* 125
DEPTH: 2.00-2.10m

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APPENDIX D

REPORT EXPLANATION NOTES

INTRODUCTION

These notes have been provided to amplify the geotechnical report in regard to classification methods, field procedures and certain matters relating to the Comments and Recommendations section. Not all notes are necessarily relevant to all reports.

The ground is a product of continuing natural and man-made processes and therefore exhibits a variety of characteristics and properties which vary from place to place and can change with time. Geotechnical engineering involves gathering and assimilating limited facts about these characteristics and properties in order to understand or predict the behaviour of the ground on a particular site under certain conditions. This report may contain such facts obtained by inspection, excavation, probing, sampling, testing or other means of investigation. If so, they are directly relevant only to the ground at the place where and time when the investigation was carried out.

DESCRIPTION AND CLASSIFICATION METHODS

The methods of description and classification of soils and rocks used in this report are based on Australian Standard 1726, the S.A.A. Site Investigation Code. In general, descriptions cover the following properties – soil or rock type, colour, structure, strength or density, and inclusions. Identification and classification of soil and rock involves judgement and the Company infers accuracy only to the extent that is common in current geotechnical practice.

Soil types are described according to the predominating particle size and behaviour as set out in the attached Unified Soil Classification Table qualified by the grading of other particles present (e.g. sandy clay) as set out below:

Soil Classification	Particle Size
Clay	less than 0.002mm
Silt	0.002 to 0.06mm
Sand	0.06 to 2mm
Gravel	2 to 60mm

Cohesive soils are classified on the basis of strength (consistency) either by use of hand penetrometer, laboratory testing or engineering examination. The strength terms are defined as follows.

Classification	Unconfined Compressive Strength kPa
Very Soft	less than 25
Soft	25 - 50
Firm	50 - 100
Stiff	100 - 200
Very Stiff	200 - 400
Hard	Greater than 400
Friable	Strength not attainable - soil crumbles.

Non-cohesive soils are classified on the basis of relative density, generally from the results of Standard Penetration Tests (S.P.T.) as below:

Relative Density	S.P.T. "N" Value (blows/300mm)
Very loose	less than 4
Loose	4 - 10
Medium dense	10 - 30
Dense	30 - 50
Very Dense	greater than 50

Rock types are classified by their geological names, together with descriptive terms regarding weathering, strength, defects, etc. Where relevant, further information regarding rock classification is given in the text of the report. In the Sydney Basin, "Shale" is used to describe thinly bedded to laminated siltstone.

SAMPLING

Sampling is carried out during drilling or from other excavations to allow engineering examination (and laboratory testing where required) of the soil or rock.

Disturbed samples taken during drilling provide information on plasticity, grain size, colour, moisture content, minor constituents and, depending upon the degree of disturbance, some information on strength and structure.

Undisturbed samples are taken by pushing a thin-walled sample tube, usually 50mm diameter (known as a U50), into the soil and withdrawing it with a sample of the soil contained in a relatively undisturbed state. Such samples yield information on structure and strength, and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Details of the type and method of sampling used are given on the attached logs.

INVESTIGATION METHODS

The following is a brief summary of investigation methods currently adopted by the Company and some comments on their use and application All except test pits, hand auger drilling and portable dynamic cone penetrometers require the use of a mechanical drilling rig which is commonly mounted on a truck chassis

Test Pits - These are normally excavated with a backhoe or a tracked excavator, allowing close examination of the in situ soils if it is safe to descend into the pit The depth of penetration is limited to about 3m for a backhoe and up to 6m for an excavator Limitations of test pits are the problems associated with disturbance and difficulty of reinstatement and the consequent effects on close-by structures Care must be taken if construction is to be made of the end bearing resistance on the cone and the frictional resistance on a separate 134mm long sleeve, immediately behind the cone Transducers in the tip of the assembly are electrically connected by wires passing through the centre of the push rods to an amplifier and recorder unit mounted on the control truck

As penetration occurs (at a rate of approximately 20mm per second) the information is output on continuouschart recorders The plotted results given in this report have been copied from the original records

The information provided on the charts comprises.

☐ Cone resistance - the actual end bearing force divided by the cross sectional area of the cone - expressed in MPa.

Sleeve friction - the frictional force on the sleeve divided by the surface area - expressed in kPa

☐ Friction ratio - the ratio of sleeve friction to cone resistance, expressed as a percentage

There are two scales available for measurement of cone resistance. The lower (A) scale (0 to 5 MPa) is used in softer soils where increased sensitivity is required. The main (B) scale has a range of 0 to 50 MPa.

The ratios of the sleeve resistance to cone resistance will vary with the type of soil encountered, with higher relative friction in clays than in sands. Friction ratios of 1% to 2% are commonly encountered in sands and occasionally very soft clays, rising to 4% to 10% in stiff clays and peats. Soil descriptions based on friction ratios are only inferred and must not be considered as exact.

Correlations between E.F.C.P. and S.P.T. values can be developed for both sands and clays but may be site specific.

Interpretation of E.F.C.P. values can be made to empirically derive modulus or compressibility values to allow calculation of foundation settlements.

Stratification can be inferred from the cone and friction traces and from experience and information from nearby boreholes etc. Where shown, this information is presented for general guidance, but must be regarded as interpretive. The test method provides a continuous profile of engineering properties but, where precise information on soil classification is required, direct drilling and sampling may be preferable.

Portable Dynamic Cone Penetrometers - Portable Dynamic Cone Penetrometer tests are carried out by driving a rod into the ground with a falling weight hammer and measuring the blows for successive 100mm increments of penetration

Two relatively similar tests are used:

Cone penetrometer (commonly known as the Scala Penetrometer) - a16mm rod with a 20mm diameter cone end is driven with a 9kg hammer dropping 510mm (AS 1289, Test F3 2) The test was developed initially for pavement subgrade investigations and correlations of the test results with California Bearing Ratio have been published by various Road Authorities

■ Perth sand penetrometer - a 16mm diameter flat ended rod is driven with a 9kg hammer dropping 600mm (AS 1289, Test F3 3) This test was developed for testing the density of sands (originating in Perth) and is mainly used in granular soils and filling

LOGS

The borehole or test pit logs presented herein are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on the frequency of sampling and the method of drilling or excavation Ideally. continuous undisturbed sampling or core drilling will enable the most reliable assessment, but is not always practicable or possible to justify on economic grounds In any case the boreholes or test pits represent only a very small sample of the total subsurface conditions

The attached explanatory notes define the terms and symbols used in preparation of the logs

Interpretation of the information shown on the logs and its application to design and construction. should therefore take into account the spacing of boreholes or test pits, the method of drilling or excavation, the frequency of sampling and testing and the possibility of other than "straight line" variations between the boreholes or test pits Subsurface conditions between boreholes or test pits may vary significantly from conditions encountered at the borehole or test pit locations

GROUNDWATER

Where groundwater levels are measured in boreholes, there are several potential problems

☐ Although groundwater may be present, in low permeability soils it may enter the hole slowly or perhaps not at all during the time it is left open

☐ A localised perched water table may lead to an erroneous indication of the true water table

☐ Water table levels will vary from time to time with Seasons or recent weather changes and may not be the same at the time of construction

☐ The use of water or mud as a drilling fluid will mask any groundwater inflow Water has to be blown out of the hole and drilling mud must be washed out of the hole or "reverted" chemically if water observations are to be made

More reliable measurements can be made by installing standpipes which are read after stabilising at intervals ranging from several days to perhaps weeks

GRAPHIC LOG SYMBOLS FOR SOILS AND ROCKS

SOIL

- FILL
- TOPSOIL
- CLAY (CL, CHI
- SILT (ML, MH)
- SANO (SP, SWI
- GRAVEL (GP, GW)
- SANOY CLAY (CL, CH)
- SILTY CLAY (CL, CH)
- CLAYEY SANO (SC)
- SILTY SANO ISM)
- GRAVELLY CLAY ICL. CHI
- CLAYEY GRAVEL (GC)
- SANOY SILT (ML)
- PEAT AND ORGANIC SOILS

ROCK

- CONGLOMERATE
- SANDSTONE
- SHALE
- SILTSTONE, MUDSTONE, CLAYSTONE
- LIMESTONE
- PHYLLITE, SCHIST
- TUFF
- GRANITE, GABBRO
- DOLERITE, DIORITE
- SALT, ANDESITE

OTHER MATERIALS

- CONCRETE
- BITUMINOUS CONCRETE. COAL
- COLLUVIUM

DEFECTS AND INCLUSIONS

- CLAY SEAM
- SHEARED OR CRUSHED SEAM
- BRECCIATED OR SHATTERED SEAMRONE
- IRONSTONE GRAVEL
- ORGANIC MATERIAL

LOG SYMBOLS

LOG COLUMN	SYMBOL	**DEFINITION**		
Groundwater Record	▼	Standing water level. Time delay following completion of drilling may be shown.		
	▶	Groundwater seepage into borehole or excavation noted during drilling or excavation.		
Samples	ES	Soil sample taken over depth indicated, for environmental analysis.		
	U50	Undisturbed 50mm diameter tube sample taken over depth indicated.		
	DB	Bulk disturbed sample taken over depth indicated.		
	DS	Small disturbed bag sample taken over depth indicated.		
Field Tests	N = 17 4,7,10	Standard Penetration Test (SPT) performed between depths indicated by lines. Individual figures show blows per 150mm penetration. 'R' as noted below.		
	N_c = 5 7 3R	Dynamic Cone Penetration Test performed between depths indicated by lines. Individual figures show blows per 150mm penetration for 60 degree solid cone driven by SPT hammer. 'R' refers to apparent hammer refusal within the corresponding 150mm depth increment.		
	VNS = 25	Vane shear reading in kPa of Undrained Shear Strength		
	PID = 100	Photoionization detector reading in ppm (Soil sample headspace test)		
Moisture Condition (Cohesive Soils)	MC>PL	Moisture content estimated to be greater than plastic limit.		
	MC≑PL	Moisture content estimated to be approximately equal to plastic limit.		
	MC<PL	Moisture content estimated to be less than plastic limit.		
(Cohesionless Soils)	D	DRY -	runs freely through fingers.	
	M	MOIST -	does not run freely but no free water visible on soil surface.	
	W	WET -	free water visible on soil surface.	
Strength (Consistency) Cohesive Soils	VS	VERY SOFT -	Unconfined compressive strength less than 25kPa.	
	S	SOFT -	Unconfined compressive strength 25-50kPa.	
	F	FIRM -	Unconfined compressive strength 50-100kPa.	
	St	STIFF -	Unconfined compressive strength 100-200kPa.	
	VSt	VERY STIFF -	Unconfined compressive strength 200-400kPa.	
	H	HARD -	Unconfined compressive strength greater than 400kPa.	
	( )	Bracketted symbol indicates estimated consistency based on tactile examination or other tests.		
Density Index/ Relative Density (Cohesionless Soils)		Density	Index (I_D) Range (%)	SPT 'N' Value Range (Blows/300mm)
	VL	Very Loose	<15	0-4
	L	Loose	15-35	4-10
	MD	Medium Dense	35-65	10-30
	D	Dense	65-85	30-50
	VD	Very Dense	>85	>50
	( )	Bracketted symbol indicates estimated density based on ease of drilling or other tests.		
Hand Penetrometer Readings	300 250	Numbers indicate individual test results in kPa on representative undisturbed material unless noted otherwise.		
Remarks	'V' bit	Hardened steel 'V' shaped bit.		
	'TC' bit	Tungsten carbide wing bit.		
	T 60	Penetration of auger string in mm under static load of rig applied by drill head hydraulics without rotation of augers.		

APPENDIX B

LAND & WATER CONSERVATION

Saint Marys Electro-magnetic Induction Survey

Dryland Salinity Investigation

NSW Department of Land and Water Conservation

LAND & WATER
CONSERVATION

aint Marys Electro-magnetic
duction Survey

Dryland Salinity Investigation

CST EMI 991001

Prepared by
Nik Henry
Central West Region
NSW Department of Land and Water Conservation

LIST OF FIGURES

LAND & WATER
CONSERVATION

ONTENTS

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December 1999

LAND & WATER CONSERVATION

SCOPE OF THE INVESTIGATION

In October 1999 the Environmental Investigation Services (EIS) division of Jeffery and Katauskas Pty Ltd (J&K) requested that a salinity investigation proposal be presented for the western area of the Comland – St Marys redevelopment site. A proposal was presented during September 1999 and an on-site meeting with staff from EIS was organised by staff of Department of Land and Water Conservation (DLWC). It was agreed that the Cowra Salt Team would assist with salinity investigations prior to redevelopment.

The proposed investigation would include an Electro-magnetic induction (EMI) survey to help with the assessment of the salinity and waterlogging hazard for the site. The investigation was carried out on two western precinct of the redevelopment site of Comland - St Marys. The EMI survey is a comparative method and when coupled with validation methods can show the distribution of certain soil characteristics within a surveyed landscape. The data can be used to assess the extent of salinity, potential salinity and waterlogging in the survey area.

SUMMARY

The aim of the investigation was to map and identify wet and possibly saline areas within the west precinct of the Comland St Marys redevelopment site (Figure 1). An EMI survey and its validation are one method to obtain site-specific data. Salinity is not just a problem in the South Creek Catchment, but is also a problem in the urban areas of the district. Salinisation arises from changes in the water balance of a catchment, which is directly related to geological features, soil characteristics, slope and especially landuse. Saline outbreaks generally occur in the lower parts of the landscape affecting some 5% at date, but could affect up to 20% of the region (Dias et *al*, 1997).

The Comland St Marys site has areas within the boundaries that could potentially become a saline hazard. These areas are associated with areas more prone to water table rise, such as waterways, flow lines, break of slope and low lying areas.

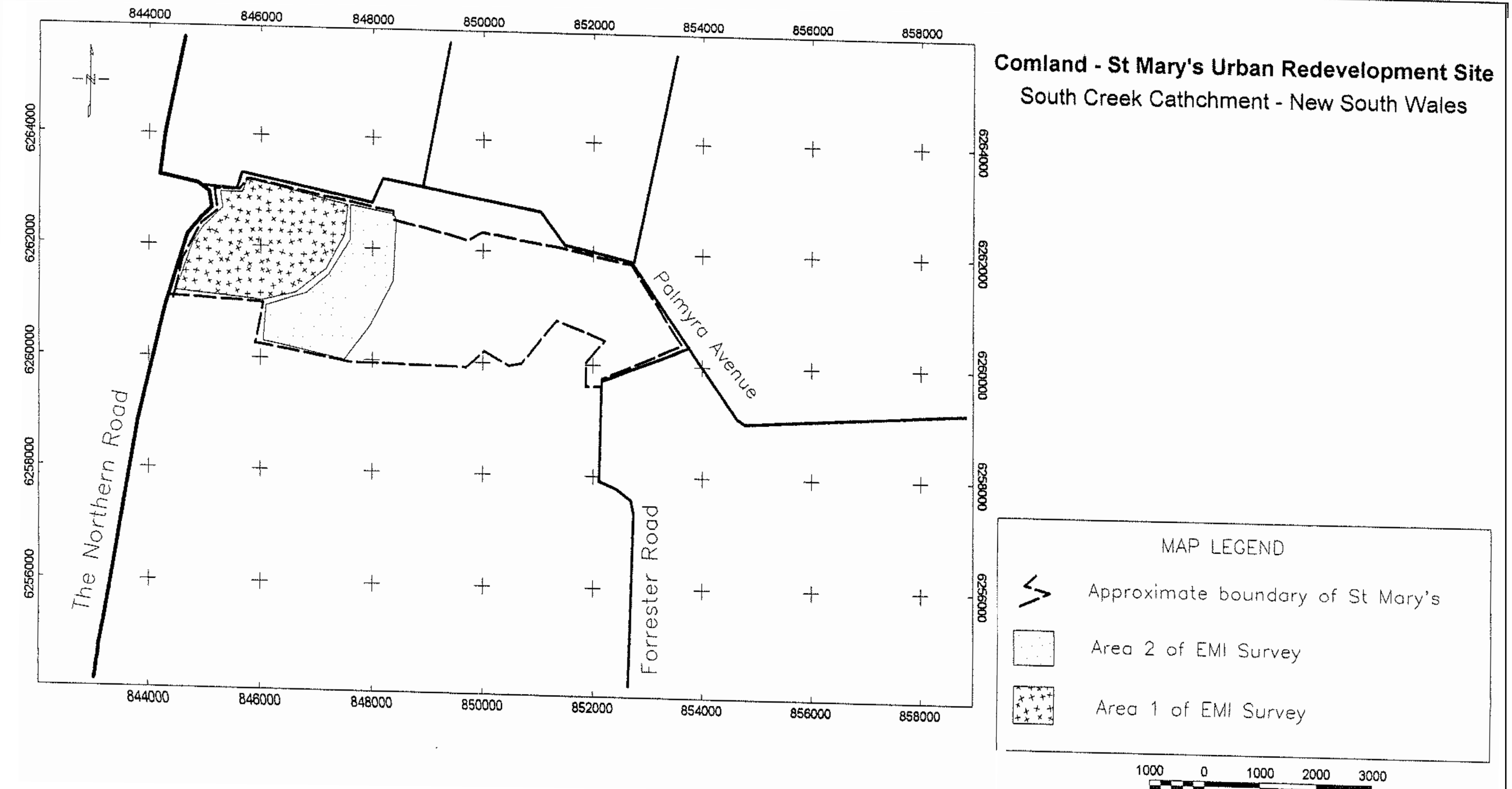
The EMI survey was carried out on two areas within the west precinct of the site and these included a relatively cleared area, Area 1 (400 hectares), which constitutes most of the site and a mainly forested area, Area 2 (240 hectares), the east of the survey site. Area 1 was highlighted as potentially more saline than Area 2 with the hazard areas being associated with the flow lines from the northern and western boundaries of the survey site.

Changes in saline hazard site conditions may be influenced by climatic changes, a series of wet years in succession may exaggerate salinity expression at the site. On-site meetings are recommended in order to explain the report and specifics about the EMI survey.

The EMI Survey of the Comland – St Marys site should be used as another layer of information in the determination of the type and accurate location of salinity, potential salinity and waterlogging at the site. Additional data sets, such as desktop geology, ground water levels and soil sampling analysis should be collated to provide the basis for validation.

Comland - St Mary's Urban Redevelopment Site

South Creek Cathchment - New South Wales



GENERAL INFORMATION

Vegetation Background

Previous clearing of natural vegetation from the land removed deep rooted and diverse vegetation communities capable of using rainfall and surface water effectively without groundwater recharge. The present grasses and sparse trees do not use all available moisture and in turn increase groundwater recharge.

In urban communities the situation is somewhat different, excess watering of garden beds and lawns increases the available water entering the soil. As with crops and pastures these gardens and lawns don't use water effectively and the excess water enters the groundwater system or storm water system and in turn rises the water table level.

Topography and Climate

The general topographic features of the survey site consisted mainly of two creek systems that feed into the South Creek and an east-west tending ridge that is near the northern part of the site. This would form two partial catchments contained within the survey site, with the general flow of these creek systems moving west to east.

The Comland – St Marys site is in a known high rainfall zone (>700 mm) and under the present vegetation conditions groundwater recharge is substantially increased. The majority of the surrounding area is urbanised and additional groundwater recharge can lead to seasonal waterlogging.

Preliminary Investigation

During the on-site inspection (13 September 1999), the Salinity Technical Officer collected water and vegetation information. This form of investigation highlighted the areas that are more prone to salinisation, involving the sampling of flow lines and creeks for electrical conductivity (EC), together with the identification of salt tolerant vegetation.

Figure 2. Salinity symptoms for the brackish northwestern flow-line entering the main storm water drain *(1319199)*

The preliminary investigation of the Comland - St Marys site found that the creek at the north boundary of the site was of a saline nature (9200 EC), which on the day was the most saline of all waterways within the survey area. The other waterways where brackish (900-1200 EC) and where flowing into the large storm water drain to the south of the survey area.

ELECTRO-MAGNETIC INDUCTION SURVEY

The Electro-magnetic induction survey was carried out a few days after the area received heavy rain (–50 mm), this was considered an appropriate time to wait before survey allowing soil moisture to distribute naturally throughout the survey area. Both areas where surveyed over a three day period.

Interpretation of EMI Survey Maps

It should be noted that these maps represent a soil's ability to conduct electricity, known as the electrical conductivity (EC). EC depends on the relative amounts of moisture, clays, gravels and cyclic salts in the soil. The instrument that is used to measure the EC of soil measures the apparent bulk electrical conductivity (EC,), which is the average of the soil layers to 6 meters under the ground (Geonics, 1992).

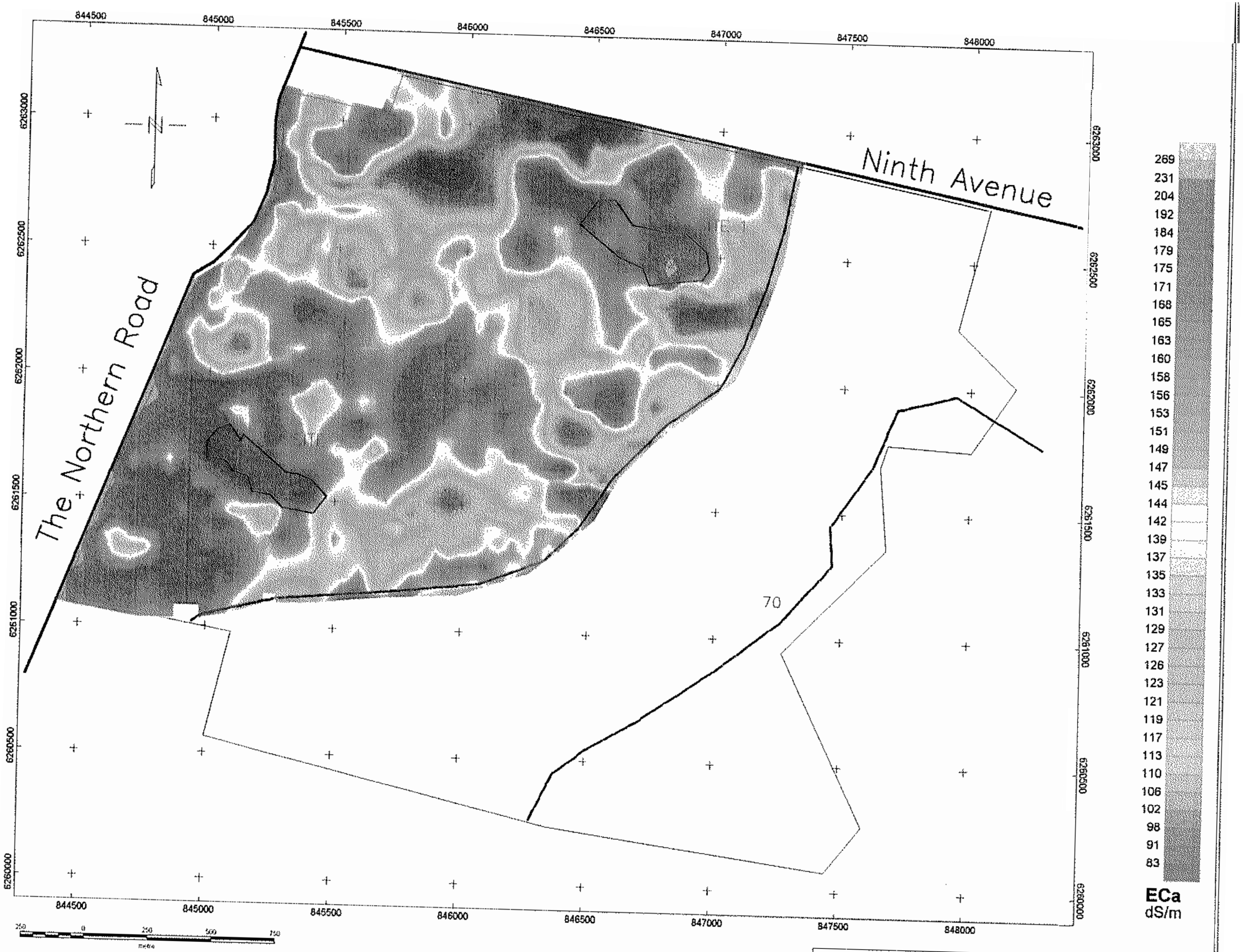
The EMI survey map is generated using the EC, readings. These maps are a representation of six main soil factors and how they are distributed across the survey site. These factors are (Nicholl et *al* 1993):

1. Total amount of pore space in the 6-meter soil profile
2. The amount of groundwater or soil moisture filling the pore spaces
3. The salinity of the groundwater or soil moisture
4. Temperature of soil profile
5. The type and amount of clay in the 6-meter soil profile
6. The amount of organic matter in the soil

Generally EMI maps show low conductivity areas as blue to green, inferring that these areas are dry sandy textured soils with little or no cyclic salts. Usually these are hills and quarries as well as geological barriers. High conductivity areas are shown as red to pink, inferring that these areas are waterlogged clayey textured soils with saline groundwater. Usually they are present in low areas adjacent to creeks, flow lines or groundwater barriers (railways, geological features).

The usual pattern seen for EMI survey maps is a gradual change from low conductivity (blue) to high conductivity (pink) and is consistent for most creeks and flow systems. For unusual distribution of colours and unusually high readings validation has to be carried out, this is also required for areas that have layered soil profiles.

