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REPORT
on
GEOTECHNICAL AND HYDROGEOLOGICAL ASSESSMENT

OAKDALE CONCEPT PLAN
EASTERN CREEK AND ERSKINE PARK

Prepared for
GOODMAN INTERNATIONAL LIMITED

Project 44711
July 2007

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REPORT ON GEOTECHNICAL AND HYDROGEOLOGICAL ASSESSMENT OAKDALE CONCEPT PLAN EASTERN CREEK AND ERSKINE PARK

1. INTRODUCTION

This report presents the results of a geotechnical and hydrogeological assessment for the proposed Oakdale Concept Plan site on Austral Brick Company Pty Ltd (Austral Brick) land lying to the south of the Sydney Water Supply Pipeline at Eastern Creek and Erskine Park (refer to Drawing 1) and associated infrastructure. The work has been conducted by Douglas Partners Pty Ltd (DP) on behalf of Goodman International Limited (Goodman).

The purpose of the study is to assess the potential impacts of the development on geology, soils and groundwater and to provide recommendations for further assessment where required.

2. SITE DESCRIPTION

The Oakdale Concept Plan site has a total area (including the existing quarry area) of approximately 419 ha and is irregular in shape with maximum plan dimensions of approximately 4.4 km (east-west) at the northern frontage with the Sydney Water Supply Pipeline and 2.1 km (north-south). The topography of the site and associated Old Wallgrove Road and Sydney Water Pipeline easements (see Drawings 1 and 2) comprises gently undulating terrain which is dissected by:

- the northerly-flowing Ropes Creek system which drains most of the farmlands (Lots 1 and 2 in DP 120679 and Lot 82 in DP 752041) lying to the west of the Austral Brick manufacturing plant.
- the westerly-flowing headwater gullies of the South Creek system which drains the western-most section of the undeveloped lands and the Sydney Water Supply Pipeline easement near Mamre Road.
- the north-easterly flowing headwaters gullies of Reedy Creek (a tributary of Eastern Creek) which drain the eastern section of the Austral Brick manufacturing plant and quarry areas and abutting section of the Sydney Water Supply Pipeline easement.
- the northerly-flowing Eastern Creek which intersects the Sydney Water Supply Pipeline easement near Prospect Reservoir.

Site grades are generally flat to slight with localised areas exhibiting slopes greater than 10%, particularly in the upper slopes about ridgelines in the western section of the site, the western bank area of Ropes Creek and the topographic high, apparently controlled by more weathering and erosion resistant volcanic breccia pipes, in the central section of the site.

There has been extensive disturbance of the eastern section of the site during the development of the site which includes the Austral Brick manufacturing plant and associated quarries. Elsewhere, the ground has been mostly cleared for grazing and ground disturbance has been limited to the construction of four farm dams, the placement of an approximately 4 m to 5 m high filling bund (refer Drawing 2) along and adjacent to Old Wallgrove Road and the construction of electricity transmission lines.

3. PROPOSED DEVELOPMENT

Goodman is proposing to develop the Oakdale Concept Plan site for employment purposes. The predominant land use would be warehousing and distribution, with ancillary office space.

Goodman is preparing a 'concept plan' for the project, in accordance with the provisions of Part 3A of the Environmental Planning and Assessment Act 1979. The proposed Oakdale concept plan subdivision layout is shown on Drawing 3.

Concurrent with the concept plan application, Goodman is also proposing to gain development approval for certain infrastructure works outside the Oakdale Concept Plan site, including:

- upgrading a section of Old Wallgrove Road (refer Drawings 1 and 5) to facilitate efficient access to the Oakdale Concept Plan site; and
- regional infrastructure associated with a rainwater harvesting scheme (refer Drawings 6 and 7) for the Western Sydney Employment Hub.

4. SCOPE AND METHODOLOGY

The objective of the assessment is to assess the potential impacts of the Oakdale Concept Plan project, and associated external infrastructure, on geological and hydrogeological resources, including impacts and development constraints in relation to:

- slope stability;
- site preparation and earthworks;
- salinity;
- acid sulphate soils;
- erosion and sedimentation; and
- groundwater.

The assessment is based on the results of:

- review of available published geological, soils, salinity and groundwater literature and data;
- review of geotechnical and salinity investigations of surrounding and included lands, including:

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  - DP projects for the adjacent M7 Hub, Lot 141 Mamre Road, CSR Land, Emmaus Catholic College and Old Wallgrove Road; and
  - reports prepared for Austral Brick;
- site inspection.

The current study has not involved any additional sub-surface testing or investigation. Where warranted, the study will recommend additional sub-surface investigation to be carried out during subsequent development of the concept plan.

4.1 Published Geological and Hydrological Data

The principal geological reference for the site area is the Penrith 1:100 000 Geological Series Sheet (Ref. 1) and accompanying notes. There is additionally site specific reference to investigation, including diamond drilling, carried out to assess the materials within the volcanic pipes at the site (Ref. 2) and clay/shale resources within Lot 2 DP 120673 and part Lot 1 DP 833901 (Ref. 3).

The principal sources of groundwater information are the online data base of the (former) Department of Land and Water (DLWC) and the site specific assessment of hydrogeological conditions carried out on behalf of Austral Brick (Ref .4) as part of the Environmental Impact Statement for proposed clay/shale extraction.

Relevant results from review of the data sources described above are included within the following report sections.

4.2 Previous Douglas Partner Investigations

Previous DP investigations within the adjacent M7 Hub, CSR Land and Lot 141 Mamre Road sites have included cone penetration tests using a truck-mounted rig, test pits excavated by tractor-mounted backhoes, cored and non-cored bores, dynamic cone penetrometer (DCP) testing, electromagnetic surveys using a Geonics EM31 system, falling weight deflectometer testing of the pavement of Old Wallgrove Road between the M7 and the eastern end of the section of road to be reconstructed as part of the Oakdale Concept Plan development.

4.3 Field Work Methods

The field work for the current assessment comprised an inspection of the Oakdale Concept Plan site by a principal engineering geologist on 13 March 2007and a subsequent inspection of the section of Old Wallgrove Road to be upgraded and the Sydney Water Supply Pipeline between Mamre Road and Prospect Reservoir on 30 March 2007.

Site features were located in relation to site boundaries and by a hand held GPS receiver. The locations of the mapping reference points (MRP 30 – 91) are shown on Drawings 1, 2, 4 to 7.

5. GEOLOGICAL AND HYDROGEOLOGICAL CONTEXT

5.1 Published Geology and Soils Data

The Penrith 1:100 000 Geological Series Sheet (Ref. 1) indicates that the site is mostly underlain by Bringelly Shale of the Wianamatta Group of Triassic age. The Bringelly Shale comprises an interbedded sequence of shale, laminite, siltstone, fine sandstone and some minor coaly bands.

Within and immediately adjacent to the site, the Bringelly Shale is intruded by at least three volcanic breccia pipes (comprising a mixture of basalt and fragments of the sedimentary country rocks). Diamond drilling carried out in about 1961 (Ref. 2) indicated that breccia extended between the shale areas separating the breccia outcrops. Larger volcanic pipes are present to the northwest (the former Erskine Park Quarry, refer Drawing 1) and the Wallgrove Quarry, approximately 2 km to the north.

Investigations of the clay/shale resources within Lot 2 DP 120673 and part Lot 1 DP 833901 (Ref. 3) intersected up to 3 m of clay overlying predominantly claystone and shale, with

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occasional siltstones and fine grained sandstones. The siltstones and sandstones were described as generally massive with limited apparent porosity and permeability and with limited fracturing or jointing,

The Bringelly Shale is mantled by alluvial deposits, comprising sand, silt and clay with some gravel bands, along the courses of the various creek systems. The distribution of the alluvium is approximately that of the South Creek Soil Landscape (refer Drawings 1, 2, 6 and 7).

The Penrith 1:100 000 Soil Landscape Sheet (Ref. 5) indicates the site is underlain by three soil landscape units (refer Drawings 1 and 2 for areal distribution). These are the:

Blacktown Soil Landscape – a residual soil landscape developed on a landscape typically comprising gently undulating rises with local relief to 30 m and slopes usually less than 5% on Wianamatta Group shales and Hawkesbury shales. The Blacktown soils are shallow to moderately deep (<1 m), red and brown podsolic soils on crests, upper slopes and well drained areas. Deep (1.5 m – 3 m) yellow podsolic soils are located on lower areas and in areas of poor drainage. These soils are derived from weathering of the underlying (typically shaly) bedrock and are highly plastic, moderately reactive, of low soil fertility, poor soil drainage, localised salinity or sodicity and moderate erodibility.

Luddenham Soil Landscape – an erosional soil landscape developed on undulating to rolling hills with local relief of 50 m to 80 m and slopes of 10% to 20% on Wianamatta Group shales, often associated with resistant sandstone bands. The Luddenham soils are shallow (<1 m), dark podsolic soils or massive earthy clays on crests; moderately deep (0.7 m to 1.5 m) yellow podsolic soils and prairie soils on lower slopes and drainage lines. The soils have highly plastic subsoils of moderately reactivity and low to moderate shrink-swell potential, low to moderate soil fertility and moderate erodibility.

South Creek Soil Landscape – a fluvial soil landscape developed in floodplains, valley flats (slopes <5% and local relief <10 m) and drainage depressions with incised channels. The South Creek soils within the site are developed on alluvium derived from Wianamatta Group shales and are often very deep layered sediments over bedrock or relict soils. Landscape limitations include flood hazard, waterlogging (seasonal or localised), permanently high water tables (localised) and high erosion hazard.

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5.2 Previous Site Investigations

The principal, relevant items of note from previous DP site investigations of adjacent areas are summarised in the following sections.

5.2.1 M7 Hub

The central and western sections of the M7 Hub site are characterised by residual clay, silty clay, sandy clay or shaly clay to depths ranging between 0.5 m and 7.5 m. The clays are generally stiff to hard and contained traces of ironstone gravel and overlie highly weathered to slightly weathered shale, siltstone, and/or sandstone. The strength of the rock is generally extremely low to very low, increasing with depth to low to medium and medium strength, with some high strength materials being intersected at depth. No groundwater was encountered test pits and bores.

5.2.2 Old Wallgrove Road

The section of Old Wallgrove Road extending some 1300 m west from the M7 Motorway is characterised by pavement material comprising a 0.025 m thick bituminous wearing surface at the surface underlain by roadbase gravel to depths generally between 0.1 m and 0.25 m. Crushed sandstone filling was encountered below the roadbase to depths between 0.2 m and 0.75 m and was inturn underlain by roadbase gravel.

The pavement and road shoulders were underlain by up to 0.9 m of general filling, comprising gravelly sand or silty clay with traces of shale or sandstone gravel and sand. It was in turn underlain by residual, mostly stiff to very stiff silty clays. Very low to medium strength, highly and moderately weathered sandstone was intersected at depths of 0.7 m at two locations below the pavement and depths between 0.15 m and 1.75 m in the road shoulders.

5.2.3 Lot 141 Mamre Road

The subsurface profile in Lot 141 is characterised by shallow, silty clay 'topsoil' (with surface vegetation and minor rootlets to shallow depth) extending to depths of up to 0.5 m but with silt and clayey silt encountered to depths of 0.4 m to 0.5 m at isolated locations. The topsoil is underlain by silty clay (of both residual and alluvial provenance) extending to depths of between 0.9 m and 8.2 m and was initially underlain by extremely low to very low strength rock. In general, the silty clays were assessed to be stiff to hard and contained traces of ironstone gravel.

5.2.4 CSR Land

In the eastern section of the CSR Land adjacent to the Oakdale Concept Plan site, the subsurface profile comprises topsoil ranging from zero to 0.8 m, with an average of about 0.2 m, underlain by alluvial and/or residual clay ranging in depth from 0.5 m to in excess of 3.4 m, the deeper profiles being typically within the gully floor. Shale, siltstone and sandstone of the Bringelly Shale was encountered at depths ranging from 0.8 m – 3.4 m on low or greater strength material, with the shallower refusal levels generally being on sandstone. In investigation bores, medium or high strength shale, siltstone or sandstone (with inferred unconfined compressive strength of about 30 MPa) was intersected below depths of 4.9 m and 5.3 m respectively.

There was apparent rapid lateral and vertical variation in lithology. It is anticipated that the strata dips gently to the northeast, although this may be locally disrupted by faulting.

5.2.5 Emmaus Catholic College

In the college site, the subsurface profile comprises topsoil generally between 0.2 m and 0.4 m depth, underlain by alluvial, very stiff silty or sandy clay or clayey sand to in excess of 3.8 m over most of the site. Residual clay and underlying shaly clay and low strength siltstone was present in higher sections of the site.

5.3 Previous Laboratory Testing

No laboratory testing has been carried out during the current assessment. However, extensive testing has formed part of the previous DP investigations of the adjacent properties. Summaries of the testing are given in the following sections.

5.3.1 M7 Hub and Old Wallgrove Road

The laboratory testing of materials from the M7 Hub and adjacent section of Old Wallgrove Road indicated:

- residual clays of medium or high plasticity which are likely to have moderate to high susceptibility to shrinkage and swell movements resulting from changes in soil moisture content.
- residual clays (ten samples) of Emerson Class Number 2, indicating that the clay filling is potential dispersive and two samples with Emerson Class Number 5 or 6 (slightly to non-dispersive).
- California bearing ratio (CBR) values ranging from 1.0% to 8% for residual clay samples prepared to a dry density ratio of approximately 100% relative to standard compaction and to approximately optimum moisture content, and soaked for four days under a surcharge load of 9 kg.
- pH, sulphate and chloride contents, which when compared to requirements of AS2159 – 1995; Table 6.1 (Ref. 6), indicates that the soils on the site are non-aggressive with regards to concrete structures.
- exchangeable sodium and Cation Exchange Capacity (CEC) values indicating, when compared with. the sodicity classes given in DLWC (Ref. 7), that the soils are highly sodic.

5.3.2 Lot 141 Mamre Road

The laboratory testing of materials from Lot 141 Mamre Road indicated:

- silty clays of high plasticity, likely to have high susceptibility to shrinkage and swell movement resulting from changes in soil moisture content. The result for the clayey silt indicates the soil is of low plasticity.
- samples of clay/silt of mostly Emerson Class Number 4, but also results of Class Number 2 and 7. The results indicate the likelihood of some dispersive behaviour of the site clays.
- California bearing ratio (CBR) values ranging from 1.5% to 4.5% for clay samples prepared to a dry density ratio of approximately 100% relative to standard compaction and to approximately optimum moisture content, and soaked for four days under a surcharge load of 9 kg.
- pH, sulphate and chloride contents, which when compared to requirements of AS2159 – 1995; Table 6.1 (Ref. 6), indicates that the soils on the site are mildly to non-aggressive with regards to concrete structures.

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5.3.3 CSR Land

The laboratory testing of materials from the CSR Land indicated:

- one non-plastic alluvial sample, three alluvial silty or sandy clay samples of low plasticity.
- residual clays of high plasticity and consequently, likely to have a moderate to high susceptibility to shrink-swell movements.
- alluvial sandy silty clay and residual clays developed on shale and sandstone bedrock generally of material of slight (Emerson Class Number 5) to negligible (Emerson Class Number 6) dispersibility. However, two samples of residual and alluvial provenance, respectively, indicated dispersive (Emerson Class Number 2) material, characteristic of saline illites.
- alluvial and residual soils from the eastern section of the land with Shrink-Swell Index (I_{ss}) values in the range 3.7% - 5.7% indicating free surface movements of the order of 26 mm – 42 mm which corresponds to Class M to Class H site classification with resect to AS 2870 – 1996 (Ref. 8).
- California bearing ratio (CBR) values ranging from 3% to 5% for alluvial clay samples and 1% - 35% (median value 3.5%) for residual clays samples prepared to a dry density ratio of approximately 100% relative to standard compaction and to approximately optimum moisture content, and soaked for four days under a surcharge load of 4.5 kg.

5.3.4 Emmaus College

The laboratory testing of materials from the college site indicated:

- residual clays of high plasticity and likely to have a moderate to high susceptibility to shrink-swell movements.
- alluvial and residual clays indicated Shrink-Swell Index (I_{ss}) values in the range 2.2% - 2.7% indicating free surface movements of the order of 35 mm – 40 mm which corresponds to Class M site classification with resect to AS 2870 – 1996 (Ref. 8).
- a California bearing ratio (CBR) value of 4.5% for an alluvial clay sample.

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5.4 Salinity Potential

5.4.1 Background

McNally (Ref. 9) describes the general hydrogeological framework relevant to Western Sydney, including this site, where the shale terrain is known for saline groundwater (due to connate salt in shales of marine origin or to windblown sea salt) and the salt accumulates by evapo-transpiration (mostly in the B-horizon of residual soils). In areas of urban development, this can lead to damage to building foundations, lower course brickwork, road surfaces and underground services, where these impact on the saline zone or where the salts are mobilised by changing groundwater levels. Seasonal water level changes of 1 m - 2 m can occur in a shallow regolith aquifer or a deeper shale aquifer due to natural causes, however urban development should be carried out with a view to maintaining the natural water balance (between surface infiltration, runoff, lateral through-flow in the regolith, and evapo-transpiration) so that long term rises do not occur in the saline groundwater level.

The former Department of Infrastructure Planning and Natural Resources (DIPNR) infers a "high salinity potential" in the lower slopes and drainage areas of South Creek gullies, Ropes Creek, Reedy Creek and Eastern Creek on mapping entitled "Salinity Potential in Western Sydney 2002" (Ref. 10). Areas of known salinity (or where air photo interpretation and field observation have confirmed indicators of salinity) are also identified on the mapping at the south-western margin of the site and also to the north of Sydney Water Supply Pipeline. These mapping inferences (see Drawing 4) are based on soil types, surface levels and general groundwater considerations but are not in general ground-truthed. Hence, it is not generally known if actual soil salinities are consistent with the potential salinities.

For purposes of description, a saline soil may be defined as containing sufficient soluble salts to adversely affect plant growth and/or land use. Generally, a level of electrical conductance of a saturated extract (ECe) in excess of 4 dS/m at 25°C is regarded as the defining characteristic of a saline soil. The boundaries of salinity classes defined by Richards (Ref. 11) are given in Table 1 (following page).

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Table 1 – Salinity Classes

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

Note: to convert from dS/m to μS/cm multiple ECe values by 1000.

Generally, soil salinity (ECe) in excess of 4 dS/m (moderately, very or highly saline) is regarded as posing some risk to an urban development or to a down-gradient area, requiring the formulation of a salinity management plan.

5.4.2 M7 Hub Site

Studies by SMEC Australia Pty Ltd for Blacktown City Council (Ref. 12) and the SEPP59 Landowner Group (Ref. 13) covered a broad area of the Eastern Creek catchment but included sampling and testing of soil and groundwater along Reedy Creek and lower slopes of the north-western portion of the M7 Hub development (immediately north of the Austral Bricks site, see Drawing 1). The testing indicated that:

- salinity levels in Reedy Creek were slightly elevated and in excess of the (then DLWC) water quality threshold of 2500 μS/cm;
- groundwater was in general highly saline and unsuitable for most purposes;
- maximum soil salinities of 3.65 - 5.11 dS/m (slightly – moderately saline) and 5.28 dS/m (moderately saline) were determined from bore samples respectively at depths of 0.5 - 4.0 m along Reedy Creek at a depth of 1.5 m in the north-western portion of the M7 Hub.

Salinity investigations by DP (Ref. 14 and 15) in the M7 Hub and adjacent section of Old Wallgrove Road generally confirmed the previous SMEC (Ref. 12 and 13) with the principal findings being that:

- very saline soil (8.3 dS/m) was identified in natural soils at a single location, at a depth of 2.5 m adjacent to Reedy Creek.
- elsewhere moderately saline conditions at worst were assessed adjacent to the riparian (alluvial) zone of Reedy Creek and adjacent lower slopes adjacent to Reedy Creek, on the

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lower slopes of the western topographic ridge and in a narrow zone in the northeast of the area between Reedy Creek and Old Wallgrove Road, where inferred underlying shales may have an elevated salt content. Highest salinities are developed in the zone from 1.0 m – 2.5 m below ground surface, generally in firm to very stiff silty clays of the B and C soil horizons.

- the western section of the area is underlain for the most part by non-saline to slightly saline soils. The areas of slightly saline conditions adjacent to the section of Old Wallgrove Road to be reconstructed as part of the Oakdale Concept Plan development are shown on Drawing 4.