The results from EMI surveys must be interpreted on a case-by-case basis. EC, values measured for one landscape cannot be directly compared to other landscapes. Due to the apparent nature in which EMI survey results are measured interpretation of survey maps is based on the variation in readings obtained not the values themselves.



St Mary's Urban Redevelopment - Lend Lease

Apparent Bulk Electrical Conductivity
EM31 - Vertical Dipole

DISCLAIMER

The NSW Land and Water Conservation (DLWC) has used reasonable effort to ensure the accuracy of the information contained in this EMI Survey Map. However, the DLWC is not responsible for any error or omission in the information. It is recommended that this map should not be used solely when making managment decisions.

Salinity Technical Officer - Lachlan Salinity Unit

Results *of* the **EMI** Survey

The patterns seen on the EMI survey map (Figure 5) shows an unusual distribution of low conductivity and high conductivity. The two areas have distinct differences, with Area 1 (Figure 3) having primarily a wider distribution of EC, readings than Area 2 (Figure 4).

There are three zones that have unusual bulk apparent electrical conductivity (EC,) readings, Zones A, B and C on the EMI Survey map (Figure 5). The yellow band of colour that surrounds these areas would best define these boundaries for the zones. Zone A is situated near the south-eastern edge of Area 1 and extends slightly northwest. Zone B constitutes the dark blue section near the northwest edge of Area 1. Zone C is reddish section just to the south of Zone B, surrounded by the light blue sections.

The rest of Area 1 (Figure 3) shows a usual distribution of gradually changing low readings on the ridge to gradually higher readings on the slopes and some low-lying areas.

For Area 2 (Figure **4)** there are two features that have gradual changes from high to low EC_a readings. Zone 1 and 2. Zone 1 is mainly the low readings confined to the northern half of Area 2 and extends into Area 1. Zone 2 constitutes the mainly red section to the south-west part of Area 2.

Conductivity anomalies are situated along two flow lines, Site 1 and Site 2 (Figure 3). Site 1 is situated at the northern boundary and Site 2 at the western boundary. Site 1 being higher in conductivity than Site 2, is the saline flow line from the suburbs to the north of the survey site. Site 2 is the brackish flow line that flows into the main storm water drain.

St Mary's Urban Redevelopment - Lend Lease

Apparent Bulk Electrical Conductivity
EM31 - Vertical Dipole

DISCLAIMER

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Salinity Technical Officer - Lachlan Salinity Unit

Figure 4. Area 2 of St Mary's EMI Survey - Apparent Bulk Electrical Conductivity

PUTTING THE PIECES TOGETHER

The preliminary investigation highlighted two main sites (Figure 3) that may have a salinity hazard, these are Sites 1 and 2. Site 2 correlates with the information collected during the preliminary investigation. These sites have definitely a waterlogging problem and should be investigated further to establish a more accurate determination of the salinity hazard.

Waterlogging sites should be treated with the same precautionary measures as saline sites when considering management and planning decisions, the effect these sites could have on residential buildings and the issues involved requires a comprehensive approach.

Zone 2 of Area 2 (Figure 4) corresponds to the naturally forested area, light blue colours on the EMI survey map, indicating dryer soil conditions when compared to the other parts of Area 2. The other blue/green areas of the survey site also correspond to hills or ridges where the soils are generally dryer and lighter in texture.

Zone A and Zone B (Figure 5), need to be related to groundwater and soil chemistry investigations. Differences between these zones and the remainder of the surveyed area should be assessed on this basis.

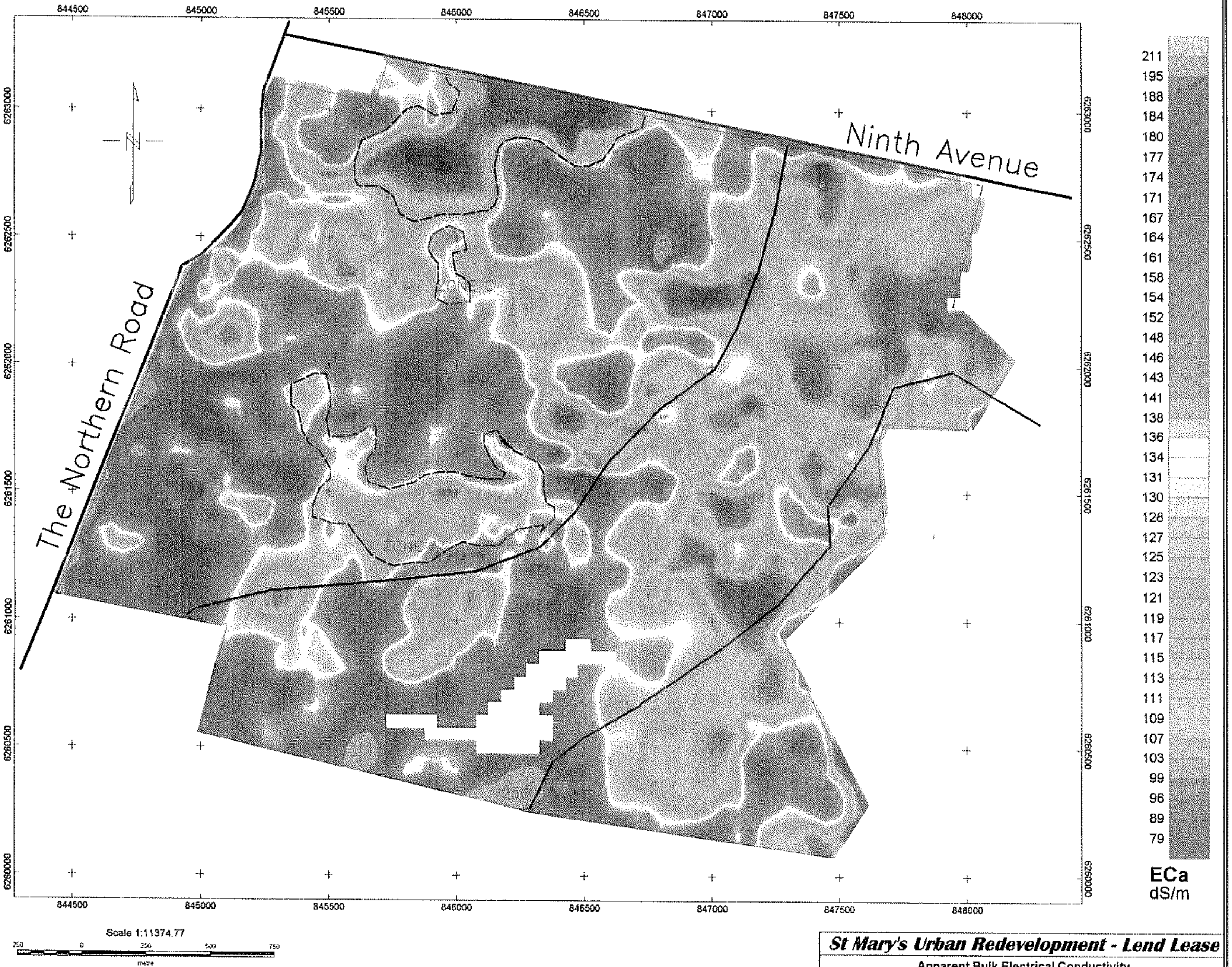
Zone A – Light blue/green area, needs to be differentiated from other survey areas using soil chemistry and soil texture results.

Zone B – Very blue area, needs to be differentiated using soil texture results that may also correspond to higher rainfall infiltration for this zone and not the presence of saline ground water.

Zone C – Red area, can be differentiated using general soil data, and possibly general geology information.

The remaining survey areas seem to correspond to generalised EMI information, blue and green areas are probably drier and have light textured soils with less cyclic salts. The red and pink areas are probably wetter with heavier textured soils.

There might be some complications with correlating collected soil information with EMI survey data, this would be related to the time the survey was conducted (after heavy rainfall). The effect associated with such an event may leach the lighter textured soils, making them less conductive. If this effect is significant then another survey should be carried during a drier season and to shallower depth.



St Mary's Urban Redevelopment - Lend Lease

Apparent Bulk Electrical Conductivity
EM31 - Vertical Dipole

DISCLAIMER

The NSW Land and Water Conservation (DLWC) has used reasonable effort to ensure the accuracy of the information contained in this EMI Survey Map. However, the DLWC is not responsible for any error or ommission in the information. It is recommended that this map should not be used soley when making managment descisions.

Salinity Technical Officer - Lachlan Salinity Unit

Figure 5: St Mary's EMI Survey map - Apparent Bulk Electrical Conductivity down to 6 meters

LAND & WATER CONSERVATION

KEY CONTACTS

NAME	**POSITION/DEPT**	TELEPHONE	AREAS OF INTEREST
Suzanne Hayward	Salinity Officer - DLWC	(02) 4721-0188	Salinity identification and extension.
Marwan Elchamy	Catchment Manager - DLWC	(02) 4721-0188	Erosion control, vegetation management, agricultural earthworks.
Nik Henry	Salinity Technical Support - DLWC	(02) 6341-1600	EMI Survey and interpretation.
Rob **Muller**	Salinity Hydrogeologist - DLWC	(02) 6341-1600	Geology and groundwater.
Alan Nicholson	Salinity Investigations Officer - DLWC	(02) 6845-2488	Salt tolerant pastures. salt tolerant trees.
Andrew Nooldridge	Salinity Extension Officer - DLWC	(02) 6341-1600	Salinity identification and management.

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LAND & WATER CONSERVATION

APPENDICES

APPENDIX A- ELECTROMAGNETIC INDUCTION THEORY

EMI is a widely used method of estimating soil salinity levels, measuring how well the soil can hold an electrical current or the apparent Electrical Conductivity (ECa). ECa is determined by the amount of sand, silt and clay in the soil, soil moisture and how much salt is present. ECa readings usually vary between two extremes (Geonics, 1992):

High conductivity readings are expected where a site has compacted, heavy clay soil which is waterlogged and for which the groundwater is highly saline.

Low conductivity readings are expected in very dry, sandy soils, (or rocks) with very little clay and very little salt.

The units of measurement used for EMI surveys are conductivity units and are called siemens *(S)*. The EM31 reads in milli siemens per centimetre (mS/cm). The electromagnetic current that a soil conducts can be related to the amount of salts present. ECa readings plotted on a map can be used to define recharge and discharge areas in a landscape. These maps coupled with geology can also help to distinguish between locally influenced salt sites and regionally influenced sites.

The EM31

The instrument used for the EMI survey was an EM31, which is operated by one person and measures the Electrical Conductivity of approximately the top three to six metres of ground. An advantage of using this unit is that the survey is quick and requires no ground disturbance.

Resolution of the EM31 is high, with changes of 5% being quickly determined. The instrument is capable of giving an extremely precise survey with information on small variations in the terrain. There are a number of things which can influence the readings of apparent conductivity; clay content, soil moisture, soil salinity, geology, as well as interference. The instrument is relatively unaffected by fences, overhead power lines and other nearby metallic objects. The EM31 is sensitive to electric fencing and underground conductors such as large pipes and drums etc. Hence there is a real need for validation of EM survey results.

APPENDIX B- EMI SURVEY METHODS

The EM31 is calibrated on areas expected to produce low conductivity values. The area used to calibrate the EM31 for the EMI survey was on the crest of the main ridge of Area 1. The AGM grid co-ordinates were 846100 E at 6262300 N.

Readings were taken every 2-4m along transacts spaced up to 20 metres apart, depending on geomorphology and field conditions. In areas where there was a higher probability of salinity occurring more readings were taken. To this extent the survey is subjective, however comparison with earlier grid style surveys shows good correlation. Regardless of sampling strategy it is important to obtain good ground coverage. This ensures the mapping program GEOSOFT Montaj has adequate data to produce accurate results.

Physical Survey

The EM31 is mounted alongside a 4WD motorbike using on a 50 mm PVC frame. Also mounted on the bike is a Trimble ProXR global positioning system (GPS), a Land Star MkIII differential GPS and the Asset Surveyor data logger. At each survey point an EMI reading is sent from the EM31 and stored with the position co-ordinates in the data logger. The data logger's memory is downloaded as required and the format of data altered to suit the GEOSOFT Montaj mapping system.

APPENDIX C- MORE ABOUT EMI SURVEY MAPS

Electro Magnetic Induction (EMI) is a widely used method of inferring soil salinity levels. The Geonics EM31 can sample 'soil conductivity' down to 6 m (18 ft) below the surface, but this depends greatly on the properties of the soil layers being surveyed. In some areas, especially ridges and crests, geology can be the main influence of readings obtained, the accurate location of the data collected is determined using a Trimble Differential GPS unit (± 1 m).

The EMI survey map is generated using the mapping program GEOSOFT Montaj, which compares only the EC, readings collected from the survey site, it shows the site divided into 40 classes from the least conductive to the most conductive. This gives an indication of the distribution of soil texture, soil moisture and cyclic salts from around the survey site.

These maps are useful in giving an indication where potential problems lie and an indication of the potential spread of current saline sites. It is important to understand the distribution of patterns on EMI survey maps to distinguish between differing soils types or recharge and discharge zones.

Low conductivity areas are blue and green, inferring that these areas are recharge areas and are generally light textured, dry and free of cyclic salts. In some cases these areas can be discharge sites, but have little or no cyclic salts in the groundwater.

High conductivity areas are red and pink, we infer that they are mainly discharge sites and generally heavy textured, moist and contain high amounts of cyclic salts. When there are different geologies within a survey area the readings obtained for crests and ridges can vary between low for shale and high for basalt. The survey readings depend on the nature of geologies being compared with the EMI survey.

Because the EM31 takes an average reading from the surface to 6 m, the maps cannot predict how far below the surface ground water will occur. Should there be need for further information on the hardware and/or software used please contact:

EM31 METER
Geoterrex Pty Ltd
7-9 George Place
ARTARMON 2064
Ph: (02) 9418-8077
Fax: (02) 9418-8581

TRIMBLE GPS
Ultimate Positioning
PO Box 291
PENNANT HILLS 2120
Ph: (02) 9484-9293
Fax: (02) 9875-3904

GEOSOFT
Software Retail
Suite 24, 32 Richardson St
WEST PERTH 6005
Ph: (08) 9322-8122
Fax: (08) 9322-8133

TABLE A
SUMMARY OF LABORATORY TEST DATA - SOILS
Piezometer Soil Samples - Electrical Conductivity, pH Chloride and Sodium

Sample	**Depth (metres)**	**EC (dS/cm)**	**Corr. Factor Texture**	**EC Sat. Paste**	**pH ($CaCl_2$)**	**Moisture %**
TP201	0.0-0.2	0.217	10	2.170	4.70	17.0
TP201	0.5	1.080	10	10.800	4.40	12.0
TP201	1	0.398	9	3.582	4.80	15.0
TP201	1.5	0.417	9	3.753	4.70	19.0
TP202	0.0-0.2	0.203	10	2.030	5.50	18.0
TP202	0.5	0.112	10	1.120	5.80	13.0
TP202	1.2	0.166	9	1.494	5.40	16.0
TP202	1.7	0.169	9	1.521	5.40	16.0
TP203	0.0-0.1	1.710	10	17.100	5.80	12.0
TP203	0.5-0.6	1.460	9	13.140	7.10	13.0
TP203	1.0-1.1	1.420	7	9.940	7.60	18.0
TP203	1.5-1.6	1.180	7	8.260	6.50	12.0
TP204	0.0-0.1	0.218	10	2.180	5.10	17.0
TP204	0.5	0.447	9	4.023	4.40	12.0
TP204	1	1.140	7	7.980	4.60	18.0
TP204	1.5	1.080	7	7.560	6.40	13.0
TP205	0.0-0.1	0.272	10	2.720	5.00	15.0
TP205	0.3	0.410	10	4.100	4.30	14.0
TP205	1.2	0.754	9	6.786	5.00	15.0
TP205	2.2	0.825	9	7.425	5.40	15.0
TP206	0.0-0.1	0.444	10	4.440	5.00	15.0
TP206	0.5	0.649	10	6.490	5.00	19.0
TP206	1	0.746	9	6.714	5.20	19.0
TP206	2	0.642	9	5.778	6.60	13.0
TP207	0.0-0.1	0.357	9	3.213	5.00	16.0
TP207	0.3	0.832	9	7.488	5.40	13.0
TP207	0.5	0.600	9	5.400	5.40	-
TP207	2	1.630	7	11.410	6.80	14.0
TP208	0.3	0.657	9	5.913	4.70	15.0
TP208	0.6	0.980	9	8.820	5.10	17.0
TP208	1	1.080	9	9.720	5.30	16.0
TP208	2.2	1.190	7	8.330	6.80	13.0
TP209	0.0-0.1	0.296	9	2.664	4.60	17.0
TP209	0.25-0.4	1.121	9	10.089	5.40	15.0
TP209	1	0.471	9	4.239	5.30	17.0
TP209	1.8	0.268	9	2.412	5.00	19.0
TP210	0	0.311	9	2.799	4.30	12.0
TP210	0.3	0.843	9	7.587	4.60	16.0
TP210	0.7	0.768	9	6.912	4.70	16.0
TP210	1.1	0.733	9	6.597	4.70	18.0

Explanation of Abbreviations

EC: Electrical Conductivity

Reported as saturated paste using correction factors for texture detailed in Hazelton and Murphy (1992)

APPENDIX E

A Commitment to Quality

ETRS Pty Ltd
A.C.N. 006 353 046
11-13 Byrne Street
Auburn NSW 2144
PO Box 6124
Silverwater DC
NSW 1811 Australia
Fax (02) 9647 2341
Phone (02) 9647 1077

REPORT NUMBER: NA99-2108
(Page 1 of 3)

DATE RECEIVED: 18 November 1999

Environmental Investigation Services
39 Buffalo Road
GLADESVLLLE NSW **2111**

ORDER NUMBER: Chain - of - Custody Records 18.11.99

CLIENT CONTACT: Ms Joanne Rosner

DESCRIPTION: Analysis of twenty (20) water sample identified as E13431F, St Marys. Filtered and acidified samples received in separate containers for metal analysis. Samples transported in an esky cooled by ice. Analysed "as received".

TEST METHODS: Sulphate by APHA 4500 - SO_4^{2-}E, Conductivity by APHA 2510 B, Ammonia-N by APHA 4500 - NH_3 B/E, pH by APHA 4500 - H^+ B, Fluoride by APHA 4500 - F - C, TKN by APHA 4500 - Norg - B, Chloride by APHA 4500 - Cl - B and metals by AAS, APHA 3111 - B, 3500 - B and Alkalinity (total), carbonate alkalinity by APHA 2320 B

TEST RESULTS: Refer Pages 2 & 3.

Dr Rama Bhat
Manager Environmental Services
03/12/99

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EIS Project: E13431F, St Marys.

TEST RESULTS· Measurements in mg/L except pH and Conductivity

Sample **ID**	**P 1D**	**P2 D**	**P3S**	**P5S**	**P5D**	**P1S**
Sulphate	1378	1132	93	1554	1501	1181
Conductivity (~ S I c ~)	24300	23300	1944	21100	21800	24100
A	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5
pI	6.90	6.25	6.23	5.66	7.58	6.90
Fl	0.5	<0.5	<0.5	<0.5	<0.5	<0.5
C:	9600	9970	462	9320	9450	11300
Total Kjeldahl Nitrogen	1.9	<0.5	0.8	1.0	0.5	0.6
Calcium	170	190	7.7	81	110	120
Sodium	6800	6200	390	5800	5400	6700
Potassium	8.9	10.4	0.64	5.2	6.0	3.9
Magnesium	897	805	6.7	778	729	920
Alkalinity (total)	1560	146	114	73	494	140
Carbonate Alkalintiy	0	0	0	0	0	0

Sample **ID**	**P3D**	**P4D**	**P4S**	**G3**	**G3**	**G6**
Sulphate	1698	1526	1649	689	1525	1082
konductivity (μS/cm)	26900	23900	23500	18700	25100	18900
Ammonia-N	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
pH	6.27	6.44	5.69	6.88	6.87	6.35
Fluoride	<0.5	<0.5	<0.5	<0.5	0.5	0.6
Chloride	13000	11900	11300	8420	11700	7840
Total Kjeldahl Nitrogen	1.2	1.4	1.6	<0.5	1.0	1.5
Calcium	250	170	75	160	140	95
Sodium	7300	7000	6600	5000	7400	5000
Potassium	16.3	11.7	2.7	21	30.8	20.4
Magnesium	1170	871	742	588	1031	539
Alkalinity (total)	203	224	78	728	130	286
Carbonate Alkalinity	0	0	0	0	0	0

Total Alkalinity measured to pH 4 9, 4.6 and 4.3 as per APHA method. Results in mgCaCO$_3$/L

NOTE:	(a)	Samples will bc disposed of thirty day. after issue of this report unless otherwise notified.
	(b)	< Denotes 'less than'. Na, Ca and K analysed by WaterTest, NATA Reg No. 1884, Report No. WK1185A and B

EIS Project: E13431F, St Marys.

TEST RESULTS: Measurements in mg/L except pH and Conductivity.

Sample	Blank	**Dupl 1**	**Dupl 2**	**D6S**	**P6D**	**P7D**
ulphate		1649	1821	2560	2116	1625
onductivity (~ S I.c ~)		24000	25800	25200	32700	30000
monia-N	<0.5	<0.5	<0.5	1.3	1.6	<0.5
	8.05	5.95	7.05	4.67	6.70	6.79
luoride	1.1	<0.5	<0.5	0.7	<0.5	<0.5
hloride	24	11450	13600	14500	12700	13200
Total Kjeldahl Nitrogen	<0 5	1.2	1.0	0.8	0.8	0.9
Calcium	0 4	63	130	60	170	160
Sodium	0.5	6500	6900	7500	7600	6700
otassium	<0.1	2.6	29.9	38.4	21.8	16.1
agnesium	<0.05	776	1080	1280	1070	805
Alkalinity (total)	62	52	484	<20	634	494
Carbonate Alkalinity	0	0	0	0	0	0

Sample **ID**	**G1**	**G4**
Sulphate	1132	1748
Conductivity (μS/cm)	30000	29100
Ammonia-N	<0.5	<0.5
pH	7.39	6.71
Fluoride	<0 5	<0 5
Chloride	11900	9500
Total Kjeldahl Nitrogen		1 2
Calcium	250	120
Sodium	5800	6300
Potassium	50	21
Magnesium	1180	903
Alkalinity (total)	1264	806
Carbonate Alkalinity	0	0

NOTE: (a) Samples will be disposed of thirty days after issue of this report unless otherwise notified.
(b) < Denotes 'less than'. Na, Ca and K analysed by WaterTest, NATA Reg No. 1884, Report No. WK1185 A and B

Dr Rama Bhat
Manager Environmental Services
03/12/99

07 Feb

ETRS

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REPORT NUMBER: NAA00-0094
(Page 1 of 3)

ETRS Pty Ltd
A.C.N. 006 353 046
11-13 Byrne Street
Auburn NSW 2144
PO Box 6124
Silverwater DC
NSW 1811 Australia
Fax (02) 9647 2341
Phone (02) 9647 1077

DATE RECEIVED 18 January 2000

Environmental Investigation Services
39 Buffalo Road
GLADESVLLLE NSW 2111

ORDER NUMBER: Chain - of - Custody Records 18.01.00

CLIENT CONTACT: Ms Joanne Rosner

DESCRIPTION: Analysis of nineteen (19) water sample identified as E13431F, St Marys. Filtered and acidified samples received in separate containers for metal analysis. Samples transported in an esky cooled by ice. Analysed "as received".

TEST METHODS: Sulphate by APHA 4500 - SO_4^{2-}E, Conductivity by APHA 2510 B, Ammonia-N by APHA 4500 - NH_3 B/E, pH by APHA 4500 - H^+ B, Fluoride by APHA 4500 - F - C, TKN by APHA 4500 - Norg - B, Chloride by APHA 4500 - Cl - B and metals by AAS, APHA 3111 - B, 3500 - B and Alkalinity (total), carbonate alkalinity by APHA 2320 B.

TEST RESULTS: Refer Pages 2 & 3.

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Dr Rama Bhat
Manager Environmental Services
01/02/00

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LABORATORY NO. 1111

TEST RESULTS: Measurements in mg/L except pH and Conductivity.