5.4.3 CSR Land and Lot 141 Mamre Road Sites

Salinity investigations by DP (Ref. 16, 17 and 18) and ERM (Ref. 19), together with DLWC records of monitoring wells in the CSR Land and Lot 141 Mamre Road (extending to the north and west from the north-western corner of the Oakdale Concept Plan site) indicated or inferred:

- variously non-saline to very saline soil conditions within the alluvial soils within the creek corridor between the CSR Land and Lot 141. The very saline soils are likely to be present at least to 2 m depth. Away from the creek bed, the testing indicated moderately saline soils at depths of 0.5 m to 1 m.
- saline conditions (4000 – 5000 mg/L total dissolved solids [TDS]) in monitoring wells in the CSR Land.
- highly saline conditions in the headwaters of the creek between the CSR Land and Lot 141 and these may result in periodic flushing of salts along the creek.
- moderately saline residual soils at depths from 0.5 m to 3 m and very saline alluvial soils depths below 1 m to 2.5 m at the south-western corner of Lot 141 (refer Drawing 5 for distribution adjacent to the Sydney Water Supply Pipeline).

5.4.4 Austral Brick Land

Water monitoring of bores in Austral Brick land lying south of the Sydney Water Supply Pipeline and west of Ferrers Road is also reported (Ref. 4) as identifying saline groundwater (TDS values ranging from 9240 mg/L to 18700 mg/L.

5.5 Acid Sulphate Soils

The site is located some 50 m above the level of estuarine soil development in which acid sulphate soils are developed. Reference to the *Prospect/Parramatta River Acid Sulfate Soil Risk Map* (Ref. 20) indicates that the closest known or potential acid sulphate soil deposits are located some 12 km to the east of the site.

5.6 Groundwater

Groundwater observations by DP have indicated groundwater intersections at depths ranging from 2.5 m to 5.3 m in alluvial infilled valley floors within the adjacent CSR Land, Lot 141 and Emmaus College sites.). Similarly, records of groundwater levels in monitoring bores installed in the CSR land indicated groundwater levels at depths ranging from 3.8 m – 19.8 m, in comparison with the groundwater levels (9 m to 12 m) in the DLWC records for these bores.

The site inspection has indicated waterlogging potential, probably due to a combination of infiltration from stream flow and groundwater flow to stream base level, in the valley floor alluvium along Ropes Creek. Similar conditions are expected along the courses of Eastern Creek and its associated tributaries.

Assessment by Old (Ref. 21) of the groundwater in the Wianamatta Group, and Bringelly Shale in particular, indicated that:

- groundwater is typically brackish to saline with TDS values in the range 4000 – 5000 mg/L (but with cases of TDS up to 31 750 mg/l being reported), the dominant ions being sodium and chloride, the water being generally unsuitable for livestock or irrigation).
- the shales have a very low intrinsic permeability and groundwater flow is likely to be dominated by fracture flow with resulting typically low yields (<1 L/s) in bores.

Measurement of TDS values of groundwater samples in Austral Brick land (Ref. 4) and CSR Land (refer Section 5.4) have confirmed saline conditions within and adjacent to the site. Similarly, testing in monitoring bores in the Austral Brick land adjacent to Ferrers Road has confirmed low hydraulic conductivity values (in the range 3.1×10^{-7} m/s to 2×10^{-8} m/s, average

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of 5 x 10^{-7} m/s) consistent with DP assessments in similar stratigraphic units elsewhere in the Western Sydney region.

6. IMPACT ASSESSMENT AND MITTIGATION STRATEGIES

6.1 Site Inspection Results

Notes describing classification methods and descriptive terms used in the current investigation and referred to in the following sections are included in Appendix A.

6.1.1 Oakdale Concept Plan Site

Within the Oakdale Concept Plan site, the principal items of note are:

- the presence of a filling bund extending along the western side of Old Wallgrove Road and for approximately 400 m westward adjacent to the boundary with the PGH property (refer Drawings 1 and 5). The surface of the filling appears to predominantly comprise ripped shale, sandstone and soils, together with some brick and terracotta fragments.
- a west-trending drainage channel between the filling bund and the PGH boundary between MRP 30 and MRP 32 exposes approximately 0.2 m of topsoil overlying variously 0.5 m to 2 m of clay soil (apparently dispersive in parts), which grades to shaly clay and thence low to medium strength fine grained sandstone.
- poorly drained conditions with the development of sedge-type grasses are present immediately to the east of the filling bund and extend to MRP 33 where the vegetation assemblage comprises she oaks (Casuarina species).
- she oak assemblages (refer Drawing 2 for distribution) are dominant along most of the gully and creek lines. The she oaks are salt tolerant and are considered to be indicators of possible salinity. The she oaks are generally located within the areas mapped as known or high salinity potential shown on Drawing 4.
- the northern-most volcanic breccia pipe (MRP 35 – 47) is marked at surface by scattered, high to very high strength, joint blocks and small outcrops which appear to have been disturbed, possibly during previous investigation by trenching.

- scattered breccia fragments in the exposed soil surface (between MRP 48 and MRP 49) may mark the edge of the south-western of the three volcanic breccia pipes.
- high strength basalt and breccia fragments in the exposed soil surface (at MRP 55).
- a minor erosion gully, 1 m deep and 5 m wide extends some 50 m downslope of MRP 50. Other minor erosion gullies of similar size and depth are present at MRP 59, 61 and 67.
- the creek floor at the southern boundary (extending east from MRP 57) is subject to flooding and waterlogging and lies immediately adjacent to an area mapped as known salinity (see Drawing 4). Seepage into the area from side gullies is ironstained.
- additional areas of apparent waterlogging were noted in a gully floor location at MRP 56, to the east of MRP 62 and where drainage is impeded along the north-western boundary approximately 500 m west of MRP 68 by spoil mounds derived from the adjacent Sydney Water Supply Pipeline.
- the western bank of Ropes Creek is apparently controlled by a band of high strength fine grained sandstone which is exposed at MRP 60 – 61, 68 and within the cutting for the Sydney Water Supply Pipeline adjacent to MRP 68 and MRP 69.
- ironcemented or lateritised, fine grained sandstone bands are exposed along the ridge crest and upper slopes at MRP 62 – 66 within the south-western corner of the site.
- there is localised, minor terracing of the soil surface along the steeper sections of north-facing slopes within the central, western section of the site.

6.1.2 Old Wallgrove Road

Along the section of Old Wallgrove Road to be reconstructed (between MRP 82 and MRP 30; refer Drawing 5), the principal items of note are:

- the existing, mostly bitumen paved, road has required cutting generally less than 1.5 m depth and filling up to 2 m deep across drainage gullies. Several sections of the road lie at natural grade.
- the cuts generally expose clay soils, lateritised in part, grading to extremely low strength shale.

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- poorly drained conditions are present at MRP 82, 85 – 86 and 89, where the filling embankments impede drainage. The poor drainage may control areas identified as slightly saline soils (refer Drawing 5 for distribution).

6.1.3 Sydney Water Supply Pipeline Easement

Along the section of the Sydney Water Supply Pipeline easement between Mamre Road and Ferrers Road (refer Drawings 6 and 7), the principal items of note are:

- three, northerly-trending drainage gullies cross the pipeline easement between Mamre Road and MRP 67 and have associated alluvial clay deposits as identified in the adjacent Emmaus College and Lot 141.
- the western and central sections of the pipeline cutting between MRP 67 and 69 expose extremely weathered to moderately weathered, interbedded shale and sandstone. Zones of apparently highly lateritised material also extend over the full cut depth (to about 5 m) and may reflect further zones of volcanic breccia.
- the eastern section of the cutting between MRP 67 and MRP 69 exposes high to very high strength sandstone, the spoil from which is stockpiled along the easement boundaries. The large block sizes (many > 1m) indicate that excavation may have required blasting.
- the easement valley floor crossings of Ropes Creek, Reedy Creek and Eastern Creek are characterised by filling apparently up to 1 m deep to provide the operational bench for pipeline construction and maintenance.
- the pipelines are located within tunnel below Old Wallgrove Road (i.e. between MRP 72 and MRP 80). The 5 m to 7 m deep cuttings leading to the tunnel section expose up to 3.5 m of clay soil overlying extremely low to low strength interbedded shale and silty sandstone.
- between Eastern Creek and Reedy Creek, the pipelines are located within cuttings ranging from 2 m to 5 m deep. Clay soils and extremely weathered rock are up to 3 m deep and overlie banded extremely low to low strength bedrock. Similar conditions are exposed in the cutting between Eastern Creek and Ferrers Road (MRP 73).
- at the pipeline crossings of Ropes Creek, reedy Creek and Eastern Creek, the vegetation assemblages are either dominated or include she oaks and are considered to be indicators potential of salinity as identified in published mapping (Ref. 10) mapping (refer Drawing 3).

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6.2 Geological and Hydrogeological Model of the Oakdale Concept Plan Site

The site comprises a small element of the Cumberland Lowlands physiographic region, which is characterised by low lying, gently undulating plains and low hills, underlain by the shales and sandstones of the Bringelly Shale. Based on the site observations, data from field investigation and associated laboratory testing of the nearby site and similar sites within similar terrain in the Sydney area, it is considered that the principal features of geological and hydrogeological significance for the site (and associated road reconstruction and stormwater harvesting pipelines sites which lying within equivalent terrain and stratigraphic units) are:

- an alluvial profile along Ropes Creek and tributary gullies. The alluvium is likely to range from 1 m – 6 m deep and derived from weathering and erosion products of interbedded shale, siltstone and sandstone of the Bringelly Shale. The profile comprises an upper zone of stiff to hard, relatively impermeable, silty clay/clay of low to high susceptibility to shrink-swell movements and possibly a more permeable, basal zone probably acting as a semi-confined aquifer.
- highly variable weathering profiles with clay profiles ranging from less than 1 m to about 9 m deep on the Bringelly Shale, which is characterised by rapid lateral and vertical variation in the lithology. Dispersive conditions, high susceptibility to shrink-swell movements and low bearing strength (particularly for road pavements) are expected within the residual soils.
- shale and siltstone bedrock initially ranging in strength from very low to low strength and potentially medium to high strength below about 5 m in many areas.
- potentially very high strength breccia at shallow depth within the pipe areas.
- weathering and erosion resistant, medium to very high strength sandstone bands irregularly distributed in the stratigraphic sequence, but probably consistently along the western bank of Ropes Creek.
- very saline soils along poorly drained sections of Ropes Creek and tributary gullies. Elsewhere, it is anticipated that most of the site will be classified as non or slightly saline, but with a scattering of moderately saline areas, particularly in footslope locations or where shale bands are preferentially salt rich.
- groundwater within the shale sequence being fracture controlled and very saline. Localised seepage areas may be present in head sections of some gullies.

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6.3 Slope Stability Constraints

The following slope stability assessment is based on the results of the geological inspection and DP involvement in similar projects. It included consideration of bedrock geology, observed or anticipated soil depth, steepness of slope relative to historical or ancient slope failures in similar materials, the disturbance of soil and vegetation cover during development, the influence of groundwater or surface saturation, and the effects of earthquake forces.

No deep seated slope stability hazards were identified within the residual profiles or the underlying Bringelly Shale. Localised soil creep is inferred within limited areas of the steeper slopes within the western section of the site.

It is anticipated that site preparation will effectively remove existing areas of creep affected soils. Localised cut slope instability may develop during benching, however it is anticipated that the management of the slope hazards will be suitably achieved by flattening of batters, rock support (e.g. rock bolting) or retaining walls construction. Following completion of the development, it is anticipated that there will be a very low risk of slope instability when assessed in accordance with the methods of the Australian Geomechanics Society (AGS) Sub-committee on Landslide Risk Management (Ref. 22).

6.4 Salinity Constraints

6.4.1 Causes of Salinity

Although saline soils and groundwater are a natural part of the Australian landscape, land management practices are now increasingly recognised as significant contributors to the expansion of salt affected areas. In particular, urban salinity is increasingly occurring around populated areas due to clearing and site development.

Salinity occurs when salts found naturally in the soil or groundwater are mobilised. Capillary rise and evaporation concentrate the salt on, and close to, the ground surface. Urban salinity becomes a problem when the natural hydrogeological balance is disturbed by human interaction. This may occur in urban areas due to changes to the water balance, increases in the volume of water into a natural system altering subsurface groundwater flows and levels, exposure of saline soils, and removal of deep rooted vegetation reducing rates of evapo-transpiration. Even small changes in sensitive areas can result in the balance being irrecoverably altered and salinisation occurring.

6.4.2 Effects of Salinity in an Urban Environment

Some building methods may also contribute to the process of urban salinity. For example, compaction of surfaces and fills in a manner which restricts groundwater flow could result in a concentration of salt in one area; cutting into slopes for building can result in saline soils or groundwater being exposed and intercepted; and the use of imported filling may be an additional source of salt or the filling may be less permeable, preventing good drainage. These issues may also result in problems with the design and construction of roads. In particular the building of embankments and the compaction of layers can interfere with groundwater flow. Also the inappropriate positioning, grading and construction of drains can result in surface and groundwater mixing and stagnant pools forming that evaporate leaving salt encrusted ground.

Excess salinity in an urban environment can result in significant problems. It can manifest itself in a number of ways resulting in damage to buildings, vegetation, soils and roads.

The effects of salinity can be observed on building materials, infrastructure including pipe work and roads as well as in vegetation. The effect of urban salinity is the result of both physical and chemical actions of the salt on concrete, bricks and metals. Salt moves into the pores of concrete and bricks and becomes concentrated when the water evaporates and can result in breakdown of materials and corrosion. Evidence of this may include crumbling, eroding or powdering of mortar or bricks, flaking of bricks, facing and cracking or corrosion of bricks.

High levels of salinity may also affect soil structure, chemistry and productivity. This can reduce plant growth which in turn alters soil structure, chemistry and nutrient levels. As soils become more saline, plant and micro-organisms decline and soil structure deteriorates. Waterlogging may also occur following a decline in nutrient levels. Over time, the alteration of soil structure can lead to the formation of gullies and other forms of soil erosion.

Salinity may also result in the corrosion of steel pipes, structural steel and reinforcement and can damage underground service pipes resulting in significant financial costs. Salinity can also have a significant effect on roads and pavements including deterioration of the bitumen seal, blistering which can lead to the formation of cracks and potholes, staining, cracking, deformation, potholes and cracking and spalling of reinforced concrete pavements.

6.4.3 Salinity Management Strategies for the Oakdale Concept Plan Site

A high salinity potential is inferred on published mapping (Ref. 10) within the lower slopes and drainage areas of Ropes Creek lying within the central section of the site. In general, investigations of the adjacent M7 Hub site to the east indicated that the high salinity potential inferred by the published mapping for the lower slopes and drainage areas of Reedy Creek was not realised except within some alluvial sediments immediately adjacent to the creek. Conversely, studies in the CSR Land and Lot 141 Mamre Road to the west indicated areas of very saline conditions, particularly within the alluvial areas and moderately saline conditions within some areas underlain by residual soils.

Additionally, it is likely that the predominantly silty clay soils will be sodic and non-aggressive to steel and mostly non-aggressive to concrete, with some potential for localised conditions moderately aggressive to concrete in areas of very saline soils.

Reference to Drawing 3 indicates that riparian corridors are to be provided along Ropes Creek and its main tributary and hence proposed the impact on the riparian zone of the creek, where most alluvium and higher salinity potential can be expected, will be somewhat limited. Elsewhere within the development area, mostly non-saline to slightly saline conditions with scattered development of moderately saline conditions are inferred. Efforts should be made, however, in the Ropes Creek catchment to prevent or restrict changes to the water balance that will result in rises in groundwater levels through the potentially more saline alluvium, bringing more saline water closer to the ground surface. As a precaution, development must be planned to mitigate against the effects of any potential salinisation that could occur.

These efforts need to be directed at all levels of the development process including:

- site design, vegetation and landscaping;
- commercial building and infrastructure construction.

In general, the following strategies are directed at:

- maintaining the natural water balance;

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

Planning of the development of the site requires careful management with a view to controlling drainage and infiltration of both surface waters and groundwater to prevent rises in groundwater levels and minimise the potential for erosion. Precautionary measures, applicable to the whole development area to reduce the potential for salinity problems, include:

- avoiding water collecting in low lying areas, along shallow creeks, floodways, in ponds, depressions, or behind fill embankments or near trenches on the uphill sides of roads. This can lead to water logging of the soils, evaporative concentration of salts, and eventual breakdown in soil structure resulting in accelerated erosion.
- roads and the shoulder areas should also be designed to be well drained, particularly with regard to drainage of surface water. There should not be excessive concentrations of runoff or ponding that would lead to waterlogging of the pavement or additional recharge to the groundwater. Road shoulders should be included in the sealing program.
- surface drains should generally be provided along the top of batter slopes of greater than 2.5 m height to reduce the potential for concentrated flows of water down slopes possibly causing scour. Well graded subsoil drainage should be provided at the base of all slopes where there are road pavements below the slope to reduce the risk of waterlogging.
- with regard to surface slopes, a minimum of 1V:100H is suggested.
- where possible materials and waters used in the construction of roads and fill embankments should be selected to contain minimal or no salt. This may be difficult for cuts and fills in lower areas where saline soils are exposed in cut or excavated then placed as filling. Under these circumstances where salinisation could be a problem, a capping layer of either topsoil or sandy materials should be placed to reduce capillary rise, act as a drainage layer and also reduce the potential for dispersive behaviour in any sodic soils.
- gypsum should be mixed into filling containing sodic soils and cuts where sodic soils are exposed on slopes to improve soil structure.

- salt tolerant grasses and trees should be considered if re-planting close to Ropes Creek and in areas of moderate and greater salinity to reduce soil erosion and maintain the existing evapo-transpiration and groundwater levels. Reference should be made to an experienced landscape planner or agronomist.
- consideration of salinity during detailed geotechnical studies for proposed buildings and infrastructure, and incorporation of appropriate design mitigation measures as required.

The entire site area is shown on published mapping (Ref. 10) as being of at least moderate salinity potential, but previous DP investigation of adjacent sites indicates that salinity of moderate classification or greater is likely to have a scattered distribution. To ensure that potential salinity impacts are appropriately considered during development of the Oakdale Concept Plan site, it is recommended that any application for development within the site, particularly the high salinity potential area shown on Drawing 4, be accompanied by a salinity report prepared by a suitably qualified geoconsultant. The report should:

- assess salinity levels across the site;
- evaluate the impacts of the development on saline land; and
- outline measures that would be adopted to mitigate and manage these impacts.

In addition, it is recommended that Goodman develop a Soil and Water Management Plan (SWMP) for the Oakdale Concept Plan site, including:

- provision for Erosion and Sediment Control Plans to be developed for each development involving ground disturbance;
- a Surface Water Monitoring Program including provision for salinity/conductivity monitoring in Ropes Creek and downstream of the site; and
- a Groundwater Monitoring Program, including provision for salinity/conductivity monitoring.

6.5 Site Preparation

Bulk earthworks are expected to involve relatively large scale cut-to-fill operations to profile the site to the layout as shown in Drawing 3. Additional, substantial filling is likely to be required for the preparation of the current Austral Brick manufacturing plant and quarries.

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Outlined in the following sections are comments related to appropriate engineering works for minimising or mitigating environmental effects during the excavation and placement of filling materials.

6.5.1 Excavation Conditions

It is expected that the excavations will encounter mostly clays and interbedded shale, siltstone and sandstone rock ranging from extremely low to very high strength. Additionally, excavations for a possible substation and service zone may intersect very high strength breccia with widely spaced joints within the outcrop of the volcanic pipe.

It is anticipated that most of the site will not be subject to significant excavation constraints. However, excavation in low to high strength bedrock will probably require the use of heavy ripping with D9 class or heavier bulldozers. It is likely that ripping of very high strength sandstone, such as exposed in the western bank of Ropes Creek and adjacent pipeline cutting, or the volcanic breccia, may result in very low productivity with even D11 class bulldozers and as such, significant excavation in these areas should be minimised as far as possible.

NSW EPA guidelines require that all material to be disposed off site, such as may be required during development of the existing Austral Bricks manufacturing plant, should be the subject of a Waste Classification Assessment. To minimise the risk of unexpected delays and disposal costs it may be preferable to conduct sampling and testing on any excess excavated soils prior to commencement of excavation.

Significant groundwater inflows into the excavations are not anticipated. Any seepage into the excavation should be minor. It is recommended that drainage be provided to limit ponding of both seepage and stormwater runoff, with the collected water being passed through sedimentation basins and monitored to ensure compliance with water quality requirements prior to discharge to Ropes Creek or reuse for moisture condition of filling within the site.

The presence of high plasticity clay and weathered shale at bulk excavation levels is likely to result in poor trafficability conditions during and after rainfall. Hence the provision of adequate site drainage and a surface capping layer (e.g. ripped sandstone) during construction will be required to reduce the inconvenience caused by poor trafficability.