Sample ID	**G 1 3.10pm 12.01.00**	**G 2 1.40pm 13.01.00**	**G 3 1.55pm 17.01.00**	**G 4 4pm 12.01.00**	**G 5 12.20pm 17.01.00**	**G 6S 9.30am 13.01.00**
Sulphate	-.-	-.-	-.-	-.-	1730	-.-
Conductivity (μS/cm)	16980	19740	20400	21900	24500	10730
Ammonia-N	-.-	-.-	-.-	-.-	<0.5	-.-
pH	7.16	7.45	7.24	6.75	6.28	4.03
Fluoride	-.-	-.-	<0.5	-.-	<0.5	0.6
Chloride	-.-	-.-	-.-	-.-	12270	-.-
Total Kjeldahl Nitrogen	-.-	-.-	0.74	-.-	1.47	-.-
Calcium	210	-.-	150	-.-	90	-.-
Sodium	4500	-.-	5000	-.-	7150	-.-
Potassium	26	- -	15	- -	18	- -
Magnesium	57	- -	890	- -	1080	- -
Alkalinity (total)	874	- -	- -	- -	307	- -
Carbonate Alkalintiy	- -	- -	- -	- -	0	- -
Total Dissolved Solids	10700	13600	14300	13800	18000	7200

Sample ID	**G 6 D 10.33am 13.01.00**	**P1D 2.20pm 13.01.00**	**P1S 2.30pm 13.01.00**	**P2D 9.10am 12.01.00**	**P3D 11.15am 12.01.00**	**P4D 8.45am 17.01.00**
Sulphate	- -	- -	- -	- -	1680	- -
Conductivity (μS/cm)	13770	22500	23400	24300	26800	25400
Ammonia-N	-.-	-.-	-.-	-.-	-.-	-.-
pH	6.64	7.53	7.12	5.85	6.69	6.60
Fluoride	-.-	0.5	-.-	-.-	-.-	-.-
Chloride	-.-	-.-	11750	-.-	15300	-.-
Total Kjeldahl Nitrogen	-.-	1.91	-.-	2.21	-.-	-.-
Calcium	-.-	-.-	-.-	-.-	-.-	-.-
Sodium	-.-	-.-	-.-	-.-	-.-	-.-
Potassium	-.-	-.-	-.-	-.-	-.-	-.-
Magnesium	-.-	-.-	-.-	-.-	-.-	-.-
Alkalinity (total)	-.-	-.-	-.-	189	-.-	-.-
Carbonate Alkalinity	-.-	-.-	-.-	-.-	-.-	-.-
Total Dissolved Solids	10100	15510	15770	17600	20200	17200

Total Alkalinity measured to pH 4..3 as per APHA method. Results in mg$CaCO_3$/L.

NOTE: (a) Samples will be disposed of thirty days after issue of this report unless otherwise notified.
(b) < Denotes 'less than'. -.- means tests not required. Na, Ca and K analysed by WaterTest, NATA Reg No. 1884, Report No. WK1185A and B

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LABORATORY NO. [illegible]

EIS Project: E13431F, St Marys.

TESTRESULTS Measurements in mg/L except pH and Conductivity

Sample ID	**P4S 9.30am 17.01.00**	**P5D 1.55pm 12.01.00**	**P5S 2.40pm 12.01.00**	**P6D 8.35am 13.01.00**	**P6S 10.00am 13.01.00**	**P7D 12.45pm 12.01.00**
Sulphate	-.-	-.-	1530	-.-	-.-	-.-
Conductivity (µS/cm)	24200	22200	22600	27900	28500	25700
Ammonia-N	-.-	<0.5	-.-	<0.5	-.-	-.-
pH	5.29	6.45	5.52	6.53	4.29	6.66
Fluoride	-.-	-.-	-.-	-.-	-.-	-.-
Chloride	-.-	-.-	-.-	-.-	-.-	-.-
Total Kjeldahl Nitrogen	-.-	-.-	-.-	2.65	-.-	-.-
Calcium	55	-.-	-.-	-.-	-.-	-.-
Sodium	5800	-.-	-.-	-.-	-.-	-.-
Potassium	2.0	-.-	-.-	-.-	-.-	-.-
Magnesium	850	-.-	-.-	-.-	-.-	-.-
Alkalinity (total)	53	-.-	-.-	-.-	-.-	-.-
Carbonate Alkalinity	- -	- -	- -	- -	- -	- -
Total Dissolved Solids	17100	17000	16800	18100	19030	19520

Sample ID	**Dup 1 18.01.00**
Sulphate	-.-
Conductivity (µS/cm)	25100
Ammonia-N	-.-
pH	5.27
Fluoride	-.-
Chloride	-.-
Total Kjeldahl Nitrogen	-.-
Calcium	-.-
Sodium	-.-
Potassium	-.-
Magnesium	-.-
Alkalinity (total)	-.-
Carbonate Alkalinity	- -
Total Dissolved Solids	18950

NOTE: (a) Samples will be disposed of thirty day. after issue of this report unless otherwise notified.
(b) < Denotes 'less than', '-.-' means tests not requested. Na, Ca and K analysed by WaterTest, NATA Reg No. 1884, Report No. WK1337

Dr Rama Bhat
Manager Environmental Services
01/02/00

DRAFT

EIS Project: E13431F, St Marys.

Tests	Preparation	Analysis
pH	Calcium Chloride extraction (1:5)	APHA 4500 - H^+ B
Conductivity	Water Extraction (1:5)	BCRI
% Moisture	AS1289.2.1.1 - 1992	AS1289.2.1.1 - 1992

NOTE: (a) % Moisture calculated as a percentage of the dry mass.
(b) Calcuim Chlroide extraction step for pH measurement nor covered by the terms of our NATA accreditation.

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EIS Project No: E13431F, St Marys

DRAFT

TEST RESULTS: Conductivity in µS/cm

Sample ID	**TP201 0-0.2m**	**TP201 0.5m**	**TP201 1.0m**	**TP201 1.5m**	**TP202 0-0.2**	**TP202 0.5**	**TP202 1.2**	**TP202 1.7**
I	4.7	4.4	4.8	4.7	5.5	5.8	5.4	5.4
onductivity (µS/cm)	217	1080	398	417	203	112	166	169
Moisture	17	12	15	19	18	13	16	16

Sample ID	**TP203 0-0.1m**	**TP203 0.5-0.6m**	**TP203 1.0-1.1m**	**TP203 1.5-1.6m**	**TP204 0-0.1m**	**TP204 0.5m**	**TP204 1.0m**	**TP204 1.5m**
[	5.8	7.1	7.6	6.5	5.1	4.4	4.6	6.4
nductivity (µS/cm)	1710	1460	1420	1180	218	447	1140	1080
moisture	12	13	18	12	17	12	18	13

Sample ID	**TP205 0-0.1m**	**TP205 0.3m**	**TP205 1.2m**	**TP205 2.2m**	**TP206 0-0.1m**	**TP206 0.5m**	**TP206 1.0m**	**TP206 2.0m**
	5.0	4.3	5.0	5.4	5.0	5.0	5.2	6.6
ıductivity (µS/cm)	272	410	754	825	444	649	746	642
Moisture	15	14	15	15	15	19	19	13

Sample ID	**TP207 0-0.1m**	**TP207 0.3m**	**TP207 0.7m**	**TP207 2.0m**	**TP208 0.3m**	**TP208 0.6m**	**TP208 1.0m**	**TP208 2.2m**
	5.0	5.4	--	6.8	4.7	5.1	5.3	6.8
ductivity (µS/cm)	357	832	--	1630	657	980	1080	1190
loisture	16	13	--	14	15	17	16	13

NOTE:	(a)	Samples will be disposed of thirty days after issue of this report unless otherwise notified.
	(b)	< Denotes 'less than', -.- means tests not requested.

REPORT NUMBER: NAA00-0751
(Page 4 of 4)

DRAFT

EIS Project No: E13431F, St Marys

a

TEST RESULTS: Conductivity in μS/cm.

Sample ID	TP209 0-0.1m	TP209 0.25-0.4m	TP209 1.0m	TP209 1.8m	TP210 0.0m	TP210 0.3m	TP210 0.7m	TP210 1.1m
H	4.6	5.4	5.3	5.0	4.3	4.6	4.7	4.7
onductivity (μS/cm)	296	1121	471	268	311	843	768	733
6 Moisture	17	15	17	19	12	16	16	18

Sample ID	Dup 1	Dup2
pH	5.6	4.8
Conductivity (μS/cm)	468	417
% Moisture	17	19

NOTE:	(a)	Samples will be disposed of thirty days after issue of this report unless otherwise notified.
	(b)	< Denotes 'less than', -.- means tests not requested.

Dr Rama Bhat
Manager Environmental Services
01/05/00

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REPORT NUMBER: NAA00-0751/1
(Page 1 of 4)

DRAFT

DATE RECEIVED: 17 April 2000

Environmental Investigation Services
39 Buffalo Road
GLADESVILLE NSW 2111

ORDER NUMBER: Chain - of - Custody Records 17.04.00

CLIENT CONTACT: Mr E. Fletcher

DESCRIPTION: Analysis of soil samples identified as project E13431F, St Marys. Samples transported in plastic bags placed in an esky cooled by ice. Analysed "as received".

TEST METHODS: Refer Page 2.

TEST RESULTS: Refer Pages 3 and 4.

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Licence No. 7944
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Dr Rama Bhat
Manager Environmental Services
01/05/00

...../2

TO:
ETRS
11-13 Byrne Street
Auburn NSW 2144
Phone: (02) 9647 1077
Fax: (02 9647 1077

Attention: Rama Bhat

Date Results Required: *2811100*

SAMPLE AND CHAIN OF CUS FORM

EIS Job Number: E13431F

Sheet 1/4

FROM:
Environmental Investigation Servic
39 Buffalo Road
Gladesville NSW 2111
Phone: (02) 9809 7322
Fax: (02) 9809 7626

Contact: Joanne Rosner

Esky with ice

Project: Soi and Groundwater Investigation
Location: St Marys
Sampler: JR CT

Tests Required

Date Sampled	Time Sampled	Location	Sample/ Borehole Number	Depth (m)	Sample Container		Sample Description	⊛ pH / EC	TDS	Alkalinity	TKN/Ammonia	Carbonate	Fluoride,	⊛ Chloride	Sulfate	Ca / Na / Mg /K		Comments/Detection Limits Required
✓ 17/1/'00	3:10 pm		G1		Glass bottle ✓ +Plastic Bottle ✓		Water	\	\	\						\		Glass: 1L plastic: 200ml (filt.)
✓ 5/1/00	1:40		G2		" Glass only ✓		"	\	\									Glass only: 500ml
✓ 7.1.'00	:55		G3		" ✓ +Plastic Bottle ✓		"	\	\		\ ⊕		\			\		⊛ TKN Only, Glass: 500ml plastic: 200
✓ 12/1/00	4.00		G4		" ✓ ✓		"	\	\									Glass: 1000ml plastic: 150ml
✓ 7/1/'00	12.20		G5		Glass ✓ " +HDPE Plastic Bottle ✗		"	\	\	\	\	\	\	\	\	\		Glass: 1L. (No plastic Bottle)

Relinquished By:
Date: 18/1/00
Time: 5.10
Received By:

Relinquished By:
Date:
Time:
Received By:

Remarks:
⊛ Conductivity by APHA 2510 B.
⊛ Chloride by APHA 4500-Cl-B.

TO:
ETRS
11-13 Byrne Street
Aurburn NSW 2144
Phone: (02) 9647 1077
Fax: 1021 9647 1077

Attention: Rama Bhat

Date Results Required: 2811100

SAMPLE AND CHAIN OF CUSTODY FORM

FROM:
Environmental Investigation Servi
39 Buffalo Road
Gladesville NSW 2111
Phone: (02) 9809 7322
Fax: (02) 9809 7626

Contact: Joanne Rosner

EIS Job Number: E13431F

Sheet 2/4

Esky with ice

Project: Soil and Groundwater Investigation

Location: St Marys

Sampler: JR / CT

								Tests Required										
Date Sampled	Time Sampled	Location	Sample/ Borehole Number	Depth (m)	Sample Container		Sample Description	pH / EC	TDS	Alkalinity	TKN/Ammonia	Carbonate	Fluoride,	Chloride	Sulfate	Ca / Na / Mg /K		Comments/Detection Limits Required
✓ 13/1/00	9·30		G6S		Glass bottle ✓		Water	✓	✓				✓					
✓ 13/1/00	10·33		G6D		" ✓		"	✓	✓									
✓ 13/1/00	2:20		P1D		" ✓		"	✓	✓		⊕ ✓		✓					⊕ TKN Only.
✓ 13/1/00	2:30		P1S		" ✓		"	✓	✓					✓				
✓ 12/1/00	9·10		P2D		" ✓		"	✓	✓	✓	⊕ ✓							⊕ TKN Only

Relinquished By:	Date: Time:	Received By:
Relinquished By:	Date: Time:	Received By:

Remarks:

TO:
ETRS
11-13 Byrne Street
Aurburn NSW 2144
Phone: (02) 9647 1077
Fax: (02) 9647 1077

Attention: Rama Bhat

Date Results Required: 2811100

SAMPLE AND CHAIN OF CUSTODY FORM

FROM:
Environmental Investigation Servic
39 Buffalo Road
Gladesville NSW 2111
Phone: (02) 9809 7322
Fax: (02) 9809 7626

Contact: Joanna Rosner

EIS Job Number: E13431F

Sheet 3/4

Esky with ice

Project: Soil and Groundwater Investigation

Location: St Marys

Sampler: JR / CT

Date Sampled	Time Sampled	Location	Sample, Borehole Number	Depth (m)	Sample Container		Sample Description	pH / EC	TDS	Alkalinity	TKN/Ammonia-N	Carbonate	Fluoride	Chloride	Sulfate	Ca / Na / Mg /K		Comments/Detection Limits Required
✓ 12/1/00	11.15		P3D		Glass bottle ✓		Water	\	\					\	\			
✓ 17/1/00	8:45am		P4D		" ✓		"	\	\									
✓ 17/1/00	9.30 am		P4S		" ✓ +HDPE= Plastic Bottle ✓		"	\	\	\						\		Glass: 600ml plastic: [illegible]00ml
✓ 12/1/00	1.55		P5D		" ✓		"	\	\		\ ⊕							⊕ Ammonia-N only.
✓ 12/1/00	2.40		P5S		" ✓		"	\	\						\			

Relinquished By:
Date:
Time:
Received By:

Remarks:

Relinquished By:
Date:
Time:
Received By:

TO:
ETRS
11-13 Byrne Street
Aurburn NSW 2144
Phone: (02) 9647 1077
Fax: (02) 9647 1077

Attention: Rarna Bhat

Date Results Required: 28/1/00

SAMPLE AND CHAIN OF CUSTODY FORM

FROM:
Environmental Investigation Ser
39 Buffalo Road
Gladesvilie NSW 2111
Phone: (02) 9809 7322
Fax: (02) 9809 7626

Contact: Joanne Rosner

EIS **Job Number:** E13431F

Sheer 4/4

Esky with ice

Project: Soil and Groundwater Investigation

Location: St Marys

Sampler: JR / CT

								Tests Required										
Date Sampled	Time Sampled	Location	Sample/ Borehole Number	Depth (m)	Sample Container		Sample Description	pH / EC	TDS	Alkalinity	TKN/Ammonia	Carbonate	Fluoride,	Chloride	Sulfate	Ca / Na / Mg /K		Comments/Detection Limits Required
✓ 13/1/00	8:35		P6D ✓		Glass bottle ✓		Water	\	\		\							
✓ 13/1/00	10.00.		P6S ✓		" ✓		"	\	\									
✓ 12/1/00	12.45		P7D ✓		" ✓		"	\	\									
12/1/00	1.30		P7S		" X		"	\	\									
✓			Dup 1		Glass ✓			\	\									

Relinquished By:	Date: Time:	Received By:	Remarks:
Relinquished By:	**Date:** **Time:**	**Received** By:	

'21 FEB 20

A Commitment to Quality

ETRS Ply Ltd
A.C.N. 006 353 046
11-13 Byrne Street
Auburn NSW 2144
PO Box 6124
Silverwater DC
NSW 1811 Australia
Fax (02) 9647 2341
Phone (02) 9647 1077

REPORT NUMBER: NAA00-0094/2
(Page 1 of 2)

DATE RECENED: 18 January 2000
Additional Tests Requested: 08 February 2000

Environmental Investigation Services
39 Buffalo Road
GLADESVILLE NSW **2111**

ORDER NUMBER: Chain - of - Custody Records 18.01.00
Fax 08.02.00

CLIENT CONTACT: Ms Joanne Rosner

DESCRIPTION: Additional analysis of two (2) water samples identified as E13431F, St Marys. Analysed "as received".

TEST METHODS: Sulphate by APHA 4500 - SO_4^{2-}E, Ammonia-N by APHA 4500 - NH_3 B/E, Fluoride by APHA 4500 - F - C, TKN by AFHA 4500 - Norg - B, Chloride by AFHA 4500 - Cl - B and Alkalinity (total), carbonate alkalinity by AFHA 2320 B.

TEST RESULTS: Refer Page 2

ISO9001:1994
Licence No. 7944
NCS International Pty Ltd

Dr Rama Bhat
Manager Environmental Services
17/02/00

...../2

NATA

This Laboratory is accredited by the National Association of Testing Authorities,Australia.The test(s) reported herein have been performed in accordance with its terms of accreditation
LABORATORY NO. 11111

REPORT NUMBER: NAA00-0094/2
(Page 2 of 2)

EIS Project: E13431F, St Marys.

TEST RESULTS: Measurements in mg/L except pH and Conductivity

Sample ID	**G 6S 9.30am 13.01.00**
Sulphate	760
Ammonia-N	0.6
Chloride	3570
Total Kjeldahl Nitrogen	2.50
Alkalinity (total)	<20
Carbonate Alkalintiy	0

Sample ID	**P6S 10.00am 13.01.00**
Sulphate	2370
Ammonia-N	<0.5
Fluoride	<0.5
Chloride	12070
Total Kjeldahl Nitrogen	1.62
Alkalinity (total)	<20
Carbonate Alkalinity	0

NOTE: (a) Samples will be disposed of thirty days after issue of this report unless otherwise notified
(b) < Denotes 'less than'.

Dr Rama Bhat
Manager Environmental Services
17/02/00

PURGE DETAILS

EIS

Groundwater Monitoring Report

Client:	**Lend lease Development**	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	P1D
Location:	Comland, St Marys	***Depth (m):***	*8.90*

WELL FINISH

☐	**Gatic Cover**	✓	**Standpipe**	☐	**PVC Pipe**

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:	Submersible Pump	**SWL – Before: (m)**	1.03	
Date:	7/11/99	**Time – Before:**	9:35	
Undertaken By:	JR	**SWL – After: (m)**	8.90	
Vol. Water Removed:	40	**Time – After:**		

Comments: Well purged dry using pump and bailer

WELL PURGE DETAILS

Method:			**SWL – Before:**	
Date:			**Time – Before:**	
Undertaken By:			**SWL – After:**	
PID Reading: (ppm)			Time – After:	
Total **Vol** Removed:				

PURGING MEASUREMENTS

Volume Removed (L)	Temp ("C)	pH	EC (mS/cm)	Eh (mV)

Comments:

WELL SAMPLING DETAILS

Method:				
Date:			**SWL – Before:**	
Undertaken By:			**Time- Before**	
pH			**Water Temperature (°C)**	
Eh (mV)			**EC: (mS/cm)**	

Containers **Used/Comments**

Tested By:	Remarks:
Date Tested:	- All measurements are corrected to ground level
Checked Bv:	- All stated Volumes are in Litres
Date:	- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend lease Development	Job No.:	E13431F
Project:	Soil and Groundwater Investigation	Well No.:	PIS
Location:	Comland, St Marys	Depth (m):	5.9m

WELL FINISH

☐ Gatic Cover ☑ Standpipe ☐ PVC Pipe

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:	Submersible pump	**SWL – Before: (m)**	1.00	
Date:	7/11/99	**Time – Before:**	10:35	
Undertaken By:	JR	**SWL – After: (m)**	5.90	
Vol. Water Removed:	65	***Time – After:***		

Comments: Well purged dry using pump and bailer, recharge 5cm in 25sec

WELL PURGE DETAILS

Method:			**SWL – Before:**	
Date:			**Time – Before:**	
Undertaken By:			**SWL – After:**	
PID Reading: (ppm)			**Time – After:**	
Total Vol Removed:				

PURGING MEASUREMENTS

Volume Removed (L)	**Temp (°C)**	**pH**	**EC (mS/cm)**	**Eh (mV)**

Comments:

WELL SAMPLING DETAILS

Method:				
Date:			**SWL – Before:**	
Undertaken By:			**Time- Before**	
pH			**Water Temperature (°C)**	
Eh (mV)			**EC: (mS/cm)**	

Containers **Used/Comments**

Tested By:	
Date Tested:	
Checked By:	
Date:	

Remarks:
- All measurements are corrected to ground level
- All stated Volumes are in Litres
- SWL is an abbreviation for standing water level

EIS

Groundwater Monitoring Report

Client:	Lend lease Development	Job No.:	E13431F
Project:	Soil and Groundwater Investigation	Well No.:	P2D
Location:	Comland, St Marys	Depth (m):	9.25

WELL FINISH

☐	**Gatic Cover**	✓	**Standpipe**	☐	**PVC Pipe**

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:	Submersible Pump	**SWL – Before: (m)**	6.11	
Date:	7/11/99	**Time – Before:**	2:00	
Undertaken By:	JR	**SWL – After: (m)**	9.25	
Vol. Water Removed:	30	**Time – After:**		

Comments: Pumped Dry using bailer and pump

WELL PURGE DETAILS

Method:			**SWL – Before:**	
Date:			Time – Before:	
Undertaken By:			SWL – After:	
PID Reading: **(ppm)**			Time – After:	
Total Vol Removed:				

PURGING MEASUREMENTS

Volume Removed (L)	Temp (°C)	pH	EC (mS/cm)	Eh (mV)

Comments:

WELL SAMPLING DETAILS

Method:				
Date:			SWL – Before:	
Undertaken By:			**Time- Before**	
pH			**Water Temperature (°C)**	
Eh (mV)			**EC: (mS/cm)**	

Containers Used/Comments

Tested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		-All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	**Lend lease Development**	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	P2S
Location:	Comland, St Marys	**Depth (m):**	4.40

WELL FINISH

☐ **Gatic Cover** ✓ **Standpipe** ☐ **PVC Pipe**

WELL DEVELOPMENT

	Stage 1		**Stage 1**	**Stage 2**
Method:	-	**SWL – Before: (m)**	-	
Date:	7/11/99	**Time – Before:**	2:45	
Undertaken By:	JR /PLW	**SWL – After: (m)**		
Vol. Water Removed:		**Time – After:**		

Comments: PIEZOMETER 'DRY'

WELL PURGE DETAILS

Method:			**SWL – Before:**	
Date:			**Time – Before:**	
Undertaken By:			**SWL – After:**	
PID Reading: (ppm)			**Time – After:**	
Total Vol Removed:				

PURGING MEASUREMENTS

Volume Removed (L)	**Temp (°C)**	**pH**	**EC (mS/cm)**	**Eh (mV)**

Comments:

WELL SAMPLING DETAILS

Method:				
Date:			**SWL – Before:**	
Undertaken By:			**Time- Before**	
pH			**Water Temperature (°C)**	
Eh (mV)			**EC: (mS/cm)**	

Containers Used/Comments

Tested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend lease Development	Job No.:	E13431F
Project:	Soil and Groundwater Investigation	Well No.:	P3D
Location:	Comland, St Marys	Depth (m):	8.60

WELL FINISH

☐	**Gatic Cover**	✓	**Standpipe**	☐	**PVC Pipe**

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:	Submersible Pump	**SWL – Before: (m)**	5.33	
Date:	8/11/99	**Time – Before:**	2:30	
Undertaken By:	JR	**SWL – After: (m)**	8.55	
Vol. Water Removed:	15	**Time – After:**		

Comments: Well purged and bailed dry

WELL PURGE DETAILS

Method:			SWL – Before:	
Date:			Time – Before:	
Undertaken By:			SWL – After:	
PID Reading: (ppm)			**Time – After:**	
Total Vol Removed:				

PURGING MEASUREMENTS

Volume Removed (L)	Temp ("C)	pH	EC (mS/cm)	Eh (mV)

Comments:

WELL SAMPLING DETAILS

Method:				
Date:			**SWL – Before:**	
Undertaken By:			**Time- Before**	
pH			**Water Temperature (°C)**	
Eh (mV)			**EC: (mS/cm)**	

Containers Used/Comments

Tested By:	
Date Tested:	
Checked By:	
Date:	

Remarks:
- All measurements are corrected to ground level
- All stated Volumes are in Litres
- SWL is an abbreviation for standing water level

EIS

Groundwater Monitoring Report

Client:	Lend lease Development	Job No.:	E13431F
Project:	Soil and Groundwater Investigation	Well No.:	P3S
Location:	Comland, St Marys	Depth **(m):**	4.15

WELL FINISH

☐	**Gatic Cover**	✓	**Standpipe**	☐	**PVC Pipe**

WELL DEVELOPMENT

	Stage 1		**Stage 1**	**Stage 2**
Method:	Submersible Pump	**SWL – Before: (m)**	0.69	
Date:	8/11/99	**Time – Before:**	3:00	
Undertaken By:	JR	**SWL – After: (m)**	4.13	
Vol. Water Removed:	10	**Time – After:**		

comments:

WELL PURGE DETAILS

Method:			SWL – Before:	
Date:			Time – Before:	
Undertaken **By:**			SWL – After:	
PID Reading: (ppm)			Time – After:	
Total Vol Removed:				

PURGING MEASUREMENTS

Volume Removed (L)	Temp **(°C)**	**pH**	EC **(mS/cm)**	**Eh (mV)**

Comments:

WELL SAMPLING DETAILS

Method:				
Date:			**SWL – Before:**	
Undertaken By:			**Time- Before**	
pH			**Water Temperature (°C)**	
Eh (mV)			**EC: (mS/cm)**	