6.5.2 Filling Conditions

The preparation of surfaces to receive new filling and the placement of the filling should be carried out under Level 1 engineering control in general accordance with AS 3798 – 2007 (Ref. 23).

The natural silty clays and weathered rock appear suitable (subject to assessment of salinity) for reuse as fill material provided the rock is crushed during compaction to a maximum size of 100 mm. Due to the expected high plasticity of the clays, care should be taken not to over-compact the clay, due to the risk of subsequent swelling. The moisture content should also be maintained after compaction by spray coating or placement of a granular surfacing. This will minimise the erosion potential of the prepared surface until the areas are covered with buildings and/or pavements.

Any imported filling should preferably be granular materials, such as ripped or crushed rock, or low plasticity clays of non-saline or low salinity classification and free of deleterious substances.

6.6 Erosion and Sedimentation

It is anticipated that the rapid variation of material types and probably varying bench levels between adjacent lots will result in a combination of for battering and retaining walls to minimise unproductive space in the development. Cut faces should be battered back for the safe construction of retaining walls or as temporary or permanent batters. A short term batter slope of 1:1 (H:V) is suggested for batter heights of up to 5.5 m in clay and extremely weathered rock. For long term, a minimum batter slope of 2:1 (H:V) is suggested, with 3:1 (H:V) being preferred to permit surface protection (e.g. by grassing) to reduce the potential for erosion of soil batters. For very low strength or better rock a batter slope of 0.75:1 (H:V) is suggested for short term and 1V:1H for long term.

Erosion of permanent batter slopes in clays is likely unless the faces of the slopes are protected. This is also applicable to the faces of shale which tend to fret readily when subjected to alternate wetting and drying. In cut faces developed in sandstone or breccia of at least medium strength, it may be possible to leave exposed faces but will require assessment of individual faces for determination of any required protection (e.g. shotcrete) or support (e.g. rock bolts). For all cuts,

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provision should be made for drainage at the top and at the base of the slopes to control any run-off and potential face erosion.

6.7 Acid Sulphate Soils

The site generally lies some 50 m or more above the formation environment of estuarine acid sulphate soils. As such, it is considered that there is no risk of estuarine acid sulphate soil conditions.

6.8 Groundwater

The intersection of free groundwater is anticipated only for excavations within the alluvial soils or immediately adjacent residual materials. Minor seepage of perched groundwater may however be expected along the soil to rock interface and fractured zones intersected by cut batters.

It is considered that the proposed bulk excavation works, which will generally be constrained by a flood prone riparian zone, will generally not intersect and will have no direct impact upon the groundwater table, provided standard procedures are followed to manage storm water runoff and subgrade drainage.

It should be noted that saline and high salinity groundwater is natural for the area and there are no management techniques which can eliminate this problem. Certain site management options are recommended to reduce the offsite environmental effects. The options include:

- the monitoring of groundwater at both upstream and downstream limits of the site.
- the maintenance and improvement of native vegetation along drainage courses and careful water management of landscaping areas associated with individual lot developments.
- minimisation of exposure of saline and sodic soils in temporary faces or stockpiles during site preparation works.
- the collection and controlled discharge of seepage from cut faces and storm water from hard surfaces of the proposed development such that the potential for localised ponding or waterlogging is minimised.

- the provision of lining of temporary or permanent ponds to minimise groundwater recharge through gravelly bands within the alluvium.
- the application of gypsum to areas of exposed soils or unpaved landscaping areas.
- protection of in-ground structures from potential salt attack.

6.9 Reconstruction of Old Wallgrove Road

It is assumed that the now proposed reconstruction of the section of Old Wallgrove Road will be carried out at or about the current alignment which includes at grade, filling embankments to 2 m high and cuts to approximately 1.5 m deep.

No testing has yet been carried out along the length of the road section however investigation of the adjacent section of Old Wallgrove Road and the M7 Hub indicate that constraints will include:

- low subgrade strength
- localised poor drainage with potential for localised salinity.

Appropriate methods to address these constraints include:

- provision of drains along the perimeter of the pavements with a longitudinal fall to discharge points to minimise the risk of ponding, particularly in those locations identified in Drawing 5.
- measures to limit ingress of salt and moisture into the substrate. This can be addressed by consideration of the type and amount of materials and water used during construction. Methods of achieving this may include limiting the salt content of material and water to less than 0.25% of soluble salts by dry mass of aggregate for at least 0.5 m depth and/or minimising permeability through compaction, stabilisation and seal characteristics and ensuring the seal is applied as soon as possible after the pavement has been compacted.
- the location of sedimentation and detention basins away from salinity and waterlogging susceptible areas (if applicable).

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6.10 Rainwater Harvesting System Pipelines

It is understood that rainwater harvesting system within the site will include collector rising and gravity mains feeding a regional header tank and thence into dual 675 mm pipes buried and/or above ground running from at least the north-western corner of the site to Ferrers Road, which lies adjacent to Prospect Reservoir. The locations of the proposed structures are shown on Drawings 6 and 7.

Geotechnical constraints to the proposed pipelines include:

- potential accelerated corrosion of buried structures in areas of very saline soils, most likely to be located about creek lines.
- possible low bearing capacity of alluvium or uncontrolled filling adjacent to creek alignments. Of particular note are the sites of the proposed regional header tank adjacent to Ropes Creek and pipe crossings of creek lines where locally require deepened or piered foundation systems may be required rather than high level footings which are expected to be suitable for areas of cut and residual soil profiles.
- requirement for use of rock breakers in low or greater strength materials in confined trench or footing excavations. Where rock breaker equipment is used adjacent to vibration sensitive sections of the Sydney Water Supply Pipeline, rock sawing may be required to limit vibration levels, which may need to be monitored to ensure compliance with relevant allowed limits.

7. CONCLUSIONS AND RECOMMENDATIONS

The site inspection, review of published literature and the results of investigations of adjacent sites has indicated that the principal geotechnical constraints affecting the proposed Oakdale Concept Plan site are:

- waterlogging which may periodically affect the floodplain of Ropes Creek and associated gullies.

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- shallow to deep clay profiles of moderately to high shrink-swell susceptibility and probably localised dispersion potential.
- variable weathered bedrock profile, resulting in rapid changes in the requirements for battering, retaining works, foundations and pavements.
- the potential requirement for heavy ripping and rock breaker use in medium and high strength (and possibly very high strength) rocks within deeper sections of the proposed bench and pipeline excavations.
- saline conditions are present within the groundwater.
- saline conditions will be present in some alluvial and residual soils, and possibly some rock strata.
- low subgrade CBR values within both alluvial and residual soils and potentially within sections of the underlying bedrock.

To address the geotechnical constraints, it will be necessary to:

- develop a comprehensive Soil and Water Management Plan including:
  - provision for detailed Erosion and Sedimentation Control Plans to be prepared for each development prior to commencement of construction;
  - a surface Water Monitoring Program, including provision for suspended solids and salinity monitoring in Ropes Creek and key tributaries upstream and downstream of the site; and
  - a Groundwater Monitoring Program, including provision for groundwater level and quality monitoring.
- prepare a salinity assessment report to accompany each project/development application.
- conduct detailed geotechnical investigations to inform the detailed design of buildings and infrastructure.

In summary, the constraints described above may be addressed by appropriate engineering works and consequently, it is considered that the proposed development can be successfully constructed, as have been the adjacent developments, such as the M7 Hub, which are located

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within effectively equivalent topographic terrain and stratigraphic sequence subject to closely similar salinity and hydrogeological conditions.

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Notes Relating to this Report
Drawings 1 – 7

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NOTES RELATING TO THIS REPORT

Introduction

These notes have been provided to amplify the geotechnical report in regard to classification methods, specialist field procedures and certain matters relating to the Discussion and Comments section. Not all, of course, are necessarily relevant to all reports.

Geotechnical reports are based on information gained from limited subsurface test boring and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

Description and Classification Methods

The methods of description and classification of soils and rocks used in this report are based on Australian Standard 1726, Geotechnical Site Investigations Code. In general, descriptions cover the following properties - strength or density, colour, structure, soil or rock type and inclusions.

Soil types are described according to the predominating particle size, qualified by the grading of other particles present (eg. sandy clay) on the following bases:

Soil Classification	Particle Size
Clay	less than 0.002 mm
Silt	0.002 to 0.06 mm
Sand	0.06 to 2.00 mm
Gravel	2.00 to 60.00 mm

Cohesive soils are classified on the basis of strength either by laboratory testing or engineering examination. The strength terms are defined as follows.

Classification	Undrained Shear Strength kPa
Very soft	less than 12
Soft	12—25
Firm	25—50
Stiff	50—100
Very stiff	100—200
Hard	Greater than 200

Non-cohesive soils are classified on the basis of relative density, generally from the results of standard penetration tests (SPT) or Dutch cone penetrometer tests (CPT) as below:

Relative Density	SPT "N" Value (blows/300 mm)	CPT Cone Value (q_c — MPa)
Very loose	less than 5	less than 2
Loose	5—10	2—5
Medium dense	10—30	5—15
Dense	30—50	15—25
Very dense	greater than 50	greater than 25

Rock types are classified by their geological names. Where relevant, further information regarding rock classification is given on the following sheet.

Sampling

Sampling is carried out during drilling to allow engineering examination (and laboratory testing where required) of the soil or rock.

Disturbed samples taken during drilling provide information on colour, type, inclusions and, depending upon the degree of disturbance, some information on strength and structure.

Undisturbed samples are taken by pushing a thin-walled sample tube into the soil and withdrawing with a sample of the soil 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 are given in the report.

Drilling Methods.

The following is a brief summary of drilling methods currently adopted by the Company and some comments on their use and application.

Test Pits — these are excavated with a backhoe or a tracked excavator, allowing close examination of the in-situ soils if it is safe to descent into the pit. The depth of penetration is limited to about 3 m for a backhoe and up to 6 m for an excavator. A potential disadvantage is the disturbance caused by the excavation.

Large Diameter Auger (eg. Pengo) — the hole is advanced by a rotating plate or short spiral auger, generally 300 mm or larger in diameter. The cuttings are returned to the surface at intervals (generally of not more than 0.5 m) and are disturbed but usually unchanged in moisture content. Identification of soil strata is generally much more reliable than with continuous spiral flight augers, and is usually supplemented by occasional undisturbed tube sampling.

Continuous Sample Drilling — the hole is advanced by pushing a 100 mm diameter socket into the ground and withdrawing it at intervals to extrude the sample. This is the most reliable method of drilling in soils, since moisture content is unchanged and soil structure, strength, etc. is only marginally affected.

Continuous Spiral Flight Augers — the hole is advanced using 90—115 mm diameter continuous spiral flight augers which are withdrawn at intervals to allow sampling or in-situ testing. This is a relatively economical means of drilling in clays and in sands above the water table. Samples are returned to the surface, or may be collected after withdrawal of the auger flights, but they are very disturbed and may be contaminated. Information from the drilling (as distinct from specific sampling by SPTs or undisturbed samples) is of relatively lower reliability, due to remoulding, contamination or softening of samples by ground water.

Non-core Rotary Drilling — the hole is advanced by a rotary bit, with water being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from 'feel' and rate of penetration.

Rotary Mud Drilling — similar to rotary drilling, but using drilling mud as a circulating fluid. The mud tends to mask the cuttings and reliable identification is again only possible from separate intact sampling (eg. from SPT).

Continuous Core Drilling — a continuous core sample is obtained using a diamond-tipped core barrel, usually 50 mm internal diameter. Provided full core recovery is achieved (which is not always possible in very weak rocks and granular soils), this technique provides a very reliable (but relatively expensive) method of investigation.

Standard Penetration Tests

Standard penetration tests (abbreviated as SPT) are used mainly in non-cohesive soils, but occasionally also in cohesive soils as a means of determining density or strength and also of obtaining a relatively undisturbed sample. The test procedure is described in Australian Standard 1289, "Methods of Testing Soils for Engineering Purposes" — Test 6.3.1.

The test is carried out in a borehole by driving a 50 mm diameter split sample tube under the impact of a 63 kg hammer with a free fall of 760 mm. It is normal for the tube to be driven in three successive 150 mm increments and the 'N' value is taken as the number of blows for the last 300 mm. In dense sands, very hard clays or weak rock, the full 450 mm penetration may not be practicable and the test is discontinued.

The test results are reported in the following form.

- In the case where full penetration is obtained with successive blow counts for each 150 mm of say 4, 6 and 7

  as 4, 6, 7
  N = 13

- In the case where the test is discontinued short of full penetration, say after 15 blows for the first 150 mm and 30 blows for the next 40 mm

  as 15, 30/40 mm.

The results of the tests can be related empirically to the engineering properties of the soil.

Occasionally, the test method is used to obtain samples in 50 mm diameter thin walled sample tubes in clays. In such circumstances, the test results are shown on the borelogs in brackets.

Cone Penetrometer Testing and Interpretation

Cone penetrometer testing (sometimes referred to as Dutch cone — abbreviated as CPT) described in this report has been carried out using an electrical friction cone penetrometer. The test is described in Australian Standard 1289, Test 6.4.1.

In the tests, a 35 mm diameter rod with a cone-tipped end is pushed continuously into the soil, the reaction being provided by a specially designed truck or rig which is fitted with an hydraulic ram system. Measurements are made of the end bearing resistance on the cone and the friction resistance on a separate 130 mm long sleeve, immediately behind the cone. Transducers in the tip of the assembly are connected by electrical 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 20 mm per second) the information is plotted on a computer screen and at the end of the test is stored on the computer for later plotting of the results.

The information provided on the plotted results 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 in percent.

There are two scales available for measurement of cone resistance. The lower scale (0—5 MPa) is used in very soft soils where increased sensitivity is required and is shown in the graphs as a dotted line. The main scale (0—50 MPa) is less sensitive and is shown as a full line.

The ratios of the sleeve friction to cone resistance will vary with the type of soil encountered, with higher relative friction in clays than in sands. Friction ratios of 1%—2% are commonly encountered in sands and very soft clays rising to 4%—10% in stiff clays.

In sands, the relationship between cone resistance and SPT value is commonly in the range:—

$$q_c \text{ (MPa)} = (0.4 \text{ to } 0.6)\ N \text{ (blows per 300 mm)}$$

In clays, the relationship between undrained shear strength and cone resistance is commonly in the range:—

$$q_c = (12 \text{ to } 18)\ c_u$$

Interpretation of CPT values can also be made to allow estimation of modulus or compressibility values to allow calculation of foundation settlements.

Inferred stratification as shown on the attached reports is assessed from the cone and friction traces and from experience and information from nearby boreholes, etc. This information is presented for general guidance, but must be regarded as being to some extent interpretive. The test method provides a continuous profile of engineering properties, and where precise information on soil classification is required, direct drilling and sampling may be preferable.

Hand Penetrometers

Hand penetrometer tests are carried out by driving a rod into the ground with a falling weight hammer and measuring the blows for successive 150 mm increments of penetration. Normally, there is a depth limitation of 1.2 m but this may be extended in certain conditions by the use of extension rods.

Two relatively similar tests are used.

- Perth sand penetrometer — a 16 mm diameter flat-ended rod is driven with a 9 kg hammer, dropping 600 mm (AS 1289, Test 6.3.3). This test was developed for testing the density of sands (originating in Perth) and is mainly used in granular soils and filling.
- Cone penetrometer (sometimes known as the Scala Penetrometer) — a 16 mm rod with a 20 mm diameter cone end is driven with a 9 kg hammer dropping 510 mm (AS 1289, Test 6.3.2). The test was developed initially for pavement subgrade investigations, and published correlations of the test results with California bearing ratio have been published by various Road Authorities.

Laboratory Testing

Laboratory testing is carried out in accordance with Australian Standard 1289 "Methods of Testing Soil for Engineering Purposes". Details of the test procedure used are given on the individual report forms.

Bore Logs

The bore logs presented herein are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on frequency of sampling and the method of drilling. Ideally, continuous undisturbed sampling or core drilling will provide the most reliable assessment, but this is not always practicable, or possible to justify on economic grounds. In any case, the boreholes represent only a very small sample of the total subsurface profile.

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes, the frequency of sampling and the possibility of other than 'straight line' variations between the boreholes.

Ground Water

Where ground water levels are measured in boreholes, there are several potential problems;

- In low permeability soils, ground water although present, 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. They may not be the same at the time of construction as are indicated in the report.
- The use of water or mud as a drilling fluid will mask any ground water inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water observations are to be made.

More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from a perched water table.

Engineering Reports

Engineering reports are prepared by qualified personnel and are based on the information obtained and on current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal (eg. a three storey building), the information and interpretation may not be relevant if the design proposal is changed (eg. to a twenty storey building). If this happens, the Company will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface condition, discussion of geotechnical aspects and recommendations or suggestions for design and construction. However, the Company cannot always anticipate or assume responsibility for:

- unexpected variations in ground conditions — the potential for this will depend partly on bore spacing and sampling frequency
- changes in policy or interpretation of policy by statutory authorities
- the actions of contractors responding to commercial pressures.

If these occur, the Company will be pleased to assist with investigation or advice to resolve the matter.

Site Anomalies

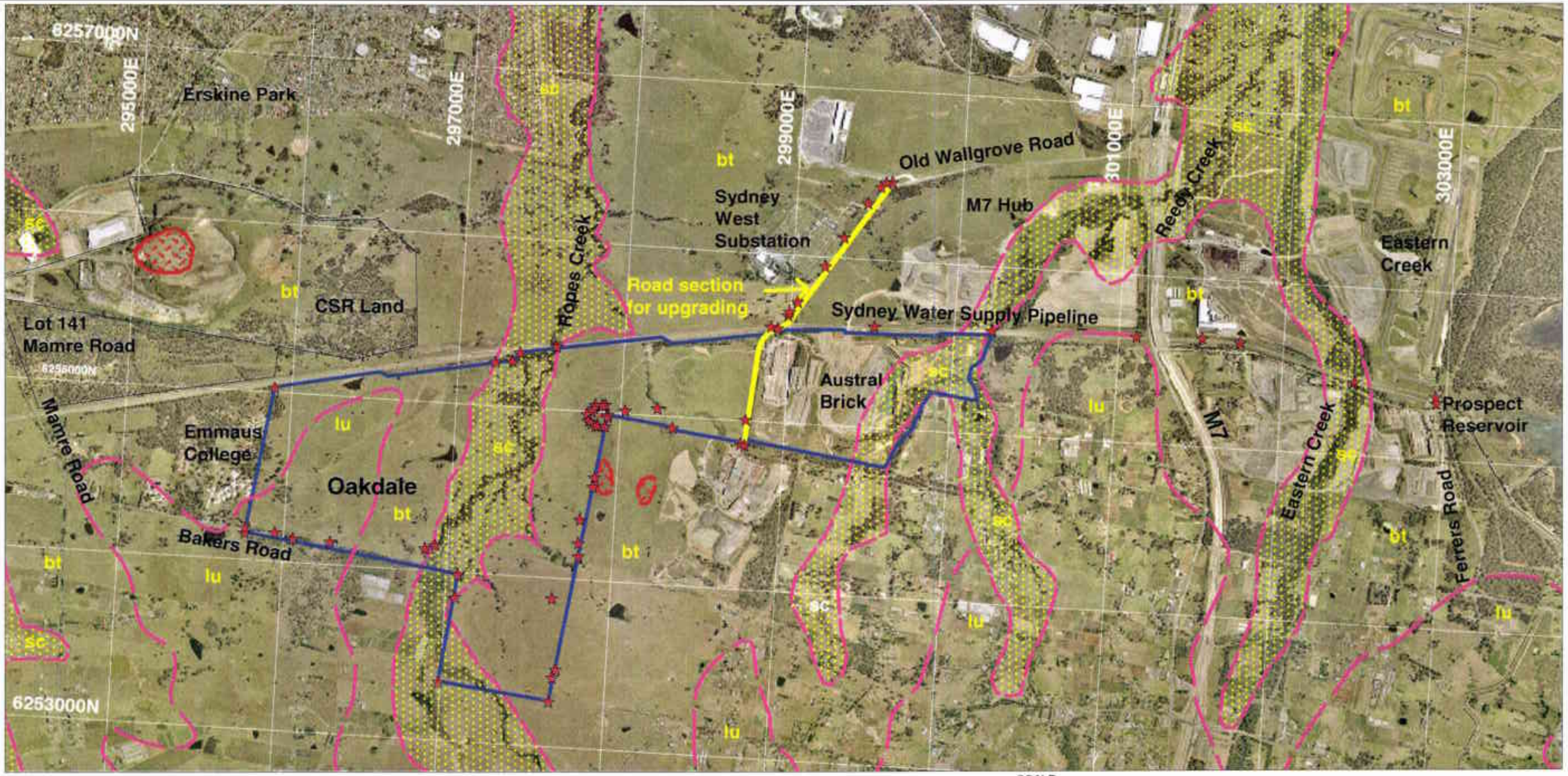
In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, the Company requests that it immediately be notified. Most problems are much more readily resolved when conditions are exposed than at some later stage, well after the event.