Containers Used/Comments

Tested By:	
Date Tested:	
Checked By:	
Date:	

Remarks:
- All measurements are corrected to ground level
- All stated Volumes are in Litres
- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	**Lend lease Development**	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	P4D
Location:	Comland, St Marys	**Depth (m):**	9.05

WELL FINISH

	Gatic Cover	✓	**Standpipe**		**PVC Pipe**

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:	Submersible Pump	**SWL – Before: (m)**	1.65	
Date:	17/11/99	**Time – Before:**		
Undertaken By:	JR	**SWL – After: (m)**	9.05	
Vol. Water Removed:	55	**Time – After:**		

Comments: Pumped and Bailed Dry

WELL PURGE DETAILS

Method:			**SWL – Before:**	
Date:			**Time – Before:**	
Undertaken By:			**SWL – After:**	
PID Reading: (ppm)			**Time – After:**	
Total Vol Removed:				

PURGING MEASUREMENTS

Volume Removed (L)	Temp ("C)	pH	EC (mS/cm)	Eh (mV)

Comments:

WELL SAMPLING DETAILS

Method:				
Date:			**SWL – Before:**	
Undertaken By:			**Time- Before**	
pH			**Water Temperature (°C)**	
Eh (mV)			**EC: (mS/cm)**	

Containers Used/Comments

Tested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	**Lend lease Development**	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	P4S
Location:	Comland, St Marys	**Depth (m):**	5.15

WELL FINISH

☐	Gatic Cover	✓	Standpipe	☐	PVC Pipe

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:	submersible pump	**SWL – Before: (m)**	2.20	
Date:	17/11/99	**Time – Before:**		
Undertaken By:	JR	**SWL – After: (m)**	2.35	
Vol. Water Removed:	80	**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:			**SWL – Before:**	
Date:			**Time – Before:**	
Undertaken By:			**SWL – After:**	
PID Reading: (ppm)			**Time – After:**	
Total Vol Removed:				

PURGING MEASUREMENTS

Volume Removed (L)	Temp (°C)	pH	EC (mS/cm)	Eh (mV)

Comments:

WELL SAMPLING DETAILS

Method:				
Date:			**SWL – Before:**	
Undertaken By:			**Time- Before**	
pH			**Water Temperature (°C)**	
Eh (mV)			**EC: (mS/cm)**	

Containers Used/Comments

Tested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

EIS

Groundwater Monitoring Report

Client:	Lend lease Develooment	Job No.:	E13431F
Project:	Soil and Groundwater Investigation	Well No.:	P5D
Location:	Comland, St Marys	Depth (m):	8.5

WELL **FINISH**

☐	Gatic Cover	☑	Standpipe	☐	PVC Pipe

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:	Submersible pump	**SWL – Before: (m)**	1.89	
Date:	3/11/99	**Time – Before:**	9:40	
Undertaken By:	BA	**SWL – After: (m)**	7.26	
Vol. Water Removed:	48	***Time – After:***		

Comments: Pumped, recovery at

WELL PURGE DETAILS

Method:			**SWL – Before:**	
Date:			**Time – Before:**	
Undertaken By:			**SWL – After:**	
PID Reading: (ppm)			**Time – After:**	
Total Vol Removed:				

PURGING MEASUREMENTS

Volume Removed (L)	***Temp (°C)***	**pH**	**EC (mS/cm)**	**Eh (mV)**

Comments:

WELL SAMPLING DETAILS

Method:				
Date:			**SWL – Before:**	_
Undertaken By:			**Time- Before**	
pH			Water Temperature **(°C)**	—
Eh (mV)			EC: **(mS/cm)**	

Containers Used/Comments

Tested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		-All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

EIS

Groundwater Monitoring Report

lient:	Lendlease Development	Job No.:	E13431F
roject:	Soil and Groundwater Investigation	Well No.:	P5S
ocation:	Cornland, St Marys	Depth (m):	5.7

VELL FINISH

☐ Gatic Cover	✓ Standpipe	☐ PVC Pipe

VELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
lethod:	Submersible Pump	SWL – Before: (m)	1.70	
)ate:	3/11199	Time – Before:	9:45	
Jndertaken By:	BA	SWL – After: (m)	5.42	
'ol. Water Removed:	20	Time – After:		

omments: 3.35m @ 11:05am

VELL PURGE DETAILS

lethod:			SWL – Before:	
)ate:			**Time – Before:**	
Indertaken By:			**SWL – After:**	
ID Reading: (ppm)			**Time – After:**	
otal Vol Removed:				

URGING MEASUREMENTS

/olume Removed (L)	**Temp (°C)**	**pH**	**EC (mS/cm)**	**Eh (mV)**

omments:

JELL SAMPLING DETAILS

lethod:				
ate:			**SWL – Before:**	
ndertaken By:			**Time- Before**	
H			**Water Temperature (°C)**	
h (mV)			**EC: (mS/cm)**	

ontainers Used/Comments

ested By:		Remarks: -All measurements are corrected to ground level -All stated Volumes are in Litres - SWL is an abbreviation for standing water level
ate Tested:		
hecked By:		
ate:		

EIS

Groundwater Monitoring Report

Client:	Lend lease Development	Job No.:	E13431F
Project:	Soil and Groundwater Investigation	Well No.:	P6D
Location:	Comland, St Marys	Depth (m):	7.4

WELL FINISH

☐ Gatic Cover ☑ Standpipe ☐ PVC Pipe

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:	submersible pump	**SWL – Before: (m)**	0.99	
Date:	3/11/99	Time – Before:	2:20	
Undertaken By:		SWL – After: (m)	5.60	
Vol. Water Removed:		Time – After:		

Comments: recovery rate 5cm in 20 seconds

WELL PURGE DETAILS

Method:			**SWL – Before:**	
Date:			**Time – Before:**	
Undertaken By:			**SWL – After:**	
PID Reading: (ppm)			**Time – After:**	
Total Vol Removed:				

PURGING MEASUREMENTS

Volume Removed (L)	Temp (°C)	pH	EC (mS/cm)	Eh (mV)

Comments:

WELL SAMPLING DETAILS

Method:				
Date:			**SWL – Before:**	
Undertaken By:			**Time- Before**	
pH			**Water Temperature (°C)**	
Eh (mV)			**EC: (mS/cm)**	

Containers Used/Comments

Tested By:	
Date Tested:	
Checked By:	
Date:	

Remarks:
- All measurements are corrected to ground level
- All stated Volumes are in Litres
- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend lease Development	Job No.:	E13431F
Project:	Soil and Groundwater Investigation	Well No.:	P6S
Location:	Comland, St Marys	Depth (m):	**4.2**

WELL FINISH

☐ Gatic Cover ☑ **Standpipe** ☐ PVC Pipe

WELL DEVELOPMENT

	Stage 1		**Stage 1**	**Stage 2**
Method:	bailer	**SWL – Before: (m)**	4.10	
Date:	3/11/99	**Time – Before:**	1:50	
Undertaken By:	BA	**SWL – After: (m)**	4.16	
Vol. Water Removed:	0.15	**Time – After:**	1:55	

Comments:

WELL PURGE DETAILS

Method:			**SWL – Before:**	
Date:			**Time – Before:**	
Undertaken By:			**SWL – After:**	
PID Reading: (ppm)			Time – After:	
Total Vol Removed:				

PURGING MEASUREMENTS

Volume Removed (L)	Temp ("C)	**pH**	EC **(mS/cm)**	Eh **(mV)**

Comments:

WELL SAMPLING DETAILS

Method:				
Date:			SWL – Before:	
Undertaken By:			**Time- Before**	
pH			Water **Temperature** **(°C)**	
Eh (mV)			**EC: (mS/cm)**	

Containers Used/Comments

Tested By:	
Date Tested:	
Checked By:	
Date:	

Remarks:
- All measurements are corrected to ground level
- All stated Volumes are in Litres
- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend lease Develooment	Job No.:	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	P7D
Location:	Comland, St Marys	**Depth (m):**	7.50

WELL FINISH

☐ **Gatic Cover** ✓ **Standpipe** ☐ **PVC Pipe**

WELL DEVELOPMENT

	Stage 1		**Stage 1**	**Stage 2**
Method:	submersible pump	**SWL – Before: (m)**	1.51	
Date:	3/11/99	**Time – Before:**	11:30	
Undertaken By:	BA	**SWL – After: (m)**	5.1	
Vol. Water Removed:	300	**Time – After:**		

Comments: recovery@1cm/s, SWL 3.17m after 20min

WELL PURGE DETAILS

Method:			SWL – Before:	
Date:			Time – Before:	
Undertaken By:			SWL – After:	
PID Reading: (ppm)			Time – After:	
Total Vol Removed:				

PURGING MEASUREMENTS

Vdume Removed (L)	Temp (°C)	pH	EC (*mS/cm*)	Eh (*mV*)

Comments:

WELL SAMPLING DETAILS

Method:				
Date:			SWL – Before:	
Undertaken By:			**Time- Before**	
pH			**Water Temperature (°C)**	
Eh (mV)			**EC: (mS/cm)**	

Containers Used/Comments

Tested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend lease Development	Job No.:	E13431E
Project:	Soil and Groundwater Investigation	Well No.:	P7S
Location:	Cornland, St Marys	Depth (m):	4.05

WELL FINISH

☐ Gatic Cover ☑ Standpipe ☐ PVC Pipe

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:	na	SWL – Before: (m)	'dry'	
Date:	3/11/99	Time – Before:	11:30	
Undertaken By:	BA	SWL – After: (m)		
Vol. Water Removed:	nil	Time – After:		

Comments: PIEZOMETER 'DRY'

WELL PURGE DETAILS

Method:			**SWL – Before:**	
Date:			**Time – Before:**	
Undertaken By:			**SWL – After:**	
PID Reading: (ppm)			**Time – After:**	
Total Vol Removed:				

PURGING MEASUREMENTS

Volume Removed (L)	Temp ("C)	pH	EC (mS/cm)	Eh (mV)

Comments:

WELL SAMPLING DETAILS

Method:				
Date:			**SWL – Before:**	
Undertaken By:			**Time- Before**	
pH			**Water Temperature (°C)**	
Eh (mV)			EC: **(mS/cm)**	

Containers Used/Comments

Tested By:
Date Tested:
Checked By:
Date:

Remarks:
- *All measurements are corrected to ground level*
- All stated Volumes are in Litres
- SWL is an abbreviation for standing water level

EIS

Groundwater Monitoring Report

Client:	**Lend lease Development**	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	***Well No.:***	G1
Location:	Comland, St Marys	**Depth (m):**	6.32

WELL FINISH

☐	**Gatic Cover**	✓	**Standpipe**	☐	**PVC Pipe**

WELL DEVELOPMENT

	Stage 1		**Stage 1**	**Stage 2**
Method:	bailer	**SWL – Before: (m)**	5.61	
Date:	7/11/99	**Time – Before:**	9:20	
Undertaken By:	JR	**SWL – After: (m)**	6.30	
Vol. Water Removed:	0.15	***Time – After:***		

Comments: bailed dry

WELL PURGE DETAILS

Method:			**SWL – Before:**	
Date:			**Time – Before:**	
Undertaken By:			**SWL – After:**	
PID Reading: (ppm)			**Time – After:**	
Total Vol Removed:				

PURGING MEASUREMENTS

Volume Removed (L)	**Temp (°C)**	**pH**	**EC (mS/cm)**	**Eh (mV)**

Comments:

WELL SAMPLING DETAILS

Method:				
Date:			**SWL – Before:**	
Undertaken By:			**Time- Before**	
pH			**Water Temperature (°C)**	
Eh (mV)			**EC: (mS/cm)**	

Containers Used/Comments

Tested By:		Remarks:
Date Tested:		**-All measurements are corrected to ground level**
Checked By:		- All **stated Volumes are in Litres**
Date:		- SWL is an abbreviation for standing water level

EIS

Groundwater Monitoring Report

Client:	**Lend lease Development**	**Job No.:**	E13431F
Project:	*Soil and Groundwater Investigation*	**Well No.:**	G2
Location:	Comland, St Marys	**Depth (m):**	5.66

WELL FINISH

☐	**Gatic Cover**	☐	**Standpipe**	☐	**PVC Pipe**

WELL DEVELOPMENT

	Stage 1		**Stage 1**	**Stage 2**
Method:	nil	**SWL – Before: (m)**	-	
Date:	8/11/99	**Time – Before:**		
Undertaken By:	JR	**SWL – After: (m)**		
Vol. Water Removed:	nil	**Time – After:**		

Comments: PIEZOMETER DRY

WELL PURGE DETAILS

Method:			**SWL – Before:**	
Date:			**Time – Before:**	
Undertaken By:			**SWL – After:**	
PID Reading: (ppm)			**Time – After:**	
Total Vol Removed:				

PURGING MEASUREMENTS

Volume Removed (L)	**Temp (°C)**	**pH**	**EC (mS/cm)**	**Eh (mV)**

Comments:

WELL SAMPLING DETAILS

Method:				
Date:			**SWL – Before:**	
Undertaken By:			**Time- Before**	
pH			**Water Temperature (°C)**	
Eh (mV)			**EC: (mS/cm)**	

Containers Used/Comments

Tested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend lease Development	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	G3
Location:	Comland, St Marys	**Depth (m):**	8.20

WELL FINISH

☐ Gatic Cover ✓ Standpipe ☐ PVC Pipe

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:	submersible pump	SWL – Before: (m)	3.72	
Date:	3/11/99	Time – Before:	12:55	
Undertaken By:	BA	SWL – After: (m)	8.14	
Vol. Water Removed:	11.5	Time – After:		

Comments: recovery 5cm in 6minutes

WELL PURGE DETAILS

Method:			SWL – Before:	
Date:			Time – Before:	
Undertaken By:			SWL – After:	
PID Reading: (ppm)			Time – After:	
Total Vol Removed:				

PURGING MEASUREMENTS

Volume Removed (L)	Temp (°C)	pH	EC (mS/cm)	Eh (mV)

Comments:

WELL SAMPLING DETAILS

Method:				
Date:			**SWL – Before:**	
Undertaken By:			**Time- Before**	
pH			**Water Temperature (°C)**	
Eh (mV)			**EC: (mS/cm)**	

Containers Used/Comments

Tested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	**Lend lease Development**	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	G6D
Location:	Comland, St Marys	**Depth (m):**	8.50

WELL FINISH

☐	**Gatic Cover**	✓	**Standpipe**	☐	**PVC Pipe**

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:	submersible pump	**SWL – Before: (m)**	4.26	
Date:	3/11/99	**Time – Before:**	9:00	
Undertaken By:	BA	**SWL – After: (m)**	8.44	
Vol. Water Removed:	10	**Time – After:**		

Comments: pumped and bailed dry

WELL PURGE DETAILS

Method:			**SWL – Before:**	
Date:			**Time – Before:**	
Undertaken By:			**SWL – After:**	
PID Reading: (ppm)			**Time – After:**	
Total Vol Removed:				

PURGING MEASUREMENTS

Volume Removed (L)	Temp (°C)	pH	EC (mS/cm)	Eh (mV)

Comments:

WELL SAMPLING DETAILS

Method:				
Date:			**SWL – Before:**	
Undertaken By:			**Time- Before**	
pH			**Water Temperature (°C)**	
Eh (mV)			**EC: (mS/cm)**	

Containers Used/Comments

Tested By:	
Date Tested:	
Checked By:	
Date:	

Remarks:
- All measurements are corrected to ground level
- All stated Volumes are in Litres
- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

lient:	Lend lease Development	Job No.:	E13431F
roject:	Soil and Groundwater Investigation	Well No.:	G6S
ocation:	Comland, St Marys	Depth (rn):	4.85

ELL FINISH

☐	Gatic Cover	☐	Standpipe	☐ PVC Pipe

ELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
ethod:	bailer	SWL – Before: (m)	4.74	
ate:	3/11/99	Time – Before:		
ndertaken By:	BA	SWL – After: (m)	4.82	
ol. Water Removed:	0.2	Time – After:		

omments:

ELL PURGE DETAILS

ethod:			SWL – Before:	
ate:			Time – Before:	
ndertaken By:			SWL – After:	
ID Reading: (ppm)			Time – After:	
otal Vol Removed:				

URGING MEASUREMENTS

olume Removed (L)	Temp (°C)	pH	EC (mS/cm)	Eh (mV)

omments:

ELL SAMPLING DETAILS

ethod:				
ate:			SWL – Before:	
ndertaken By:			**Time- Before**	
H			**Water Temperature (°C)**	
h (mV)			**EC: (mS/cm)**	

ontainers **Used/Comments**

ested By:		Remarks:
ate Tested:		- All measurements are corrected to ground level
hecked By:		- All stated Volumes are in Litres
ate:		- SWL is an abbreviation for standing water level

SAMPLING DETAILS

ROUND ONE

Groundwater Monitoring Report

Client:	Lend Lease Development	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	P1S
Location:	Comland, St Marys	**Depth (m):**	5.90

WELL FINISH

☐ **Gatic Cover** ☑ **Standpipe** ☐ **PVC Pipe**

WELL DEVELOPMENT

	Stage 1		**Stage 1**	**Stage 2**
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:	Bailer	**SWL – Before:**	1.0
Date:	16/11/99	**Time – Before:**	1:30
Undertaken By:	JR	**SWL – After:**	5.90
PID Reading: (ppm)	na	**Time – After:**	
Total Vol Removed:	14		

PURGING MEASUREMENTS

Volume Removed (L)	***Temp ("C)***	**pH**	***EC* (mS/cm)**	***Eh* (mV)**
2	19.5	6.42	35.3	170.0
5	18.8	6.52	35.4	172.8
8.5	18.5	6.60	35.3	176.5
13	18.9	6.64	35.7	179.6

Comments: Well purged dry, final bailer used as sample

WELL SAMPLING DETAILS

Method:	bailer		
Date:	16/11/99	**SWL – Before:**	-
Undertaken By:	JR	**Time- Before**	1:45
pH	6.67	**Water Temperature (°C)**	19.3
Eh (mV)	185.5	**EC: (mS/cm)**	35.6

Containers Used/Comments

2 * 1 L Glass bottles, aluminium foil seals and plastic lids

2* 500mL HDPE Plastic bottles, acidified with HNO_3

Tested By:	
Date Tested:	
Checked By:	
Date:	

Remarks:

- All measurements are corrected to ground level
- All stated Volumes are in Litres
- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	Job No.:	E13431F
Project:	Soil and Groundwater Investigation	Well No.:	P1D
Location:	Comland, St Marys	Depth (m):	8.70

WELL **FINISH**

☐	**Gatic Cover**	☑	**Standpipe**	☐	**PVC Pipe**

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		Time – After:		

Comments:

WELL PURGE DETAILS

Method:	Bailer	**SWL – Before:**	2.05
Date:	16/11/99	**Time – Before:**	1:50
Undertaken By:	JR	**SWL – After:**	6.7
PID Reading: (ppm)	na	**Time – After:**	
Total Vol Removed:	16		

PURGING MEASUREMENTS

Volume Removed (L)	Temp (°C)	pH	EC (mS/cm)	Eh (mV)
2.5	18.8	6.63	30.0	183.2
5	18.8	6.70	36.3	169.7
8.0	19.1	6.72	36.4	169.2
12.0	18.7	6.66	36.6	170.9

Comments: Sampling undertaken at 16L as water became extremely silty

WELL SAMPLING DETAILS

Method:	bailer		
Date:	16/11/99	**SWL – Before:**	2.05
Undertaken By:	JR	**Time- Before**	2:10
pH	6.68	**Water Temperature (°C)**	18.9
Eh (mV)	170.2	**EC: (mS/cm)**	36.5

Containers Used/Comments

2 * 1 L Glass bottles, aluminium foil seals and plastic lids

2* 500mL HDPE Plastic bottles, acidified with HNO_3

Tested By:	Remarks:
Date Tested:	- All measurements are corrected to ground level
Checked By:	- All stated Volumes are in Litres
Date:	- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	P2S
Location:	Comland, St Marys	**Depth (m):**	4.40

WELL FINISH

☐ Gatic Cover ☑ Standpipe ☐ PVC Pipe

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:	na	**SWL – Before:**	PIEZOMETER DRY
Date:	16/11/99	**Time – Before:**	
Undertaken By:	JR	**SWL – After:**	
PID Reading: (ppm)	na	**Time – After:**	
Total Vol Removed:	nil		

PURGING MEASUREMENTS

Volume Removed (L)	Temp (°C)	pH	EC (mS/cm)	Eh (mV)
Piezometer 'Dry'				

Comments:

WELL SAMPLING DETAILS

Method:				
Date:			**SWL – Before:**	
Undertaken By:			**Time- Before**	
pH	-		**Water Temperature (°C)**	
Eh (mV)			**EC: (mS/cm)**	

Containers Used/Comments

No Sample Obtained

Tested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	Job No.:	E13431F
Project:	Soil and Groundwater Investigation	Well No.:	P2D
Location:	Comland, St Marys	Depth (m):	9.23

WELL FINISH

☐	Gatic Cover	✓	Standpipe	☐	PVC Pipe

WELL DEVELOPMENT

	Stage 1		**Stage 1**	**Stage 2**
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		Time – After:		

Comments:

WELL PURGE DETAILS

Method:	Submersible pump/bailer	**SWL – Before:**	6.15
Date:	16/11/99	**Time – Before:**	9:00
Undertaken By:	JR	**SWL – After:**	8.5
PID Reading: (ppm)	na	**Time – After:**	9:45
Total Vol Removed:	12.5		

PURGING MEASUREMENTS

Volume Removed (L)	**Temp (°C)**	**pH**	**EC (mS/cm)**	**Eh (mV)**
5		5.59	27.8	218.8
7		5.73	28.7	222.9
10		5.54	31.4	228.3

Comments: Sample taken from final bails, beyond this volume water became extremely silty

WELL SAMPLING DETAILS

Method:	Bailer		
Date:	16/11/99	**SWL – Before:**	
Undertaken By:	JR	**Time- Before**	9:00
pH	5.54	**Water Temperature (°C)**	
Eh (mV)	226.3	**EC: (mS/cm)**	33.3

Containers Used/Comments

2 • 1 L Glass bottles, aluminium foil seals and plastic lids

2* 500mL HDPE Plastic bottles, acidified with HNO_3

Tested By:	
Date Tested:	
Checked By:	
Date:	

Remarks.
- All measurements are corrected to ground level
- All stated Volumes are in Litres
- SWL is an abbreviation for standing water level

EIS

Groundwater Monitoring *Report*

Client:	Lend Lease Development	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	P3S
Location:	Comland, St Marys	**Depth (m):**	4.13

WELL FINISH

☐ **Gatic Cover** ☑ **Standpipe** ☐ **PVC Pipe**

WELL DEVELOPMENT

	Stage 1		**Stage 1**	**Stage 2**
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:	Bailer	**SWL – Before:**	2.35
Date:	16/11/99	**Time – Before:**	10:55
Undertaken By:	JR	**SWL – After:**	dry
PID Reading: (ppm)	na	**Time – After:**	11:15
Total Vol Removed:	6		

PURGING MEASUREMENTS

Volume Removed (L)	**Temp (°C)**	**pH**	**EC (mS/cm)**	**Eh (mV)**
2.5	22.7	6.06	1.956	198.8
5	19.7	6.22	1.790	198.8

Comments: Piezometer purged dry at 6L, sample obtained from final bails

WELL SAMPLING DETAILS

Method:	Bailer			
Date:	16/11/99		**SWL – Before:**	
Undertaken By:	JR		**Time- Before**	
pH	6.22		**Water Temperature (°C)**	19.8
Eh (mV)	198.9		**EC: (mS/cm)**	1.800

Containers Used/Comments

2 * 1 L Glass bottles, aluminium foil seals and plastic lids
2* 500mL HDPE Plastic bottles, acidified with HNO_3

Tested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	Job No.:	E13431F
Project:	Soil and Groundwater Investigation	Well No.:	: P3D
Location:	Comland, St Marys	Depth (m):	8.58

WELL FINISH

☐ Gatic Cover ☑ Standpipe ☐ PVC Pipe

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:		SWL – Before: (m)		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		Time – After:		

Comments:

WELL PURGE DETAILS

Method:	Bailer	**SWL – Before:**	5.10
Date:	16/11/99	**Time – Before:**	10:20
Undertaken By:	JR	**SWL – After:**	dry
PID Reading: (ppm)	na	**Time – After:**	10:45
Total Vol Removed:	12		

PURGING MEASUREMENTS

Volume Removed (L)	**Temp (°C)**	**pH**	**EC (mS/cm)**	**Eh (mV)**
4	19.7	5.57	39.1	241.0
7	20.0	5.58	40.0	242.1
11	20.3	5.83	40.2	241.5

Comments: Piezometer bailed dry at 12L, samples obtained from final bails

WELL SAMPLING DETAILS

Method:	Bailer			
Date:	16/11/99		**SWL – Before:**	
Undertaken By:			**Time- Before**	
pH	5.93		**Water Temperature (°C)**	20.9
Eh (mV)	235.5		**EC: (mS/cm)**	41.6