Reproduction of Information for Contractual Purposes

Attention is drawn to the document "Guidelines for the Provision of Geotechnical Information in Tender Documents", published by the Institution of Engineers, Australia. Where information obtained from this investigation is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. The Company would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

The Company will always be pleased to provide engineering inspection services for geotechnical aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.



LEGEND

- ALLUVIUM
- VOLCANIC BRECCIA
- SOIL LANDSCAPE BOUNDARY
- lu LUDDENHAM SOIL LANDSCAPE
- bt BLACKTOWN SOIL LANDSCAPE
- sc SOUTH CREEK SOIL LANDSCAPE
- ★ MAPPING REFERENCE POINT
- SITE BOUNDARY

Douglas Partners
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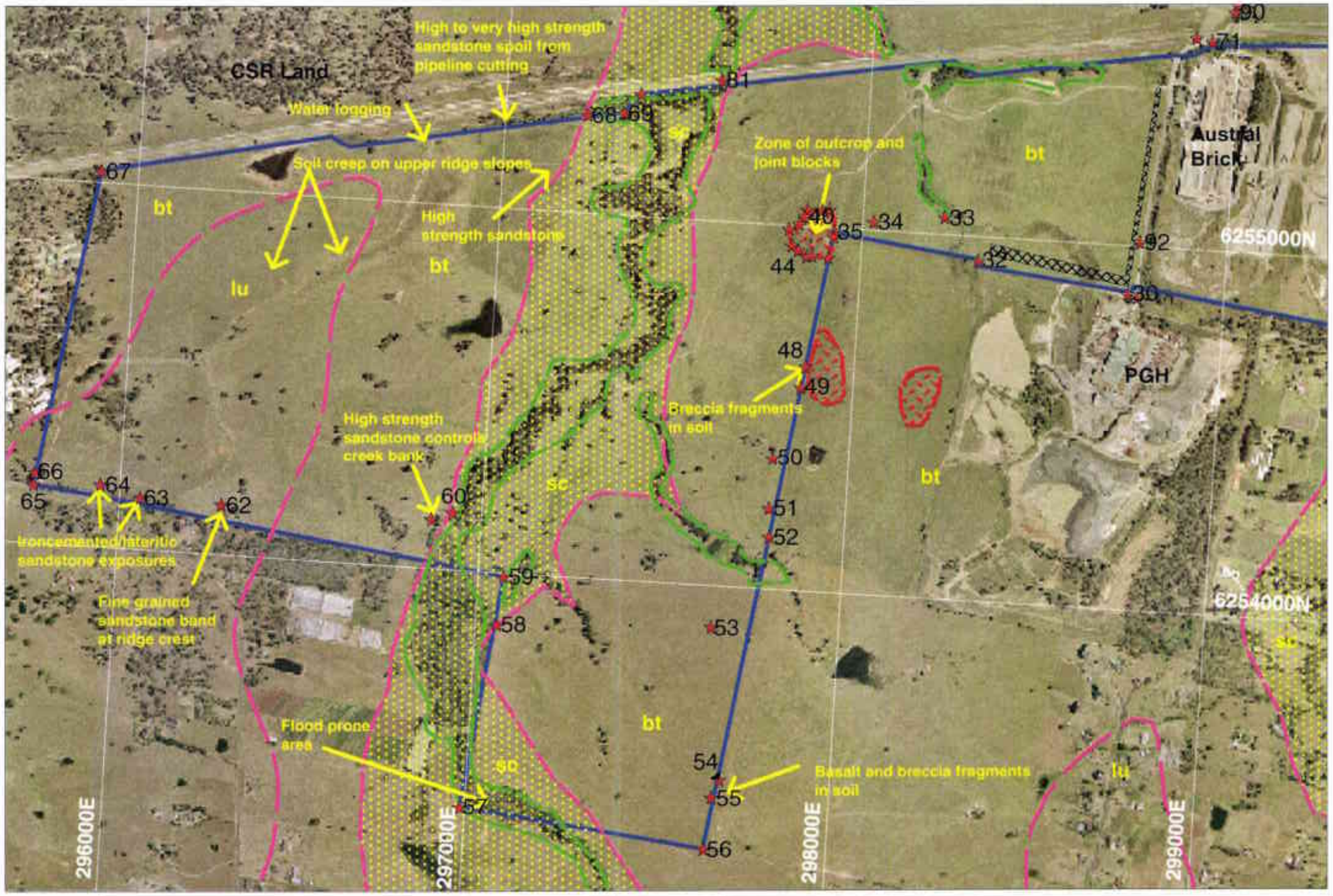
Sydney, Newcastle, Brisbane, Wollongong, Campbelltown, Melbourne, Perth, Wyong, Townsville, Cairns, Darwin, Canberra Gold Coast, Sunshine Coast

Title: **LOCALITY PLAN AND DISTRIBUTION OF SOIL LANDSCAPES**
OAKDALE CONCEPT PLAN
EASTERN CREEK AND ERSKINE PARK

Client: GOODMAN INTERNATIONAL LTD			Office: Sydney
Drawn by: GRW	Scale: 1:40000 @A4	Project Number: 44711	Drawing No: 1
Approved by: GRW		Date: July 2007	



LEGEND

	FILLING
	ALLUVIUM
	VOLCANIC BRECCIA
	SOIL LANDSCAPE BOUNDARY
lu	LUDDENHAM SOIL LANDSCAPE
bt	BLACKTOWN SOIL LANDSCAPE
sc	SOUTH CREEK SOIL LANDSCAPE
★	MAPPING REFERENCE POINT
	SITE BOUNDARY
	CASUARINA SPECIES

SCALE

0 500 1000m

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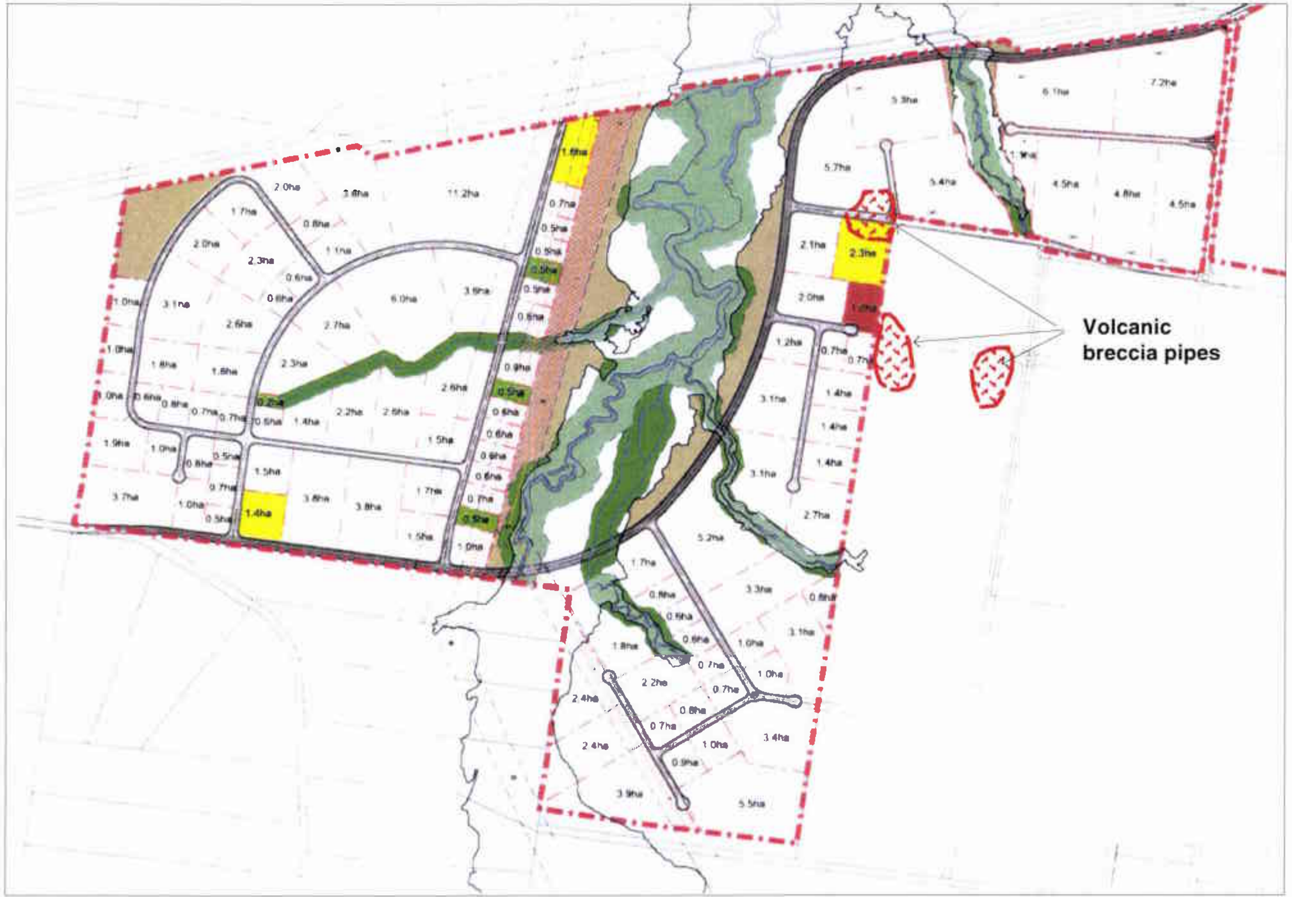
Gold Coast, Sunshine Coast

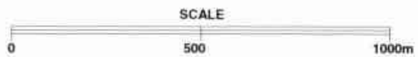
Title: **SITE FEATURES AND DISTRIBUTION OF SOIL LANDSCAPES**
OAKDALE CONCEPT PLAN
EASTERN CREEK AND ERSKINE PARK

Client: GOODMAN INTERNATIONAL LTD			Office: Sydney
Drawn by: GRW	Scale: 1:20000 @A4	Project Number: 44711	Drawing No: 2
Approved by: GRW		Date: July 2007	



Legend

- Riparian Zone
- 1 in 100 Flood Zone
- Detention Basins
- Estate Park/ Amenities
- Services Zone
- Substation
- Electrical Easements



Note: Layout details from
Goodman International Ltd Drawing OAK CP06(A)

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Sydney, Newcastle, Brisbane, Wollongong, Campbelltown, Melbourne, Perth, Wyong, Townsville, Cairns, Darwin, Canberra
Gold Coast, Sunshine Coast

Title: **PRELIMINARY SUBDIVISION LAYOUT**
OAKDALE CONCEPT PLAN
EASTERN CREEK AND ERSKINE PARK

Client: GOODMAN INTERNATIONAL LTD			Office: Sydney
Drawn by: GRW	Scale: 1:20000 @A4	Project Number: 44711	Drawing No: 3
Approved by: GRW		Date: July 2007	

KNOWN SALINITY

Areas where there is a known occurrence of saline soil, or where air photo interpretation and field observations have confirmed more than one of these:

a - scalding
b - salt efflorescence
c - vegetation dieback
d - salt tolerant plant species
e - waterlogging

A high relative wetness index occurs in these areas.