Containers Used/Comments

2 * 1 L Glass bottles, aluminium foil seals and plastic lids

2* 500mL HDPE Plastic bottles, acidified with HNO_3

Tested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		-All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	P4D
Location:	Comland, St Marys	**Depth (m):**	9.05

WELL FINISH

☐	**Gatic Cover**	✓	**Standpipe**	☐	**PVC Pipe**

WELL DEVELOPMENT

	Stage 1		**Stage 1**	**Stage 2**
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:	Bailer	**SWL – Before:**	1.65
Date:	16/11/99	**Time – Before:**	11:30
Undertaken By:	JR	**SWL – After:**	
PID Reading: (ppm)	na	**Time – After:**	
Total Vol Removed:	12		

PURGING MEASUREMENTS

Volume Removed (L)	**Temp (°C)**	**pH**	**EC (mS/cm)**	**Eh (mV)**
2	23.5	5.95	35.1	226.5
5	23.3	6.00	35.1	204.3
8	23.0	5.86	35.3	208.1
11	21.8	5.88	36.4	207.1

Comments: Sample taken at 12L as water became extremely silty

WELL SAMPLING DETAILS

Method:	Bailer			
Date:	16/11/99		**SWL – Before:**	final bail
Undertaken By:	JR		**Time- Before**	11:43
pH	6.03		**Water Temperature (°C)**	20.5
Eh (mV)	213.3		**EC: (mS/cm)**	37.7

Containers Used/Comments

2 * 1 L Glass bottles, aluminium foil seals and plastic lids
2* 500mL HDPE Plastic bottles, acidified with HNO_3

Tested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

EIS

Groundwater Monitoring Report

Client:	Lend Lease Development	Job No.:	E13431F
Project:	Soil and Groundwater Investigation	Well No.:	P4S
Location:	Comland, St Marys	Depth (m):	5.15

WELL FINISH

☐ Gatic Cover	☑ Standpipe	☐ PVC Pipe

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:		SWL – Before: (m)		
Date:		Time – Before:		
Undertaken By:		SWL – After: (m)		
Vol. Water Removed:		Time – After:		

Comments:

WELL PURGE DETAILS

Method:	Bailer	**SWL – Before:**	1.50
Date:	16/11/99	**Time – Before:**	11:45
Undertaken By:	JR	**SWL – After:**	
PID Reading: (ppm)	*na*	***Time – After:***	
Total Vol Removed:	21		

PURGING MEASUREMENTS

Volume Removed (L)	**Temp (°C)**	**pH**	**EC (mS/cm)**	**Eh (mV)**
3	22.0	5.28	32.3	218.4
6.5	22.6	5.21	32.8	21.04
8.5	22.9	5.22	33.8	208.2
13	23.4	5.18	32.8	201.0
17	22.1	5.23	33.5	184.0

Comments: Sample obtained at 21L as water became extremely silty beyond this volume

WELL SAMPLING DETAILS

Method:				
Date:			**SWL – Before:**	
Undertaken By:			**Time- Before**	
pH			**Water Temperature (°C)**	
Eh (mV)			EC: **(mS/cm)**	

Containers Used/Comments

2 * 1 L Glass bottles, aluminium foil seals and plastic lids

1* 500mL HDPE Plastic bottles, acidified with HNO_3

Tested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	P5S
Location:	Comland, St Marys	**Depth (m):**	5.70

WELL FINISH

☐	**Gatic Cover**	☑	**Standpipe**	☐	**PVC Pipe**

WELL DEVELOPMENT

	Stage 1		**Stage 1**	**Stage 2**
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:	Bailer	**SWL – Before:**	1.80
Date:	17/11/99	**Time – Before:**	3:00
Undertaken By:	JR	**SWL – After:**	dry
PID Reading: (ppm)	na	**Time – After:**	
Total Vol Removed:	13		

PURGING MEASUREMENTS

Volume Removed (L)	**Temp (°C)**	**pH**	**EC (mS/cm)**	**Eh (mV)**
3	19.8	5.59	25.9	187.2
6	18.2	5.57	25.6	193.3
9	17.8	5.65	25.8	195.6

Comments: Bailed dry, sample obtained from final bails

WELL SAMPLING DETAILS

Method:	bailer			
Date:	17/11/99		**SWL – Before:**	final bail
Undertaken By:	JR		**Time- Before**	3:10
pH	5.75		**Water Temperature (°C)**	17.7
Eh (mV)	199.9		**EC: (mS/cm)**	25.9

Containers Used/Comments

2 * 1 L Glass bottles, aluminium foil seals and plastic lids
2* 500mL HDPE Plastic bottles, acidified with HNO_3

Tested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	Job No.:	E13431F
Project:	Soil and Groundwater Investigation	Well No.:	P5D
Location:	Comland, St Marys	Depth (m):	8.55

WELL FINISH

☐	**Gatic Cover**	✓	**Standpipe**	☐	**PVC Pipe**

WELL DEVELOPMENT

	Stage 1		**Stage 1**	**Stage 2**
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:	Submersible Pump/Bailer	**SWL – Before:**	1.80
Date:	17/11/99	**Time – Before:**	3:30
Undertaken By:	JR	**SWL – After:**	8.55
PID Reading: (ppm)	na	**Time – After:**	4:00
Total Vol Removed:	42		

PURGING MEASUREMENTS

Volume Removed (L)	**Temp (°C)**	**pH**	**EC (mS/cm)**	**Eh (mV)**
2	18.2	6.17	24.6	185.7
5	17.9	6.21	24.0	184.2
9	17.8	6.21	24.0	149.4
12	17.8	5.94	24.4	145.3
15	17.7	5.85	24.5	147.4
22	17.6	5.82	25.5	147.3
28	17.5	5.75	24.6	151.4
34	17.4	5.77	24.1	150.2
38	17.5	6.06	24.5	127.2

Comments: Pumped / Bailed dry sample taken from last bailer

WELL SAMPLING DETAILS

Method:	bailer			
Date:	17/11/99		**SWL – Before:**	final bail
Undertaken By:	JR		**Time- Before**	4:00
pH	6.07		**Water Temperature (°C)**	17.4
Eh (mV)	125.3		**EC: (mS/cm)**	24.5

Containers Used/Comments

2 * 1 L Glass bottles, aluminium foil seals and plastic lids

2* 500mL HDPE Plastic bottles, acidified with HNO_3

Tested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	P6S
Location:	Comland, St Marys	**Depth (m):**	4.20

WELL FINISH

☐	**Gatic Cover**	✓	**Standpipe**	☐	**PVC Pipe**

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:	Bailer	**SWL – Before:**	3.45
Date:	17/11/99	**Time – Before:**	11:00
Undertaken By:	JR	**SWL – After:**	dry
PID Reading: (ppm)	na	**Time – After:**	
Total Vol Removed:	3		

PURGING MEASUREMENTS

Volume Removed (L)	Temp (°C)	pH	EC (mS/cm)	Eh (mV)
2	17.5	4.83	32.7	237.7

Comments: Bailed dry following removal of 3L

WELL SAMPLING DETAILS

Method:	bailer			
Date:	17/11/99		**SWL – Before:**	final bail
Undertaken By:	JR		**Time- Before**	11:05
pH	4.83		**Water Temperature (°C)**	17.3
Eh (mV)	249.3		**EC: (mS/cm)**	32.8

Containers Used/Comments

1 * 1 L Glass bottles, aluminium foil seals and plastic lids
1* 500mL HDPE Plastic bottles, acidified with HNO_3

Tested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	P6D
Location:	Comland, St Marys	**Depth (m):**	7.50

WELL FINISH

☐	**Gatic Cover**	✓	**Standpipe**	☐	**PVC Pipe**

WELL DEVELOPMENT

	Stage 1		**Stage 1**	**Stage 2**
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:	Bailer	**SWL – Before:**	1.05
Date:	17/11/99	**Time – Before:**	11:10
Undertaken By:	JR	**SWL – After:**	dry
PID Reading: (ppm)	na	**Time – After:**	
Total Vol Removed:	45		

PURGING MEASUREMENTS

Volume Removed (L)	**Temp (°C)**	**pH**	**EC (mS/cm)**	**Eh (mV)**
5	18.2	6.33	32.3	242.3
10	17.9	6.42	32.5	220.0
13.5	18.1	6.33	32.4	200.3
16	18.2	6.42	32.2	174.3
19	18.0	6.40	32.2	158.4
22	18.2	6.47	32.0	143.5
25	18.6	6.71	31.9	116.1
31	18.6	6.69	31.8	99.2
35	19.6	6.67	31.8	78.3
41	20.7	6.75	31.0	60.0

Comments:

WELL SAMPLING DETAILS

Method:	Bailer			
Date:	17/11		**SWL – Before:**	final bail
Undertaken By:	JR		**Time- Before**	
pH	6.91		**Water Temperature (°C)**	22.0
Eh (mV)	69.9		**EC: (mS/cm)**	31.6

Containers Used/Comments

2 * **1** L Glass bottles, aluminium foil seals and plastic lids
2* 500mL HDPE Plastic bottles, acidified with HNO_3

Tested By:		Remarks: - All measurements are corrected to ground level - All stated Volumes are in Litres - SWL is an abbreviation for standing water level
Date Tested:		
Checked By:		
Date:		

Groundwater Monitoring Report

Client:	Lend Lease Development	Job No.:	E13431F
Project:	Soil and Groundwater Investigation	Well No.:	P7S
Location:	Comland, St Marys	Depth (m):	4.05

WELL FINISH

	Gatic Cover	✓	**Standpipe**		**PVC Pipe**

WELL DEVELOPMENT

	Stage 1		**Stage 1**	**Stage 2**
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:		SWL – Before:	Piezometer 'dry'
Date:	17/11//99	**Time – Before:**	
Undertaken By:	1:45	**SWL – After:**	
PID Reading: (ppm)	na	**Time – After:**	
Total Vol Removed:	nil		

PURGING MEASUREMENTS

Volume Removed (L)	**Temp (°C)**	**pH**	**EC (mS/cm)**	**Eh (mV)**
PIEZOMETER				
'DRY'				

Comments:

WELL SAMPLING DETAILS

Method:				
Date:			**SWL – Before:**	
Undertaken By:			**Time- Before**	
pH			**Water Temperature (°C)**	
Eh (mV)			**EC: (mS/cm)**	

Containers Used/Comments

No sampling undertaken

Tested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	Job No.:	E13431F
Project:	Soil and Groundwater Investigation	Well No.:	P7D
Location:	Cornland, St Marys	Depth **(m):**	7.50

WELL FINISH

Gatic Cover	✓ Standpipe	PVC Pipe

WELL PURGE DETAILS

Method:	Bailer	**SWL – Before:**	1.65
Date:	17/11/99	**Time – Before:**	1:45
Undertaken By:	JR	**SWL – After:**	2.00
PID Reading: (ppm)	na	**Time – After:**	2:25
Total Vol Removed:	70		

PURGING MEASUREMENTS

Volume Removed (L)	Temp (°C)	pH	EC (mS/cm)	Eh (mV)
2	20.7	6.72	27.7	147.5
5	19.8	6.96	28.4	129.3
8.5	19.1	6.99	28.1	123.5
12	19.0	6.94	28.6	121.5
16	19.4	6.87	28.4	56.4
20	20.8	6.84	27.9	88.9
24	20.2	6.86	28.4	90.3
29	19.5	6.93	28.6	96.0
35	20.4	7.00	28.4	97.8
40	20.6	6.90	28.2	106.9
45	20.2	6.91	28.6	102.6
50	18.5	7.07	28.6	110.0
55	18.5	6.97	28.5	112.3
60	18.5	7.01	28.4	120.7
65	18.2	7.01	28.5	121.1

Comments:

VELL SAMPLING DETAILS

lethod:	bailer			
ate:	17/11/99		**SWL – Before:**	2.00
ndertaken By:	JR		**Time- Before**	2:25
H	6.95		**Water Temperature (°C)**	20.3
h (mV)	123.1		**EC: (mS/cm)**	28.4

ontainers Used/Comments

* 1 L Glass bottles, aluminium foil seals and plastic lids

• 500mL HDPE Plastic bottles, acidified with HNO_3

ested By:		Remarks:
ate Tested:		- All measurements are corrected to ground level
hecked By:		- All stated Volumes are in Litres
ate:		- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	G1
Location:	Comland, St Marys	**Depth (m):**	6.30

WELL FINISH

☐ **Gatic Cover** ☑ **Standpipe** ☐ **PVC Pipe**

WELL DEVELOPMENT

	Stage 1		**Stage 1**	**Stage 2**
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:	bailer	**SWL – Before:**	5.5
Date:	17/11/99	**Time – Before:**	
Undertaken By:	JR	**SWL – After:**	Dry
PID Reading: (ppm)	na	**Time – After:**	
Total Vol Removed:	2.0		

PURGING MEASUREMENTS

Volume Removed (L)	**Temp (°C)**	**pH**	**EC (mS/cm)**	**Eh (mV)**
No purging undertaken due to minimal water volume				

Comments:

WELL SAMPLING DETAILS

Method:	Bailer			
Date:	17/11/99		**SWL – Before:**	as above
Undertaken By:	JR		***Time- Before***	
pH	6.92		**Water Temperature (°C)**	22.3
Eh (mV)	152.3		**EC: (mS/cm)**	32.6

Containers Used/Comments

2 * 1 L Glass bottles, aluminium foil seals and plastic lids

2* 500mL HDPE Plastic bottles, acidified with HNO_3

Tested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	G2
Location:	Comland, St Marys	**Depth (m):**	5.66

WELL FINISH

Gatic Cover	✓ Standpipe	PVC Pipe

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:		**SWL – Before: (m)**		—
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:		**SWL – Before:**	Piezometer 'dry'
Date:		**Time – Before:**	
Undertaken By:		**SWL – After:**	
PID Reading: (ppm)		**Time – After:**	
Total Vol Removed:			

PURGING MEASUREMENTS

Volume Removed (L)	Temp (°C)	pH	EC (mS/cm)	Eh (mV)

Comments: PIEZOMETER 'DRY'

WELL SAMPLING DETAILS

Method:	No Sampling			
Date:	**Undertaken**		**SWL – Before:**	
Undertaken By:			**Time- Before**	
pH			**Water Temperature (°C)**	
Eh (mV)			**EC: (mS/cm)**	

Containers Used/Comments

No **sampling**

Tested By:		Remarks: - All **measurements are corrected** to **ground** level - All stated Volumes are in Litres - SWL is an abbreviation for standing water level
Date Tested:		
Checked By:		
Date:		

Groundwater Monitoring *Report*

Client:	Lend Lease Development	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	G3
Location:	Comland, St Marys	**Depth (m):**	8.20

WELL FINISH

☐ **Gatic Cover** ☑ **Standpipe** ☐ **PVC Pipe**

WELL DEVELOPMENT

	Stage 1		**Stage 1**	**Stage 2**
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:	Bailer	**SWL – Before:**	6.55
Date:	16/11/99	**Time – Before:**	12:45
Undertaken By:	JR	**SWL – After:**	dry
PID Reading: (ppm)	na	**Time – After:**	
Total Vol Removed:	8		

PURGING MEASUREMENTS

Volume Removed (L)	**Temp (°C)**	**pH**	**EC (mS/cm)**	**Eh (mV)**
2	19.9	6.39	20.8	190.3
5	20.0	6.47	23.3	188.7

Comments: Purged dry at 8L, samples obtained from final bails

WELL SAMPLING DETAILS

Method:	Bailer			
Date:	16/11/99		**SWL – Before:**	final bails
Undertaken By:	JR		**Time- Before**	12:50
pH	6.39		**Water Temperature (°C)**	20.0
Eh (mV)	184.0		**EC: (mS/cm)**	25.8

Containers Used/Comments

2 * 1 L Glass bottles, aluminium foil seals and plastic lids

2* 500mL HDPE Plastic bottles, acidified with HNO_3

Tested **By:**	Remarks:
Date Tested:	- All measurements are corrected to ground level
Checked By:	- All stated Volumes are in Litres
Date:	- SWL is an abbreviation for standing water level

Groundwater Monitoring *Report*

Client:	Lend Lease Development	Job No.:	E13431F
Project:	Soil and Groundwater investigation	Well No.:	G4
Location:	Comland, St Marys	Depth (m):	8.70

WELL FINISH

☐ Gatic Cover ☑ Standpipe ☐ PVC Pipe

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:		SWL – Before: (m)		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:	Bailer	SWL – Before:	1.60
Date:	16/11/99	**Time** – Before:	3:30
Undertaken By:	JR	**SWL – After:**	4.2
PID Reading: (ppm)	na	**Time – After:**	3:45
Total Vol Removed:	13		

PURGING MEASUREMENTS

Volume Removed (L)	Temp (°C)	pH	EC (mS/cm)	Eh (mV)
2	19.4	6.21	31.8	152.1
5	18.9	6.46	32.7	92.2
8.5	19.0	6.47	32.6	78.9
11	18.8	6.48	32.6	68.1

Comments: Piezometer purged dry, sample obtained from last bails

WELL SAMPLING DETAILS

Method:	Bailer			
Date:	16/11/99		**SWL – Before:**	4.2
Undertaken By:	JR		**Time- Before**	3:45
pH	6.56		**Water Temperature (°C)**	18.6
Eh (mV)	61.1		**EC: (mS/cm)**	32.5

Containers Used/Comments

2 * 1 L Glass bottles, aluminium foil seals and plastic lids
2* 500mL HDPE Plastic bottles, acidified with HNO_3

Tested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	G5
Location:	Comland, St Marys	**Depth (m):**	8.10

WELL FINISH

☐ **Gatic Cover** ☑ **Standpipe** ☐ **PVC Pipe**

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:	Bailer	**SWL – Before:**	5.0
Date:	17/11/99	**Time – Before:**	10:00
Undertaken By:	JR	**SWL – After:**	dry
PID Reading: (ppm)	na	**Time – After:**	
Total Vol Removed:	10		

PURGING MEASUREMENTS

Volume Removed (L)	Temp (°C)	pH	EC (mS/cm)	Eh (mV)
2.5	20.1	6.10	29.4	237.0
5	18.6	6.30	31.2	259.1
9	18.2	6.52	31.7	224.2

comments:

WELL SAMPLING DETAILS

Method:	Bailer			
Date:	17/11/99		**SWL – Before:**	last bail
Undertaken By:	JR		**Time- Before**	
pH	6.81		**Water Temperature (°C)**	18.1
Eh (mV)	*208.1*		**EC: (mS/cm)**	31.5

Containers Used/Comments

2 * 1 L Glass bottles, aluminium foil seals and plastic lids

2* 250mL HDPE Plastic bottles, acidified with HNO_3

Tested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	G6D
Location:	Comland, St Marys	**Depth (m):**	8.50

WELL FINISH

☐ **Gatic Cover** ☑ **Standpipe** ☐ **PVC Pipe**

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:	Bailer	**SWL – Before:**	5.55
Date:	17/11/99	**Time – Before:**	1:15
Undertaken By:	JR	**SWL – After:**	dry
PID Reading: (ppm)	na	**Time – After:**	
Total Vol Removed:	8		

PURGING MEASUREMENTS

Volume Removed (L)	Temp (°C)	pH	EC (mS/cm)	Eh (mV)
3	20.8	6.15	7.94	151.3
5.5	20.6	6.40	20.1	159.0

Comments:

WELL SAMPLING DETAILS

Method:	Bailer			
Date:	17/11/99		**SWL – Before:**	last bail
Undertaken By:	JR		**Time- Before**	
pH	6.54		**Water Temperature (°C)**	20.6
Eh (mV)	148.0		**EC: (mS/cm)**	20.3

Containers Used/Comments

2 * 1 L Glass bottles, aluminium foil seals and plastic lids

2* 250mL HDPE Plastic bottles, acidified with HNO_3

Tested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

EIS

Groundwater Monitoring Report

Client:	Lend Lease Development	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	G6S
Location:	Cornland, St Marys	**Depth (m):**	4.85

WELL FINISH

☐ **Gatic Cover**	✓ **Standpipe**	☐ **PVC Pipe**

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:		**SWL – Before:**	Piezometer 'dry'
Date:		**Time – Before:**	
Undertaken By:		**SWL – After:**	
PID Reading: (ppm)		**Time – After:**	
Total Vol Removed:			

PURGING MEASUREMENTS

Volume Removed (L)	Temp (°C)	pH	EC (mS/cm)	Eh (mV)
	piezometer dry			

Comments:

WELL SAMPLING DETAILS

Method:				
Date:			**SWL – Before:**	
Undertaken By:			**Time- Before**	
pH			**Water Temperature (°C)**	
Eh (mV)			**EC: (mS/cm)**	

Containers Used/Comments

No sampling undertaken as piezometer 'dry'

ested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

SAMPLING DETAILS

ROUND TWO

Groundwater Monitoring Report

Client:	Lend Lease Development	Job No.:	E13431F
Project:	Soil and Groundwater Investigation	Well No.:	PIS
Location:	Comland, St Marys	Depth (rn):	5.90

WELL FINISH

☐ Gatic Cover	☑ Standpipe	☐ PVC Pipe

WELL DEVELOPMENT

	Stage 1		**Stage 1**	**Stage 2**
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:	Submersible pump/Bailer	**SWL – Before:**	1.43
Date:	13/1/00	**Time – Before:**	1:58
Undertaken By:	JR/CT	**SWL – After:**	5.62
PID Reading: (ppm)	na	**Time – After:**	2:25
Total Vol Removed:	22		

PURGING MEASUREMENTS

Volume Removed (L)	**Temp (°C)**	**pH**	**EC (mS/cm)**	**Eh (mV)**
2	23.5	6.61	26.1	168.2
4	21.2	6.64	26.1	169.1
6	20.4	6.69	24.5	168.3
8	20.0	6.67	24.6	170.2
10	19.7	6.68	25.7	170.8
12	19.8	6.77	27.2	170.9
14	19.7	6.75	27.1	169.8
16	19.5	6.95	27.2	170.1

Comments: final bailer used as sample

WELL SAMPLING DETAILS

Method:	bailer		
Date:	13/1/00	**SWL – Before:**	
Undertaken By:	JR/CT	**Time- Before**	2:20
pH	6.95	**Water Temperature (°C)**	19.6
Eh (mV)	165.6	**EC: (mS/cm)**	27.4

Containers **Used/Comments**

2 * 1 L Glass bottles, aluminium foil seals and plastic lids

Tested By:	
Date Tested:	
Checked By:	
Date:	

Remarks:
- All measurements are corrected to ground level
- All stated Volumes are in Litres
- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	Job No.:	E13431F
Project:	Soil and Groundwater Investigation	Well No.:	P1D
Location:	Comland, St Marys	Depth (m):	8.70

WELL FINISH

☐	**Gatic Cover**	✓	**Standpipe**	☐	**PVC Pipe**

WELL DEVELOPMENT

	Stage 1		**Stage 1**	**Stage 2**
Method:		**SWL – Before: (m)**		

Comments:

WELL PURGE DETAILS

Method:	Bailer	**SWL – Before:**	1.42
Date:	13/1/00	**Time – Before:**	2:20
Undertaken By:	JR	**SWL – After:**	8.41
PID Reading: (ppm)	na	**Time – After:**	3:05
Total Vol Removed:	36		

PURGING MEASUREMENTS

Volume Removed (L)	**Temp (°C)**	**pH**	**EC (mS/cm)**	**Eh (mV)**
2.5	20.9	6.37	27.0	175.9
5	20.9	6.54	27.0	176.2
8	20.9	6.58	27.1	175.1
10	20.7	6.53	26.5	175.8
12	20.2	6.54	26.6	175.1
15	20.0	6.60	26.7	171.0
18	19.8	6.58	25.0	167.2
20.5	19.8	6.60	24.9	165.3
23	19.8	6.73	27.1	160.3
25	19.9	6.76	26.8	160.0
28	21. 4	7.09	27.3	149.4

Comments:

WELL SAMPLING DETAILS

Method:	bailer		
Date:	16/11/99	**SWL – Before:**	2.05
Undertaken By:	JR	**Time- Before**	2:10
pH	6.68	**Water Temperature (°C)**	18.9
Eh (mV)	170.2	**EC: (mS/cm)**	36.5

Containers Used/Comments

2 * 1 L Glass bottles, aluminium foil seals and plastic lids

2* 500mL HDPE Plastic bottles, acidified with HNO_3

Tested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	Job No.:	E13431F
Project:	Soil and Groundwater Investigation	Well No.:	P2S
Location:	Comland, St Marys	Depth (m):	4.40

WELL FINISH

☐	Gatic Cover	✓	Standpipe	☐	PVC Pipe

WELL DEVELOPMENT

	Stage 1		**Stage 1**	**Stage 2**
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:	na	**SWL – Before:**	PIEZOMETER DRY
Date:	16/11/99	**Time – Before:**	
Undertaken By:	JR	**SWL – After:**	
PID Reading: (ppm)	na	**Time – After:**	
Total Vol Removed:	nil		

PURGING MEASUREMENTS

Volume Removed (L)	**Temp (°C)**	**pH**	**EC (mS/cm)**	**Eh (mV)**
Piezometer				
'Dry'				

Comments:

WELL SAMPLING DETAILS

Method:				
Date:			**SWL – Before:**	
Undertaken By:			**Time- Before**	
pH			**Water Temperature (°C)**	
Eh (mV)			**EC: (mS/cm)**	

Containers **Used/Comments**

2 * 1 L Glass bottles, aluminium foil seals and plastic lids

2* 500mL HDPE Plastic bottles, acidified with HNO_3

Tested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	P2D
Location:	Comland, St Marys	**Depth (m):**	9.23

WELL FINISH

☐ **Gatic Cover** ☑ **Standpipe** ☐ **PVC Pipe**

WELL DEVELOPMENT

	Stage 1		**Stage 1**	**Stage 2**
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:	Submersible pump/bailer	**SWL – Before:**	6.05
Date:	12/1/00	**Time – Before:**	9:10
Undertaken By:	JR/CT	**SWL – After:**	6.90
PID Reading: (ppm)	na	**Time – After:**	10:20
Total Vol Removed:	31		

PURGING MEASUREMENTS

Volume Removed (L)	**Temp (°C)**	**pH**	**EC (mS/cm)**	**Eh (mV)**
2	21.1	5.74	28.5	26.37
4	20.8	5.67	28.9	265.0
6	20.4	5.69	28.9	264.2
8	20.4	5.71	29.0	263.4
10	20.3	5.73	29.0	262.6
12	21.8	5.48	29.4	260.8
16	21.0	5.75	28.9	260.2
20	20.8	5.75	28.9	260.1
25	20.8	5.75	29.0	259.6
30	20.7	5.75	28.8	259.6

Comments:

WELL SAMPLING DETAILS

Method:	Bailer		
Date:	12/1/00	**SWL – Before:**	6.90
Undertaken By:	JR/CT	**Time- Before**	10:20
pH	5.80	**Water Temperature (°C)**	21.0
Eh (mV)	257.7	**EC: (mS/cm)**	28.7

Containers Used/Comments

2 * 1 L Glass bottles, aluminium foil seals and plastic lids

Tested By:	
Date Tested:	
Checked By:	
Date:	

Remarks:
- All measurements are corrected to ground level
- All stated Volumes are in Litres
- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	Job No.:	E13431F
Project:	Soil and Groundwater Investigation	Well No.:	P3S
Location:	Comland, St Marys	Depth (m):	4.13

WELL FINISH

☐	**Gatic Cover**	✓	**Standpipe**	☐	**PVC Pipe**

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:		**SWL – Before: (m)**		
Date:		Time – Before:		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:	Bailer	**SWL – Before:**	4.00
Date:	12/1/00	**Time – Before:**	
Undertaken By:	JR	**SWL – After:**	
PID Reading: (ppm)	na	**Time – After:**	
Total Vol Removed:	0.20		

PURGING MEASUREMENTS

Volume Removed (L)	**Temp (°C)**	**pH**	**EC (mS/cm)**	**Eh (mV)**
Insufficient volume of water present to undertake purging				

Comments: Piezometer purged dry at 6L, sample obtained from final bails

WELL SAMPLING DETAILS

Method:				
Date:	Insufficient volume in well to undertake sampling		**SWL – Before:**	
Undertaken **By:**			**Time- Before**	
pH			**Water Temperature (°C)**	
Eh (mV)			**EC: (mS/cm)**	

Containers **Used/Comments**

Tested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

EIS

Groundwater Monitoring Report

Client:	Lend Lease Development	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	P3D
Location:	Comland, St Marys	**Depth (m):**	8.58

WELL FINISH

☐	**Gatic Cover**	✓	**Standpipe**	☐	**PVC Pipe**

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Val. Water Removed:		**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:	Bailer	**SWL – Before:**	5.24
Date:	12/1/00	**Time – Before:**	11:15
Undertaken By:	JR/CT	**SWL – After:**	8.58
PID Reading: (ppm)	na	**Time – After:**	11:40
Total Vol Removed:	11		

PURGING MEASUREMENTS

Volume Removed (L)	Temp (°C)	pH	EC (mS/cm)	Eh (mV)
2	24.7	5.57	30.0	264.4
4	22.9	5.55	29.9	255.0
6	21.7	5.58	30.0	245.2
8	21.0	5.65	31.3	243.5
10	21.1	5.94	31.9	233.9

Comments: Piezometer bailed dry at 11L, samples obtained from final bails

WELL SAMPLING DETAILS

Method:	Bailer			
Date:	12/1/00		**SWL – Before:**	
Undertaken By:	JR/CT		**Time- Before**	
pH	6.01		**Water Temperature (°C)**	20.9
Eh (mV)	233.0		**EC: (mS/cm)**	32.3

Containers Used/Comments

2 * 1 L Glass bottles, aluminium foil seals and plastic lids

2* 500mL HDPE Plastic bottles, acidified with HNO_3

Tested By:		Remarks:
Date Tested:		- *All measurements are corrected to ground level*
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	P4D
Location:	Comland, St Marys	**Depth (m):**	9.05

WELL FINISH

☐	**Gatic Cover**	✓	**Standpipe**	☐	**PVC Pipe**

WELL DEVELOPMENT

	Stage 1		**Stage 1**	**Stage 2**
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:	Bailer	**SWL – Before:**	1.60
Date:	17/1/00	**Time – Before:**	8:45
Undertaken By:	JR/CT	**SWL – After:**	9.02
PID Reading: (ppm)	na	**Time – After:**	
Total Vol Removed:	20		

PURGING MEASUREMENTS

Volume Removed (L)	Temp (°C)	pH	EC (mS/cm)	Eh (mV)
2	21.1	6.00	29.2	-
5	20.8	6.08	30.4	215.6
8	20.1	5.93	30.1	213.6
10	21.0	6.03	30.3	208.7
12	20.4	6.17	30.3	198.6
15	20.3	6.19	29.5	197.7
18	19.9	6.34	25.3	190.9

Comments: Sample taken at 20L as water became extremely silty, further 4.5L removed

WELL SAMPLING DETAILS

Method:	*Bailer*			
Date:	17/1/00		**SWL – Before:**	8.83
Undertaken By:	JR/CT		**Time- Before**	10:22
pH	6.55		**Water Temperature (°C)**	19.9
Eh (mV)	176.4		**EC: (mS/cm)**	19.9

Containers Used/Comments

2 * 1 L Glass bottles, aluminium foil seals and plastic lids
2* 500mL HDPE Plastic bottles, acidified with HNO_3

Tested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	P4S
Location:	Comland, St Marys	**Depth (m):**	5.15

WELL FINISH

☐ **Gatic Cover** ☑ **Standpipe** ☐ **PVC Pipe**

WELL DEVELOPMENT

	Stage 1		**Stage 1**	**Stage 2**
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:	Bailer	**SWL – Before:**	1.60
Date:	17/1/00	**Time – Before:**	9:30
Undertaken By:	JR/CT	**SWL – After:**	3.11
PID Reading: (ppm)	na	**Time – After:**	9:47
Total Vol Removed:	53		

PURGING MEASUREMENTS

Volume Removed (L)	**Temp (°C)**	**pH**	**EC (mS/cm)**	**Eh (mV)**
2	20.7	5.67	20.9	161.6
4	20.3	5.33	26.1	164.7
6	20.1	5.31	25.5	160.0
10	19.9	5.23	26.0	157.9
12	19.8	5.23	25.9	156.3
15	19.7	5.22	25.9	155.7
18	19.7	5.23	25.9	155.0
20	19.7	5.23	25.1	151.3
22	19.6	5.27	24.3	151.7
24	19.5	5.26	24.4	151.6
26	19.5	5.27	25.8	150.9
28	19.5	5.26	25.9	151.1
30	19.6	5.25	25.8	151.7
32	19.6	5.26	25.9	150.8
34	19.6	5.25	25.8	150.9
36	19.5	5.25	25.9	151.7
38	19.6	5.25	25.8	151.7
40	19.6	5.26	25.9	150.9
42	19.6	5.26	25.9	151.6
44	19.6	5.27	25.9	149.8
46	19.6	5.27	25.9	149.8
48	19.6	5.26	26.0	151.0
50	19.6	5.26	26.0	150.9

Comments:

WELL SAMPLING DETAILS

Method:	Bailer			
Date:	17/1/00		**SWL – Before:**	3.11
Undertaken By:	JR/CT		**Time- Before**	9:47
pH	5.26		**Water Temperature (°C)**	19.8
Eh (mV)	151.5		**EC: (mS/cm)**	25.9

Containers Used/Comments

2 • 1 L Glass bottles, aluminium foil seals and plastic lids

Tested By: Date Tested: Checked By: Date:	Remarks: - All measurements are corrected to ground level - All stated Volumes are in Litres - SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	Job No.:	E13431F
Project:	Soil and Groundwater Investigation	Well No.:	P5S
Location:	Comland, St Marys	Depth (m):	5.70

WELL FINISH

☐ Gatic Cover ☑ Standpipe ☐ PVC Pipe

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:	Bailer	SWL – Before:	1.95
Date:	12/1/00	Time – Before:	2:40
Undertaken By:	JR	SWL – After:	4.93
PID Reading: (ppm)	na	Time – After:	2:51
Total Vol Removed:	10		

PURGING MEASUREMENTS

Volume Removed (L)	**Temp (°C)**	**pH**	**EC (mS/cm)**	**Eh (mV)**
2	21.1	4.80	23.8	242.5
5	19.6	4.80	22.2	245.5
8	19.1	4.94	22.3	239.3

Comments: Bailed dry, sample obtained from final bails

WELL SAMPLING DETAILS

Method:	bailer			
Date:	12/1/00		**SWL – Before:**	final bails
Undertaken By:	JR		**Time- Before**	
pH	5.13		**Water Temperature (°C)**	19.1
Eh (mV)	231.5		**EC: (mS/cm)**	22.6

Containers **Used/Comments**

2 * 1 L Glass bottles, aluminium foil seals and plastic lids

2* 500mL HDPE Plastic bottles, acidified with HNO_3

Tested By:		Remarks: - Al' measurements are corrected to ground level - All stated Volumes are in Litres - SWL is an abbreviation for standing water level
Date Tested:		
Checked By:		
Date:		

Groundwater Monitoring Report

Client:	Lend Lease Development	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	P5D
Location:	Comland, St Marys	**Depth (m):**	8.55

WELL FINISH

☐	**Gatic Cover**	✓	**Standpipe**	☐	**PVC Pipe**

WELL DEVELOPMENT

	Stage 1		**Stage 1**	**Stage 2**
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		

Comments:

WELL PURGE DETAILS

Method:	Submersible Pump/Bailer	**SWL – Before:**	1.60
Date:	12/1/00	**Time – Before:**	1:55
Undertaken By:	JR/CT	**SWL – After:**	8.33
PID Reading: (ppm)	na	**Time – After:**	2:28
Total Vol Removed:	30		

PURGING MEASUREMENTS

Volume Removed (L)	**Temp (°C)**	**pH**	**EC (mS/cm)**	**Eh (mV)**
2	26.2	5.06	20.9	226.3
5	23.8	6.10	22.7	159.9
8	21.1	6.07	23.4	157.0
13	20.5	5.91	23.3	158.1
16	20.4	5.83	23.1	158.0
20	20.0	5.7	23.1	156.8
24	19.7	6.12	23.8	113.8
28	19.2	6.27	25.1	100.6

Comments: Water became extremely silty so sample taken at 28L

WELL SAMPLING DETAILS

Method:	bailer			
Date:	12/1/00		**SWL – Before:**	5.15
Undertaken By:	JR		**Time- Before**	2:28
pH	6.36		**Water Temperature (°C)**	19.8
Eh (mV)	93.8		**EC: (mS/cm)**	25.1

***Containers* Used/Comments**

2 * *1* L Glass bottles, aluminium foil seals and plastic lids

Tested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	P6S
Location:	Comland, St Marys	**Depth (m):**	4.20

WELL FINISH

☐ **Gatic Cover** ✓ **Standpipe** ☐ **PVC Pipe**

WELL DEVELOPMENT

	Stage 1		**Stage 1**	**Stage 2**
Method:		**SWL –** Before: (m)		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:	Bailer	**SWL – Before:**	1.48
Date:	13/1/00	**Time – Before:**	10:00
Undertaken By:	JR/CT	**SWL – After:**	4.19
PID Reading: (ppm)	na	**Time – After:**	10:14
Total Vol Removed:	9		

PURGING MEASUREMENTS

Volume Removed (L)	**Temp (°C)**	**pH**	**EC (mS/cm)**	**Eh (mV)**
2	21.7	4.02	26.2	223.0
5	21.0	4.17	23.9	241.8
7	20.1	4.11	23.8	287.0

Comments: Purged dry at 10L sample obtained from bailers

WELL SAMPLING DETAILS

Method:	bailer			
Date:	13/1/00		**SWL – Before:**	final bail
Undertaken By:	JR/CT		**Time- Before**	10:15
pH	4.26		**Water Temperature (°C)**	21.7
Eh (mV)	323.3		**EC: (mS/cm)**	26.2

Containers **Used/Comments**

1 • 1 L Glass bottles, aluminium foil seals and plastic lids

1* 500mL HDPE Plastic bottles, acidified with HNO_3

Tested By:		Remarks.
Date Tested:		- All measurements are corrected to ground level
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	P6D
Location:	Comland, St Marys	**Depth (m):**	7.50

WELL FINISH

☐	**Gatic Cover**	✓	**Standpipe**	☐	**PVC Pipe**

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:	Bailer	**SWL – Before:**	0.94
Date:	13/1/00	**Time – Before:**	8:35
Undertaken By:	JR/CT	**SWL – After:**	7.37
PID Reading: (ppm)	na	**Time – After:**	9:29
Total Vol Removed:	51		

PURGING MEASUREMENTS

Volume Removed (L)	Temp (°C)	pH	EC (mS/cm)	Eh (mV)
5	20.5	5.74	27.1	142.0
10	19.8	5.60	28.2	129.1
13	19.6	5.81	28.2	119.2
15	19.3	5.69	28.4	117.4
18	19.2	5.75	28.5	116.4
20	19.2	5.81	28.7	92.8
25	19.6	6.19	28.5	73.5
30	19.2	6.25	29.1	63.3
35	19.0	6.36	29.0	60.7
40	19.1	6.4	29.3	49.3
45	19.2	6.50	29.0	47.3

Comments:

WELL SAMPLING DETAILS

Method:	Bailer			
Date:	13/1/00		**SWL – Before:**	final bail
Undertaken By:	JR		**Time- Before**	
pH	6.91		**Water Temperature (°C)**	22.0
Eh (mV)	69.9		**EC: (mS/cm)**	31.6

Containers Used/Comments

2 * 1 L Glass bottles, aluminium foil seals and plastic lids

2* 500mL HDPE Plastic bottles, acidified with HNO_3

Tested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	Job No.:	E13431F
Project:	Soil and Groundwater Investigation	Well No.:	P7S
Location:	Comland, St Marys	Depth (m):	4.05

WELL FINISH

☐ **Gatic Cover** ✓ **Standpipe** ☐ **PVC Pipe**

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:		**SWL – Before:**	Piezometer 'dry'
Date:	12/1/00	**Time – Before:**	1:30
Undertaken By:	JR/CT	**SWL – After:**	
PID Reading: (ppm)	na	**Time – After:**	
Total Vol Removed:	nil		

PURGING MEASUREMENTS

Volume Removed (L)	Temp ("C)	pH	EC (mS/cm)	Eh (mV)
PIEZOMETER 'DRY'				

Comments:

WELL SAMPLING DETAILS

Method:				
Date:			**SWL – Before:**	
Undertaken By:			**Time- Before**	
pH			**Water Temperature (°C)**	
Eh **(mV)**			EC: **(mS/cm)**	

Containers **Used/Comments**

No sampling undertaken

Tested By:		Remarks:
Date Tested:		-All measurements are corrected to ground level
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	P7D
Location:	*Comland, St Marys*	***Depth (m):***	*7.50*

WELL FINISH

☐	**Gatic Cover**	✓	**Standpipe**	☐	**PVC Pipe**

WELL PURGE DETAILS

Method:	Bailer	**SWL – Before:**	1.80
Date:	*12/1/00*	**Time – *Before:***	*12:45*
Undertaken By:	JR/CT	**SWL – After:**	2.42
PID Reading: (ppm)	na	**Time – After:**	1:10
Total Vol Removed:	70		

PURGING MEASUREMENTS

Volume Removed (L)	**Temp (°C)**	**pH**	**EC (mS/cm)**	**Eh (mV)**
2	23.3	6.35	25.9	191.5
4	21.5	6.38	27.3	1760
7	20.7	6.37	27.1	174.6
10	20.1	6.36	27.2	172.9
14	19.3	6.37	27.4	169.5
18	19.2	6.35	27.5	168.9
22	19.2	6.39	27.4	167.9
25	19.3	6.41	27.5	166.5
28	19.6	6.51	27.5	157.0
31	19.9	6.46	27.4	155.0
34	20.0	6.47	27.4	155.4
38	19.9	6.48	27.2	155.1
42	19.8	6.49	27.2	153.8
46	19.8	6.51	27.2	152.4
50	19.6	6.51	27.4	152.5
54	19.4	6.65	27.5	145.0
58	19.2	6.54	27.4	144.4
62	19.6	6.54	27.4	145.0
65	20.5	6.55	27.4	145.3

Comments:

WELL SAMPLING DETAILS

Method:	bailer			
Date:	12/1/00		**SWL – Before:**	2.42
Undertaken By:	JR/CT		**Time- Before**	1:10
pH	6.59		**Water Temperature (°C)**	20.4
Eh (mV)	144.3		**EC: (mS/cm)**	27.5

Containers Used/Comments

2 * 1 L Glass bottles, aluminium foil seals and plastic lids

Tested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	Job No.:	E13431F
Project:	Soil and Groundwater Investigation	Well No.:	G1
Location:	Cornland, St Marys	Depth (m):	6.30

WELL FINISH

☐ Gatic Cover ☑ Standpipe ☐ PVC Pipe

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:	bailer	SWL – Before:	3.58
Date:	17/1/00	Time – Before:	3:10
Undertaken By:	JR/CT	SWL – After:	5.60
PID Reading: (ppm)	na	Time – After:	3:20
Total Vol Removed:	6		

PURGING MEASUREMENTS

Volume Removed (L)	Temp ("C)	pH	EC **(mS/cm)**	Eh **(mV)**
2	20.8	6.86	19.49	150.6
4	20.6	7.06	11.35	146.1

Comments: Bailed dry, sample obtained from final bails

WELL SAMPLING DETAILS

Method:	Bailer			
Date:	17/1100		SWL – Before:	
Undertaken By:	JR/CT		**Time-** Before	3:20
pH	7.02		Water Temperature **(°C)**	20.7
Eh (mV)	151.3		EC: **(mS/cm)**	19.18

Containers Used/Comments

2 * 1 L Glass bottles, aluminium foil seals and plastic lids

2* 500mL HDPE Plastic bottles, acidified with HNO_3

Tested By:		Remarks:
Date Tested:		-All measurements are corrected to ground level
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	G2
Location:	Comland, St Marys	**Depth (m):**	5.66

WELL FINISH

☐	**Gatic Cover**	✓	**Standpipe**	☐	**PVC Pipe**

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:		SWL – Before: (m)		
Date:		Time – Before:		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		**Time** – After:		

Comments:

WELL PURGE DETAILS

Method:	Bailer	SWL – Before:	5.13
Date:	13/1/00	Time – Before:	1:37
Undertaken By:	JR/CT	SWL – After:	dry (5.65)
PID Reading: (ppm)	na	Time – After:	1:45
Total Vol Removed:	1.5		

PURGING MEASUREMENTS

Volume Removed **(L)**	**Temp** (°C)	**pH**	EC **(mS/cm)**	Eh **(mV)**
No purging undertaken due to insufficient volume of water				

Comments:

WELL SAMPLING DETAILS

Method:	Bailer			
Date:	13/1/00		**SWL – Before:**	
Undertaken By:	JR/CT		**Time- Before**	
pH	7.01		**Water Temperature (°C)**	21.0
Eh (mV)	171.1		**EC: (mS/cm)**	22.7

Containers Used/Comments

1 * 1L Glass bottle with foil seal

Tested By:	Remarks:
Date Tested:	- All measurements are corrected to ground level
Checked By:	- All stated Volumes are in Litres
Date:	- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	Job No.:	E13431F
Project:	Soil and Groundwater Investigation	Well No.:	G3
Location:	Comland, St Marys	Depth (m):	8.20

WELL FINISH

☐ Gatic Cover ☑ Standpipe ☐ PVC Pipe

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		
Undertaken **By:**		SWL – After: (m)		
Vol. Water Removed:		**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:	Bailer	**SWL – Before:**	4.65
Date:	17/1/00	Time – Before:	1:55
Undertaken By:	JR/CT	**SWL – After:**	8.05
PID Reading: (ppm)	na	**Time – After:**	2.04
Total Vol Removed:	8		

PURGING MEASUREMENTS

Volume Removed (L)	Temp (°C)	pH	EC (mS/cm)	Eh (mV)
2	20.3	6.38	22.4	171.2
4	19.7	6.42	23.4	173.2
6	19.5	6.48	22.5	170.8

Comments: Purged dry at 8L, samples obtained from final bails

WELL SAMPLING DETAILS

Method:	Bailer			
Date:	17/1/00		**SWL – Before:**	final bails
Undertaken By:	JR/CT		**Time- Before**	2:04
pH	6.50		**Water Temperature (°C)**	19.4
Eh (mV)	168.6		**EC: (mS/cm)**	22.6

Containers Used/Comments

2 * 1 L Glass bottles, aluminium foil seals and plastic lids

2* 500mL HDPE Plastic bottles, acidified with HNO_3

Tested By:	Remarks:
Date Tested:	-All measurements are corrected to ground level
Checked By:	- All stated Volumes are in Litres
Date:	- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	G4
Location:	Comland, St Marys	**Depth (m):**	8.70

WELL **FINISH**

☐ Gatic Cover ☑ Standpipe ☐ PVC Pipe

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		

Comments:

WELL PURGE DETAILS

Method:	Bailer	SWL – Before:	1.43
Date:	12/1/00	Time – Before:	4:00
Undertaken By:	JR/CT	SWL – After:	5.60
PID Reading: (ppm)	na	Time – After:	4:38
Total **Vol** Removed:	40		

PURGING MEASUREMENTS

Volume Removed (L)	Temp (°C)	pH	EC (mS/cm)	Eh (mV)
2	23.0	5.97	25.5	87.0
5	22.0	6.04	27.0	74.3
8	20.8	6.13	27.4	72.4
9	20.6	6.20	27.5	58.9
11	22.4	6.30	27.5	65.8
13	21.1	6.33	27.6	57.3
15	21.1	6.42	26.9	54.5
17	21.5	6.56	26.3	44.7
21	22.7	6.50	26.2	41.4
23	21.8	6.52	25.9	37.9
25	20.8	6.49	24.4	43.2
29	19.9	6.46	24.8	47.3
33	19.4	6.49	24.8	23.4
37	19.2	6.48	24.9	48.1

Comments:

WELL SAMPLING DETAILS

Method:	Bailer			
Date:	12/1/00		**SWL – Before:**	5.60
Undertaken By:	JR/CT		**Time- Before**	4:37
pH	6.07		**Water Temperature (°C)**	19.2
Eh (mV)	47.7		**EC: (mS/cm)**	24.6

Containers Used/Comments

2 * 1 L Glass bottles, aluminium foil seals and plastic lids

2* 500mL HDPE Plastic bottles, acidified with HNO_3

Tested By:	Remarks:
Date Tested:	- All measurements are corrected to ground level
Checked By:	-All stated Volumes are in Litres
Date:	- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	Job No.:	E13431F
Project:	Soil and Groundwater Investigation	Well No.:	G4
Location:	Cornland. St Marys	Depth (m):	8.70

WELL **FINISH**

☐	Gatic Cover	✓	Standpipe	☐	PVC Pipe

WELL DEVELOPMENT

	Stage 1		**Stage 1**	**Stage 2**
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		

Comments:

WELL PURGE DETAILS

Method:	Bailer	**SWL – Before:**	1.43
Date:	12/1/00	**Time – Before:**	4:00
Undertaken By:	JR/CT	**SWL – After:**	5.60
PID Reading: (ppm)	na	**Time – After:**	4:38
Total Vol Removed:	40		

PURGING MEASUREMENTS

Volume Removed (L)	**Temp (°C)**	**pH**	**EC (mS/cm)**	**Eh (mV)**
2	23.0	5.97	25.5	87.0
5	22.0	6.04	27.0	74.3
8	20.8	6.13	27.4	72.4
9	20.6	6.20	27.5	58.9
11	22.4	6.30	27.5	65.8
13	21.1	6.33	27.6	57.3
15	21.1	6.42	26.9	54.5
17	21.5	6.56	26.3	44.7
21	22.7	6.50	26.2	41.4
23	21.8	6.52	25.9	37.9
25	20.8	6.49	24.4	43.2
29	19.9	6.46	24.8	47.3
33	19.4	6.49	24.8	23.4
37	19.2	6.48	24.9	48.1

Comments:

WELL SAMPLING DETAILS

Method:	Bailer			
Date:	12/1/00		***SWL – Before:***	5.60
Undertaken By:	JR/CT		**Time- Before**	4:37
pH	6.07		**Water Temperature (°C)**	19.2
Eh (mV)	47.7		**EC: (mS/cm)**	24.6

Containers Used/Comments

2 * I L Glass bottles, aluminium foil seals and plastic lids

2* 500mL HDPE Plastic bottles, acidified with HNO_3

Tested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	Job No.:	E13431F
Project:	Soil and Groundwater Investigation	Well No.:	G5
Location:	Comland, St Marys	Depth (m):	8.10

WELL FINISH

☐ Gatic Cover ☑ Standpipe ☐ PVC Pipe

WELL DEVELOPMENT

	Stage 1		Stage 1	Stage 2
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		
Undertaken By:		SWL – After: (m)		
Vol. Water Removed:		Time – After:		

Comments:

WELL PURGE DETAILS

Method:	Bailer	**SWL – Before:**	4.66
Date:	17/1/00	Time – Before:	12:20
Undertaken By:	JR/CT	**SWL – After:**	7.88
PID Reading: (ppm)	na	**Time – After:**	12:26
Total Vol Removed:	11		

PURGING MEASUREMENTS

Volume Removed (L)	Temp (°C)	pH	EC (mS/cm)	Eh (mV)
2	20.2	6.07	28.0	165.0
4	19.7	5.81	27.8	174.2
6	19.4	5.93	26.6	167.8
8	19.3	5.81	27.4	162.6

Comments: Bailed dry after 11 L, sample obtained from final bailer

WELL SAMPLING DETAILS

Method:	Bailer			
Date:	17/1/00		**SWL – Before:**	final bail
Undertaken By:	JR/CT		**Time- Before**	
pH	6.25		**Water Temperature (°C)**	19.4
Eh (mV)	156.5		**EC: (mS/cm)**	28.5

Containers Used/Comments

2 * 1 L Glass bottles, aluminium foil seals and plastic lids
2* 250mL HDPE Plastic bottles, acidified with HNO_3

Tested By:		Remarks:
Date Tested:		- All measurements are corrected to ground level
Checked By:		- All stated Volumes are in Litres
Date:		- SWL is an abbreviation for standing water level

Groundwater Monitoring Report

Client:	Lend Lease Development	**Job No.:**	E13431F
Project:	Soil and Groundwater Investigation	**Well No.:**	G6S
Location:	Comland, St Marys	**Depth (m):**	4.85

WELL FINISH

☐	**Gatic Cover**	✓	**Standpipe**	☐	**PVC Pipe**

WELL DEVELOPMENT

	Stage 1		**Stage 1**	**Stage 2**
Method:		**SWL – Before: (m)**		
Date:		**Time – Before:**		
Undertaken By:		**SWL – After: (m)**		
Vol. Water Removed:		**Time – After:**		

Comments:

WELL PURGE DETAILS

Method:	Bailer	**SWL – Before:**	5.38
Date:	13/1/00	**Time – Before:**	10:33
Undertaken By:	JR/CT	**SWL – After:**	dry
PID Reading: (ppm)	na	**Time – After:**	12:23
Total Vol Removed:	6		

PURGING MEASUREMENTS

Volume Removed (L)	**Temp (°C)**	**pH**	**EC (mS/cm)**	**Eh (mV)**
2	21.9	6.95	7.08	228.1
4	20.5	6.02	8.48	228.6

comments:

WELL SAMPLING DETAILS

Method:	Bailer			
Date:	13/1/00		**SWL – Before:**	final bail
Undertaken By:	JR/CT		**Time- Before**	12:23
pH	6.07		**Water Temperature (°C)**	20.2
Eh (mV)	228.0		**EC: (mS/cm)**	9.81

Containers Used/Comments

No sampling undertaken as piezometer 'dry'

Tested By:	
Date Tested:	
Checked By:	
Date:	

Remarks:
- All measurements are corrected to ground level
- All stated Volumes are in Litres
- SWL is an abbreviation for standing water level

C.3 EIS Investigations Volume 3

ENVIRONMENTAL INVESTIGATION SERVICES

REPORT

TO

LEND LEASE DEVELOPMENT

ON

SOIL AND GROUNDWATER INVESTIGATION

FOR

PROPOSED RESIDENTIAL REDEVELOPMENT

AT

COMLAND, ST MARYS

VOLUME 3: URBAN CAPABILITY MAPPING

PREPARED IN CONJUNCTION WITH

SINCLAIR KNIGHT MERZ PTY LTD

31 MAY, 2000

REF: E13431FRPT – VOL3

Associate Director and Principal : E H Fletcher BSc (Eng) ME CPE
39 BUFFALO ROAD GLADESVILLE NSW 2111 TELEPHONE: (02) 9809 7322 (02) 9807 0200 FAX: (02) 9809 7626
EIS IS A DIVISION OF JEFFERY & KATAUSKAS PTY LTD A.C.N 003 550 801
Directors: R P Jeffery BE DIC MSc B F Walker BE DIC MSc P Stubbs BSc MIEAust

TABLE OF CONTENTS

NOTE:
Lend Lease Development Pty Limited and Comland, commissioned Sinclair Knight Merz Pty Limited (SKM) directly to prepare Urban Capability Maps of the Western Precinct at the St Marys site in conjunction with collection of the data by EIS (presented in Volumes 1 and 2). The mapping was undertaken in accordance with the DLWC and NSW EPA publication *Managing Urban Stormwater, Source Control* (1998) - Part D - Urban Land Capability Assessment).

1. Introduction

An urban development capability assessment is a process that considers the physical limitations and soil constraints effecting urban development and introduces the concepts of "Soil Landscape Mapping" and 'Urban Capability Planning" as a means of identifying and recording these potential limitations.

2. Purpose of Urban Capability Assessment

The purpose of an urban capability assessment is to identify the site specific physical and soil limitations early in the planning stages. These specific limitations can then be considered (prior to development) during the detailed design stage and appropriate actions taken to manage or overcome them thereby allowing responsible development

Therefore, the main purpose of urban capability maps is to identify limitations for the purposes of providing acceptable solutions to them.

3. Description of Urban Capability Maps

There are two types of urban capability maps that can be prepared (Ref: DLWC and *NSW EPA, Managing Urban Stormwater, Source Control Dec 1998, Part D - Urban Land Capability Assessment). These are:*

1. **Broadscale urban capability maps and**
2. **Specific urban capability maps.**

Both of these types of urban capability maps have been prepared for the Western sector of the site.

1) Broadscale Urban Capability Maps

These maps are developed from an assessment of the interaction between the landform, soils and hydrological features of proposed urban lands. They are designed to assist in overall planning and management in a proposed urban development area. This level of assessment does not require to consider the specific proposed landuses for the western sector. There are five Broadscale Urban Capability Maps that have been prepared for the Western sector. Each of these five maps that are described below and copies of the maps are enclosed in this report. The five Broadscale Urban Capability Maps are:

1 -	Broadscale Generic Urban Capability Map
2 and 2a -	Slope/Terrain Analysis Map
3 -	Soil & Landform Associations
4 -	Best Use Management

Map No 1 - Broadscale Generic Urban Capability Map

The urban land capability classification entails collection of data on soils, landform, drainage, erosion and geology, and the evaluation of these data in relation to proposed development. The relevant parameters and soil limitations that have been assessed for the western sector of the Site include:

- ☐ Slopes
- ☐ Erodibility of subsoils
- ☐ Shrink swell
- ☐ Permeability of soils
- ☐ Shallow soils
- ☐ Rock depth
- ☐ Water table levels
- ☐ Flooding
- ☐ Mass movement
- ☐ Waterlogging, and
- ☐ Other topographical features

Out of this evaluation, the enclosed Broadscale generic urban capability map (No1 of 5) has been produced.

This urban capability procedure divides land into five primary classes, as shown on *Table 1*.

These categories are further divided into sub-classes on the basis of the types of constraints affecting different areas. For this purpose, the classes have subscripts attached with each subscript indicating a particular constraint. The subscripts are shown on *Table 2*.

Table 1 - General Urban Capability Classes

Class	Description
A	Areas with little or no physical limitations to urban development.
B	Areas with minor to moderate physical limitations to urban development. These limitations may influence design and impose certain management requirements on development to ensure a stable land surface is maintained both during and after development.
C	Areas with moderate physical limitations to urban development. These limitations may be overcome by careful design and by adopting site management practices to ensure the maintenance of a stable land surface.
D	Areas with severe limitations to urban development, which will be difficult to overcome, requiring detailed site investigation and engineering design.
E	Areas where no form of urban development is recommended because of very severe physical limitations which are very difficult to overcome.

Table 2- General Urban Capability Constraints

Soil Limitations:		Other Limitations:	
Subscript	Limitation	Subscript	Limitation
C	High permeability	f	Flooding
D	Shallow soil	m	Mass movement
E	Erodibility	r	Rock outcrop
L	Low permeability	s	Slope
P	Shrink/swell	t	Topographic feature (wave erosion, rock fall, run-on, etc.)
		w	Potential waterlogging
		y	Permanent high water table level)

Interpretation of results for Map 1 of 5

The broadscale generic assessment indicates that for the majority area on site, there are minor to moderate limitations for urban development (refer to ***Table 1***). These areas are coloured in green on map 1 and are represented by Class B.

There are also two separate areas on site where the limitations to urban development are moderate. These areas are coloured in orange representing Class C areas. This is primarily due to the overall associated soil characteristics and other limitations listed on ***Table 2*** particularly Slope and waterlogging.

Existing drainage lines on site have been designated as areas with high limitation to urban development. This is due to the associated flooding impact in these areas. Subject to provision of alternative and appropriate drainage paths, some of these existing drains could be reclassified as C or B.

Maps No 2 and 2a - Slope/Terrain Analysis Map

The slope analysis was undertaken on grids with cell sizes of 20m. The purpose of the analysis was to determine the extent and the range of slopes available on the Western Sector of the site. This information is critical for identifying areas on site that are likely to be subject to higher soil losses during the construction stages and would therefore require more careful Soil & Water Management measures. The output from this analysis was used in the preparation of Map No 3 and 4 - Soil & Landform Associations and Best Use Management.

Interpretation of results for Maps 2 and 2a of 5

The slope analysis on Map No2 of 5 indicates that the majority of the western sector has gently inclined slopes of approximately 1% to 3% with localised slopes of less that 1% along the main two creek lines on site. Steeper slopes of 3% to more than 5% also exist predominantly across a crest on the site running East to West. Generally, slopes steeper than 10 % are confined to only few localised areas on site. Overall, the site is considered not to have very steep slopes for the purposes of Soil and Water Management.

Map 2a of 5 represents the same result as Map 2 of 5 except that the analysis was undertaken using a Triangulated irregular network with smaller cell size grids which allows a greater definition around local features such as the existing drains, tracks, bunkers, and dirt roads on site.

Map No 3 - Soil & Landform Associations

The purpose of the soil & Landform map is to differentiate between various areas on site that fall under different categories. These categories provide a relative measure of soil constraints on site and are based on a number of parameters including:

- ☐ Soil Loss class
  - — Rainfall Erosivity for the entire site
  - — Soil erodibility at various locations on site
  - — Slope length / Gradient at various locations on site
  - — Erosion Control practices
  - — Ground Cover management
- ☐ Subsoil type (C,F or D)
- ☐ Soil hydrological group (surface runoff potential)

All the above parameters are further described on map No 3

Interpretation of results for Maps 3 of 5

There are six categories that have been derived for the western sector of the site, class 1 representing the least degree of constraint and therefore the highest urban capability and Class 6 representing the highest degree of constraint and therefore the lowest urban capability.

The majority area on site is represented by category 2 representing a lower degree of constraints, which will still require proper Soil & Water Management.

The category 6 areas merely represent areas where greater emphasis on adequate Soil & Water Management is required in comparison to other areas on site.

Map No 4 of 5 - Best Use Management

The purpose of the Best Use Management plan is to provide general information on how to manage various portions of each subcatchment on site for each of the catchments identified on the plan. The table on the map provides information on the sedimentation basin requirements depending on the previously identified soil loss classes and in accordance with the requirements of the Department's of Housing Manual *"Soils & Construction, 1998"*. The table also provides useful recommendations on periods of the year when disturbance or construction over some areas on site should be avoided.

Interpretation of results for Map 4 of 5

The table on map No4 indicates that the volumetric requirement (per unit area of upslope catchment) for sedimentation basins on site varies from less than 80m3/ha to 505 m3/ha.
This corresponds to erosion hazards in the disturbed catchments ranging from "Very Low" to "High" as indicated on map No4.

The assessment of rainfall zone and seasonal influences of rainfall for the western sector indicate that (when adopting normal Soil & Water management measures) for a small portion of the site (Category 6 - in Red), disturbance of the site is best avoided for the months of September to March. Similarly, for another portion of the site (Category5 - in Orange), disturbance of the site is best avoided for the month of February. Proposing to adopt more stringent Soil & Water Management controls for these two areas shown on Map No4 can however reduce these categories.

For the majority of the site (Categories 1 to 4) there are no limitations on periods of the year of "no-disturbance"

2) Specific Urban Capability Maps

Specific urban capability have the purpose of assessing the ability of a parcel of land to support a particular desirable or proposed landuse type without serious erosion and sedimentation occurring during construction, as well as possible instability and drainage problems in the long term.

Map No 5 - Specific Urban Capability Map

The specific assessment type is similar to Broadscale type but includes local parameters such as soil loss class, rainfall erosivity, soil erodibility, slope length, management practice and soil cover. Additional land attributes are also considered for the specific assessment type (eg. reactive soil, hydrologic group, potential acid sulphate soils (not applicable for the western sector), salinity, and other parameters.

Specific urban capability is ranked on the basis of the severity of the limitations that are likely to affect urban land use. (Ref. DLWC and *NSW EPA, Managing Urban Stormwater, Source Control Dec 1998, Part D - Urban Land Capability Assessment)*. These three classes are:

1 **low limitations** for urban development represent areas with little or no physical limitations. Standard building designs may be used;

2. **moderate limitations** may influence design and impose certain management requirement on developments to ensure a stable land surface is maintained

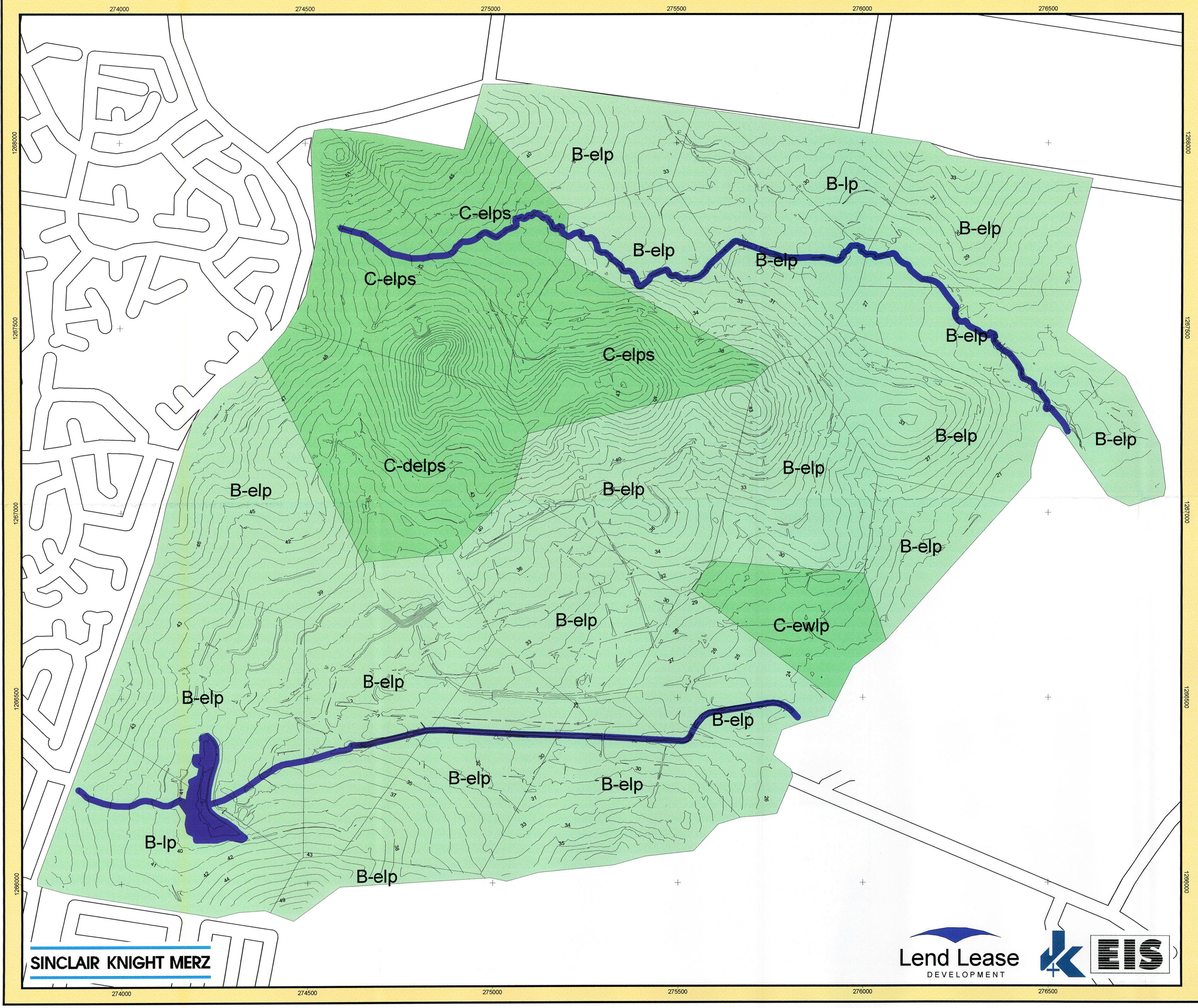
Table 4 - Constraints that were considered for Specific Urban Development

Land Attribute	Mapping Symbols			
	Low	High	Moderate	High
Depth to bedrock (m)	-	<0.5	r	R
Reactive soil	-	YES	v	V
Slope gradient (%)	-	>10	s	S
Depth to permanent watertable (m)	-	<0.3	y	Y
Flooding hazard	-	>100 yr ARI	f	F
Mass movement hazard	-	Yes	m	M
Soil loss class	-	>3	e	E
Salinity hazard	-	YES	d	D
Soil hydrologic group	-	Group D	h	H
Potential waterlogging	-	YES	w	W

Interpretation of results for Map 5 of 5

The specific urban capability assessment indicates that the site constraints are moderate for all the proposed land uses on site (refer to ***Table 3***). Various areas of the site are associated with constraints as indicated on Map 5 and defined on *Table 4*. , this reinforces the need for the implementation of the recommended soil management strategies described in section 7 of Volume 1.

Overall, the Western precinct is considered to have a relatively high urban capability with the exception of drainage paths, detention basins and wetlands which have a high degree of constraints.



Urban Capability Map
No 1 of 5

Broadscale Generic Urban Capability Map

ST MARYS DEVELOPMENT
(WESTERN SECTOR)

St Marys.
Projection: UTM, ISG Zone 56/1
Contour Interval : 1 Metre
Printed: June 2001

Project No:
File: st marys.apr
Location: U:\Projects\In06010 St Marys\St_Marys

Legend

Class	Degree of Constraint
A	Low
B	Minor to Moderate
C	Moderate
D	High
E	Severe

Urban Capability
↑ Higher
↓ Lower

Existing Drainage Flowpaths
▬ Primary Creek

This broadscale urban capability procedure divides land into five primary classes

Class	Description
A	Areas with little or no physical limitations to urban Development
B	Areas with minor to moderate physical limitations to urban development. These limitations may influence design and impose certain managemtn requirements on development to ensure a stable land surface is maintained both during and after development.
C	Areas with moderate physical limitations to urban development. These limitations may be overcome by careful design and by adopting site management practices to ensure the maintenance of a stabler land surface.
D	Areas with severe limitations to urban development which will be difficult to overcome, requiring detailed site investigation and engineering design.
E	Areas where no form of urban development is recommended because of very Severe physical limitations which are very difficult to overcome.

Source: Managing Urban Stormwater, source control, NSW EPA Draft Dec 1998, Part D, Table 4

These classes should not be used as a basis to preclude development in their own right. Specific sites require consideration of all factors, constraints and limitations, as well as techniques for managing each factor. (ref: page 56 of above source reference)

Subscript	**Soil Limitations**	Subscript	**Other Limitations**
c	High Permeability	f	Flooding
d	Shallow Soils	m	Mass Movement
e	Erodibility (k> 0.04)	r	Rock Depth
l	Low Permeability	s	Slope (>5%)
p	Shrink/Swell	t	Topographical features
		w	Potential waterlogging
		y	Permanent high water level

Example: Subclass B-elp represents land with minor to moderate physical constraints to urban development, the constraints being erodibility, low permeability and shrink-swell characteristics of the soil.

N

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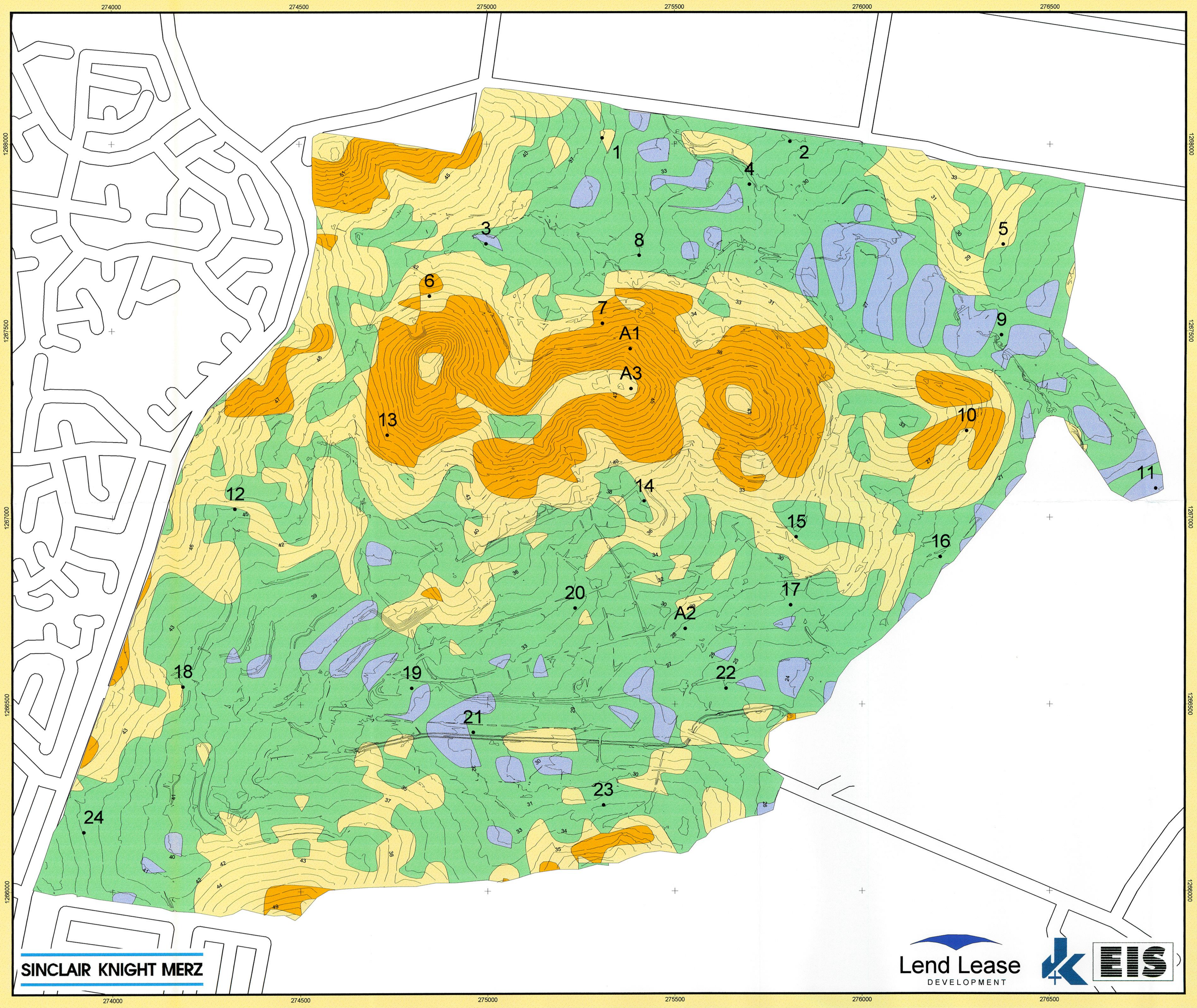
200 0 200 400 Meters



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Urban Capability Map
No 2 of 5

Slope/Terrain Analysis Plan

ST MARYS DEVELOPMENT
(WESTERN SECTOR)

St Marys.
Projection: UTM, ISG Zone 56/1
Contour Interval : 1 Metre
Printed: June 2001

Project No:
File: st marys.apr
Location: U:\Projects\In06010 St Marys\St_Marys

Legend

● Soil Test Pit

Existing Terrain Slope

	Percentage Slope Gradient	Description
🟦	0 - 1%	level to very gently inclined
🟩	1 - 3%	gently inclined
🟨	3 - 5%	gently undulating
🟧	> 5%	rolling

Note: Test pits No. 3, 4, 9, 12 and 16 are located near local depressions in the topography (eg: near creeks)

N

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200 0 200 400 Meters

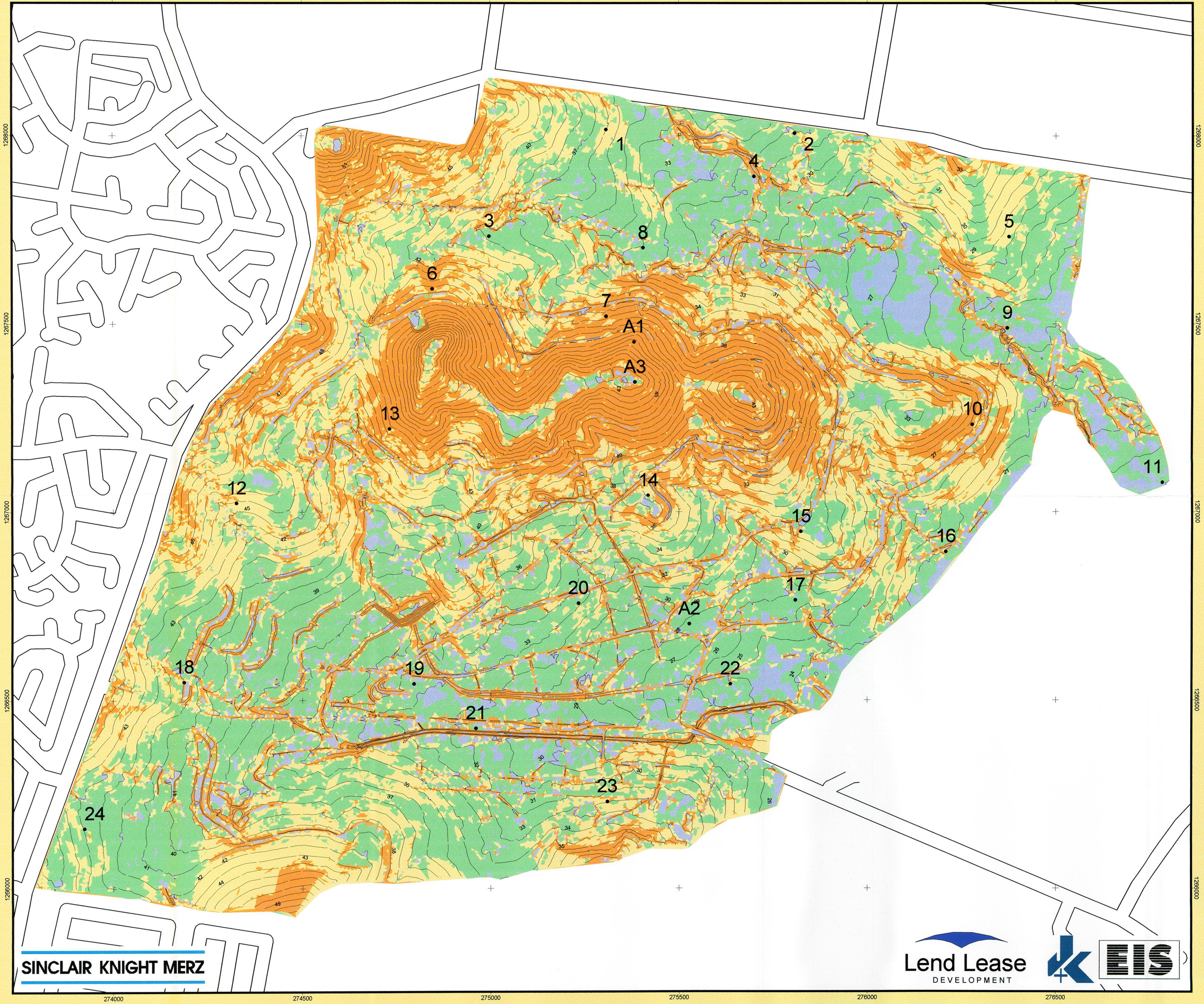
Urban Capability Map
No 2a of 5

Slope/Terrain Analysis Plan

ST MARYS DEVELOPMENT
(WESTERN SECTOR)

St Marys.
Projection: UTM, ISG Zone 56/1
Contour Interval : 1 Metre
Printed: June 2001

Project No:
File: st marys.apr
Location: U:\Projects\In06010 St Marys\St_Marys



Legend

● Soil Test Pit

Existing Terrain Slope

	Percentage Slope Gradient	Description
🟦	0 - 1%	level to very gently inclined
🟩	1 - 3%	gently inclined
🟨	3 - 5%	gently undulating
🟧	> 5%	rolling

Note: Test pits No. 3, 4, 9, 12 and 16 are located near local depressions in the topography (eg: near creeks)

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1:5000

200 0 200 400 Meters

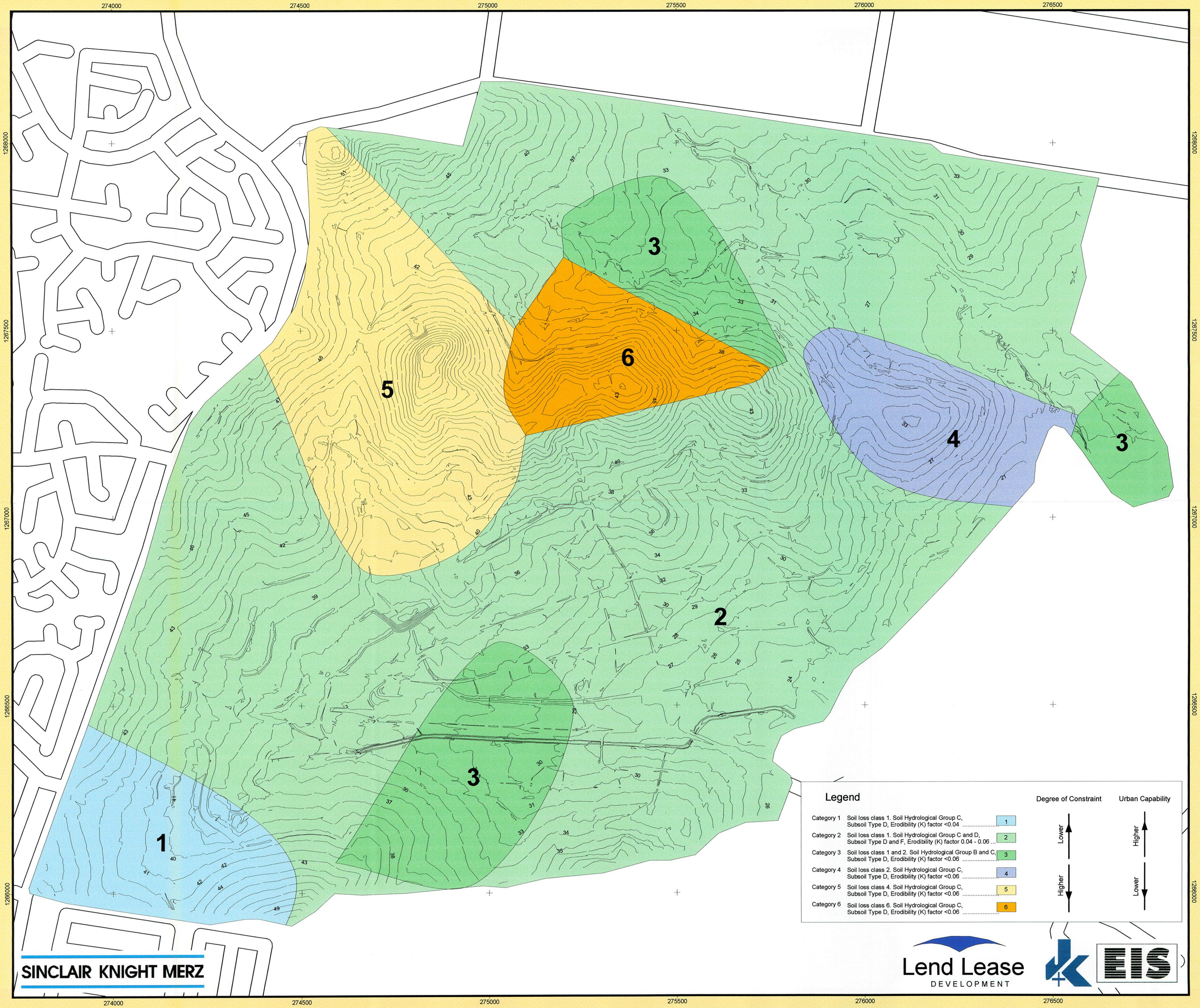
Urban Capability Map
No 3 of 5

Soil and Landform Associations

ST MARYS DEVELOPMENT
(WESTERN SECTOR)

St Marys.
Projection: UTM, ISG Zone 56/1
Contour Interval : 1 Metre
Printed: June 2001

Project No:
File: st marys.apr
Location: U:\Projects\In06010 St Marys\St_Marys



Legend

Category 1	Soil loss class 1. Soil Hydrological Group C, Subsoil Type D, Erodibility (K) factor <0.04	1
Category 2	Soil loss class 1. Soil Hydrological Group C and D, Subsoil Type D and F, Erodibility (K) factor 0.04 - 0.06 ...	2
Category 3	Soil loss class 1 and 2. Soil Hydrological Group B and C, Subsoil Type D, Erodibility (K) factor <0.06	3
Category 4	Soil loss class 2. Soil Hydrological Group C, Subsoil Type D, Erodibility (K) factor <0.06	4
Category 5	Soil loss class 4. Soil Hydrological Group C, Subsoil Type D, Erodibility (K) factor <0.06	5
Category 6	Soil loss class 6. Soil Hydrological Group C, Subsoil Type D, Erodibility (K) factor <0.06	6

Degree of Constraint	Urban Capability
Lower ↑	Higher ↑
Higher ↓	Lower ↓

1. The soil categories provide a measure of the degree of soil constraints on site based on a number of measured and derived parameters, this is futher described in the legend. The soil categories are a function of several parameters including soil loss class (Rainfall erosivity, Soil erodibility, slope length/gradient, erosion control practices, ground cover and managementpractices, subsoil type and soil hydrological group). These parameters are futher described below.

2. Soil Loss Class

The calculated soil loss is a measure of the mass of soil loss from a catchment per unit area (ha) over a peroid of time, typically expressed on an annual basis. The soil loss class definition has been obtained from Appendix C of the Department of Housing's "Soil & Construction" Manual, known as "The Blue Book" and is summarised in the table below.

Soil Loss Class	Calculated Soil Loss (Tonnes/ha/yr)	Erosion Hazard
1	=< 250	very low
2	251 - 300	low
3	301 - 375	low to moderate
4	376 - 500	moderate
5	501 - 750	high
6	751 - 1500	very high
7	1501 - 3700	extreme

3. R-Factor

The R-factor (rainfall erosivity) is a measure of the abilty of rainfall to cause erosion. It has been derived for the St Marys site, in accordance with section A1 of the Department of Housing's \"Soils & Construction\" Manual, known as "The Blue Book".

4. Soil Erodibility Factor

The K-factor is a measure of the susceptibility of soil particles to detachment and transport by rainfall. K-factors were derived from assessments of direct field measurements. Two separate assessments were undertaken, the first assessment was based on PSA and organic Carbon, the second assessment was based on soil structure and profile permeability. The higher value of K was adopted. The K ratings were as follows:

K < 0.02 - low
K = 0.02 - 0.04 - moderate
K = 0.04 - 0.06 - high
K > 0.06 - very high

5. Slopes

Slopes were obtained from a detailed (0.25m interval) ground survey.

6. Subsoil Type

The subsoil type is defined by the % amount of soil particles finer than 20 microns and the % amount of dipersible fines as further described below.

Type C - 33 percent or less of the subsoil consists of particles finer than 0.02mm
Type F - more than 33 percent of the subsoil consists of particles finer than 0.02mm
Type D - 10 percent of the subsoil is comprised of dispersible fines.

The subsoil types has been classified into the above three categories, on the basis of how effectively they can settle in a sedimentation basin.

7. Soil Hydrological Group

The soil hydrological group is a measure of their runoff potential. Their definition has been obtained from Appendix F of The Blue Book and is summarised below.

- * A - very low runoff potential
- * B - low to moderate runoff potential
- * C - moderate to high runoff potential
- * D - very high runoff potential

N

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200 0 200 400 Meters

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Urban Capability Map
No 4 of 5

Best Management Construction Practices

ST MARYS DEVELOPMENT
(WESTERN SECTOR)

St Marys.
Projection: UTM, ISG Zone 56/1
Contour Interval : 1 Metre
Printed: June 2001

Project No:
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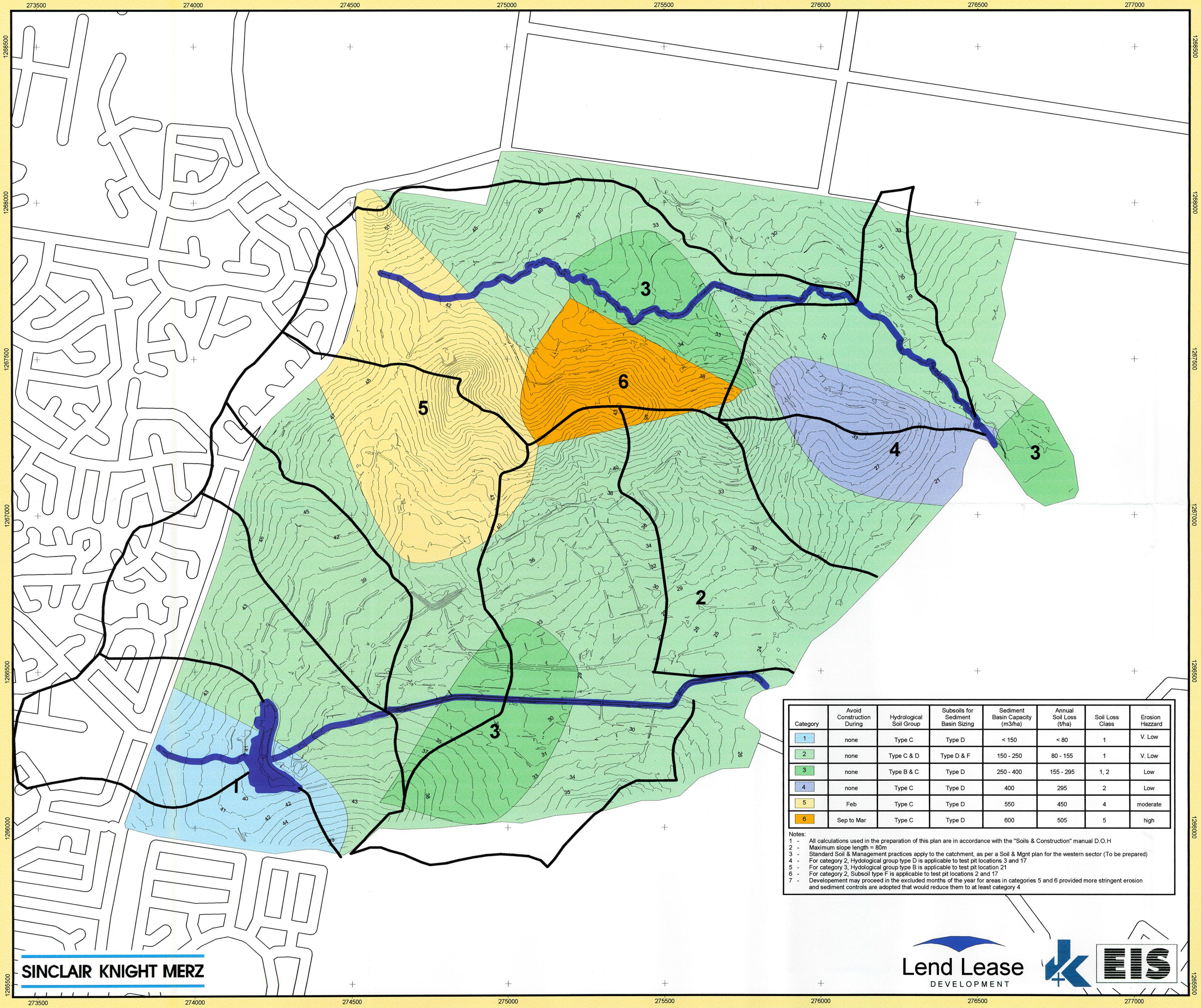

Category	Avoid Construction During	Hydrological Soil Group	Subsoils for Sediment Basin Sizing	Sediment Basin Capacity (m3/ha)	Annual Soil Loss (t/ha)	Soil Loss Class	Erosion Hazzard
1	none	Type C	Type D	< 150	< 80	1	V. Low
2	none	Type C & D	Type D & F	150 - 250	80 - 155	1	V. Low
3	none	Type B & C	Type D	250 - 400	155 - 295	1, 2	Low
4	none	Type C	Type D	400	295	2	Low
5	Feb	Type C	Type D	550	450	4	moderate
6	Sep to Mar	Type C	Type D	600	505	5	high

Notes:
1 - All calculations used in the preparation of this plan are in accordance with the "Soils & Construction" manual D.O.H
2 - Maximum slope length = 80m
3 - Standard Soil & Management practices apply to the catchment, as per a Soil & Mgnt plan for the western sector (To be prepared)
4 - For category 2, Hydological group type D is applicable to test pit locations 3 and 17
5 - For category 3, Hydological group type B is applicable to test pit location 21
6 - For category 2, Subsoil type F is applicable to test pit locations 2 and 17
7 - Developement may proceed in the excluded months of the year for areas in categories 5 and 6 provided more stringent erosion and sediment controls are adopted that would reduce them to at least category 4

Legend

Degree of Constraint

Category 1 Soil loss class 1. Soil Hydrological Group C, Subsoil Type D, Erodibility (K) factor <0.04 1
Category 2 Soil loss class 1. Soil Hydrological Group C and D, Subsoil Type D and F, Erodibility (K) factor 0.04 - 0.06 ... 2
Category 3 Soil loss class 1 and 2. Soil Hydrological Group B and C, Subsoil Type D, Erodibility (K) factor <0.06 3
Category 4 Soil loss class 2. Soil Hydrological Group C, Subsoil Type D, Erodibility (K) factor <0.06 4
Category 5 Soil loss class 4. Soil Hydrological Group C, Subsoil Type D, Erodibility (K) factor <0.06 5
Category 6 Soil loss class 6. Soil Hydrological Group C, Subsoil Type D, Erodibility (K) factor <0.06 6

Lower ↑
Higher ↓

Drainage

Primary Creek

(These areas indicate locations of likely concentration of surface funoff that require protection from erosion if they are disturbed)

Catchment Boundaries

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200 0 200 400 Meters

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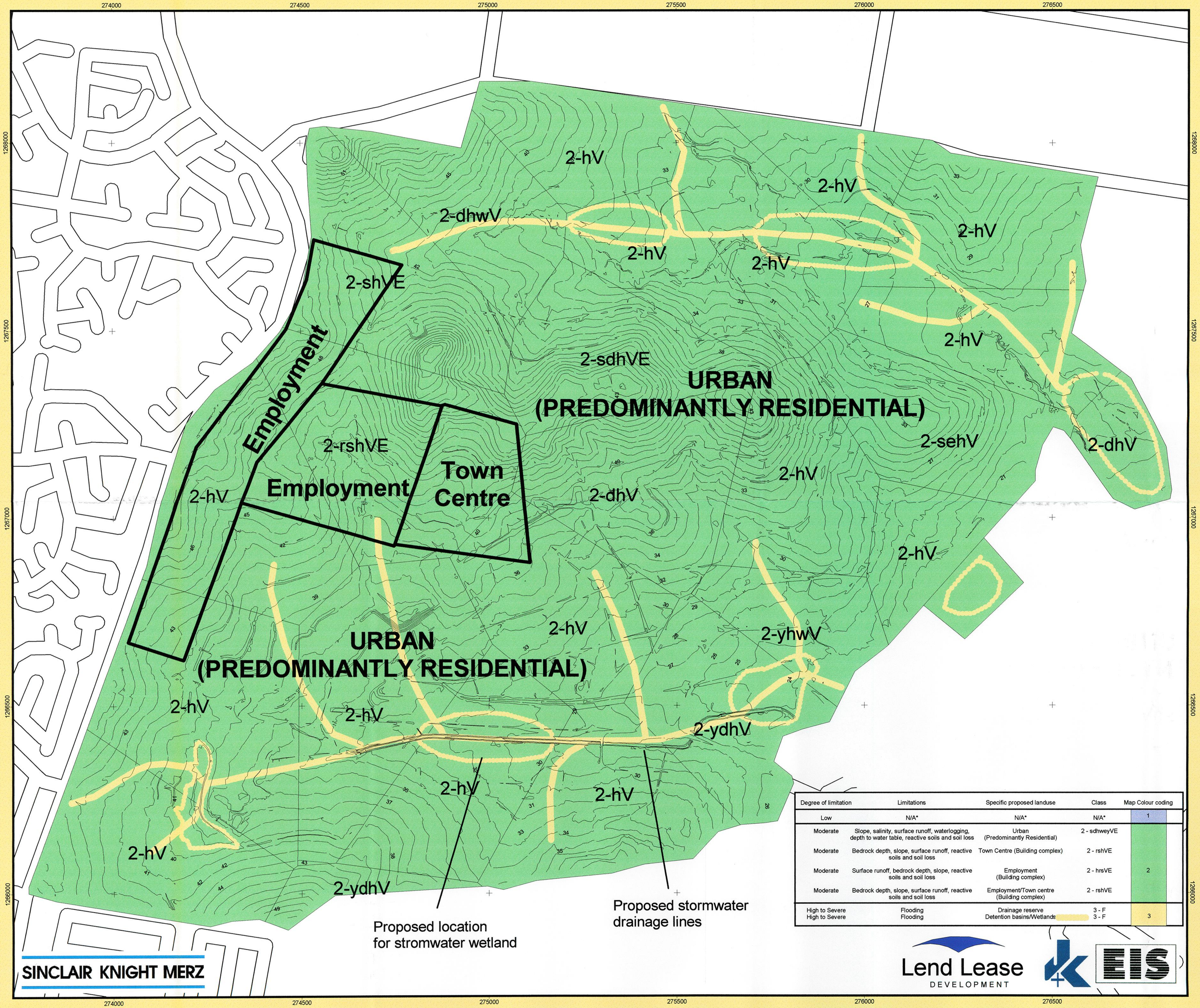
Urban Capability Map
No 5 of 5



Degree of limitation	Limitations	Specific proposed landuse	Class	Map Colour coding
Low	N/A*	N/A*	N/A*	1
Moderate	Slope, salinity, surface runoff, waterlogging, depth to water table, reactive soils and soil loss	Urban (Predominantly Residential)	2 - sdhweyVE	2
Moderate	Bedrock depth, slope, surface runoff, reactive soils and soil loss	Town Centre (Building complex)	2 - rshVE	
Moderate	Surface runoff, bedrock depth, slope, reactive soils and soil loss	Employment (Building complex)	2 - hrsVE	
Moderate	Bedrock depth, slope, surface runoff, reactive soils and soil loss	Employment/Town centre (Building complex)	2 - rshVE	
High to Severe High to Severe	Flooding Flooding	Drainage reserve Detention basins/Wetlands	3 - F 3 - F	3

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Specific Urban Capability Map

ST MARYS DEVELOPMENT
(WESTERN SECTOR)

St Marys.
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Project No:
File: st marys.apr
Location: U:\Projects\In06010 St Marys\St_Marys

Legend

Class	Degree of Constraint	Urban Capability
1	Low	High
2	Medium	Medium
3	High	Low

Degree of Constraint		
Low	High	Constraint Description
r	R(<0.5m)	Depth of bedrock
v	V	Reactive Soil
s(5%-10%)	S(>10%)	Slope gradient
y	Y(<0.3m)	Depth to permanent water table
n/a	M	Mass movement hazard
e	E(>= class 3)	Soil loss class
d	D	Salinity hazard (depth 0.3-0.5m)
h	H	Hydrological group (surface runoff potential)
w	W	Potential Waterlogging
n/a	F	Flooding

Class	Description	Remarks
1	The particular land use is acceptable, with any land, soil or water constraints occurring only at a low degree	LOW LIMITATIONS for urban development are areas with little or no physical limitations. Standard building designs may be used.
2	The particular land use is acceptable. However, one or more land, soil or water constraints exist at a moderate (but not high) degree and which require specialised management and/or construction techniques.	MODERATE LIMITATIONS may influence design and impose certain management requirement on develoments to ensure a stable land surface is maintained during and after develpment. These limitations can be overcome by careful design and by adoption of site management techniques that ensure land surface stability.
3	The particular land use may not be acceptable. However, one or more land, soil or water constraints exist at a high degree and should be subject to special approval by the development consent authority. Usually such constraints are dependant on further specialised geotechnical/ engineering, soil or water conservation advise.	HIGH TO SEVERE LIMITATIONS for urban development include areas with limitations that are difficult to overcome, requiring detailed site investigation and engineering design. Some areas may be so unsuitable for urban development that they are best left undisturbed

Source: Managing Urban Stormwater, source control, NSW EPA, Draft Dec 1998 Part D, Table 7

Note: Special urban capability is the ability of a parcel of land to support a particular intensity of urban development without serious erosion and sedimentation occuring during construction.

N

1:5000

200 0 200 400 Meters