HIGH SALINITY POTENTIAL

Areas where soil, geology, topography and groundwater conditions predispose a site to salinity. These conditions are similar to areas of known salinity (see above). These areas are most common in lower slopes and drainage systems where water accumulation is high (ie. high relative wetness index).

MODERATE SALINITY POTENTIAL

Areas on Wianamatta Group Shales and Tertiary Alluvial Terraces. Scattered areas of scalding and indicator vegetation have been noted but no concentrations have been mapped. Saline areas may occur in this zone, which have not yet been identified or may occur if risk factors change adversely.

SCALE

0 1000 2000 3000 4000m

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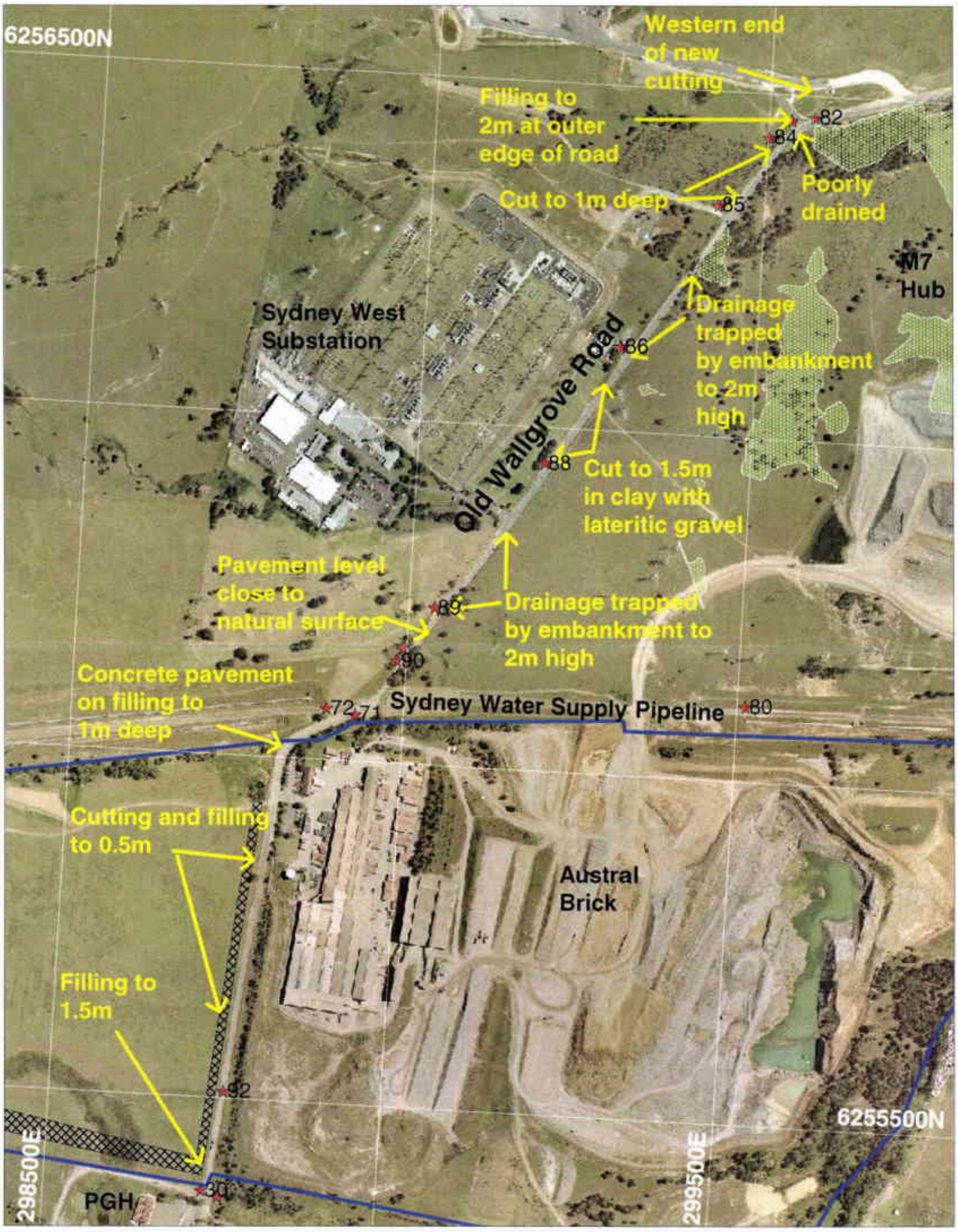
Title: **DISTRIBUTION OF SALINITY POTENTIAL**
OAKDALE CONCEPT PLAN
EASTERN CREEK AND ERSKINE PARK

Client: GOODMAN INTERNATIONAL LTD			Office: Sydney
Drawn by: GRW	Scale: 1:40000 @A4	Project Number: 44711	Drawing No: 4
Approved by: GRW		Date: July 2007	



LEGEND

FILLING

SLIGHTLY SALINE SOILS (ECe MEASUREMENTS)

MAPPING REFERENCE POINT

SITE BOUNDARY

SCALE

0 250 500m

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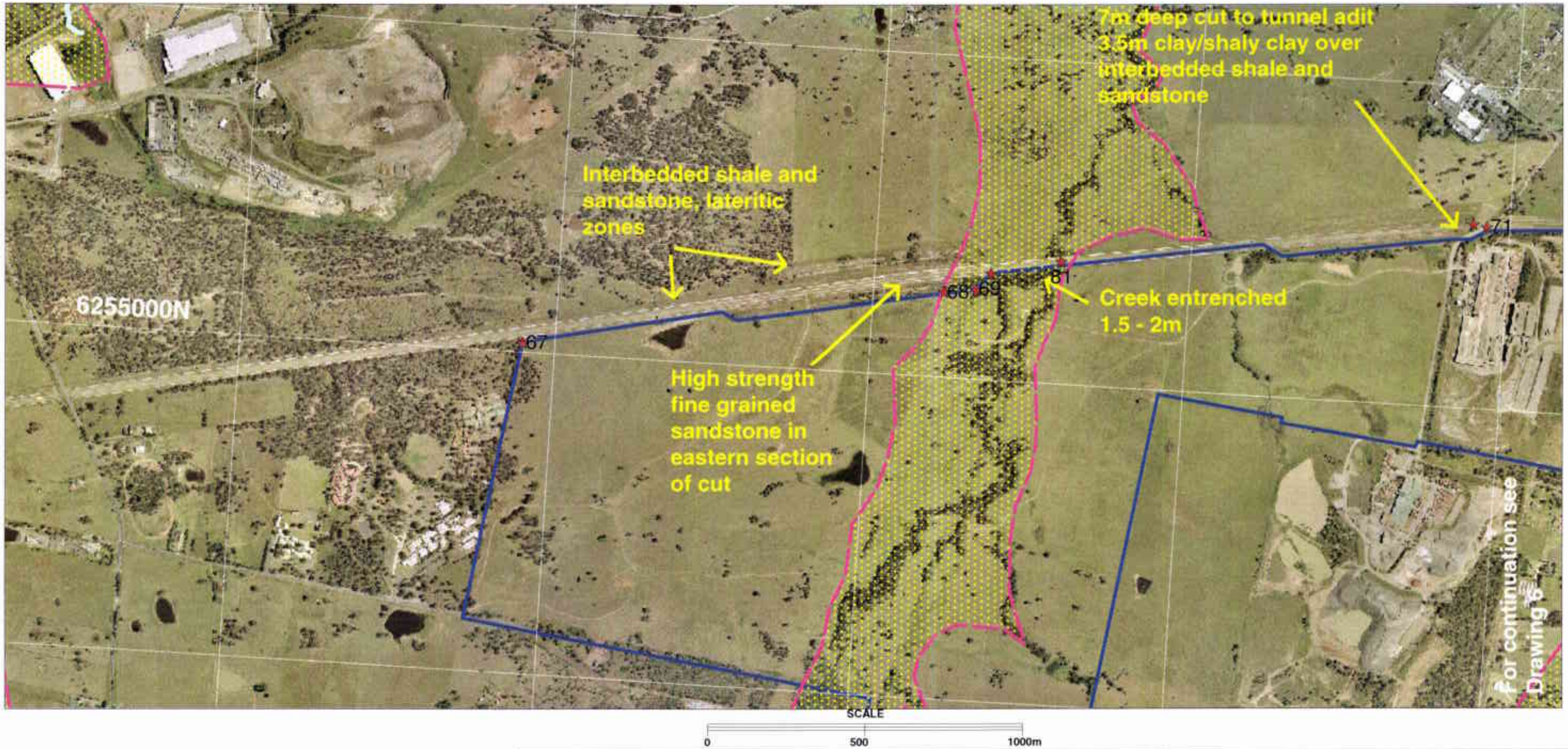
Title:	RECONSTRUCTION OF OLD WALLGROVE ROAD OAKDALE CONCEPT PLAN EASTERN CREEK AND ERSKINE PARK		
Client: GOODMAN INTERNATIONAL LTD			Office: Sydney
Drawn by: GRW	Scale:1:10000@A4	Project Number: 44711	Drawing No: 5
Approved by: GRW		Date: July 2007	



LEGEND

- ALLUVIUM
- SOIL LANDSCAPE BOUNDARY
- SC SOUTH CREEK SOIL LANDSCAPE
- ★ MAPPING REFERENCE POINT
- SITE BOUNDARY
- VERY SALINE AREA BOUNDARY
- MODERATELY SALINE AREA BOUNDARY

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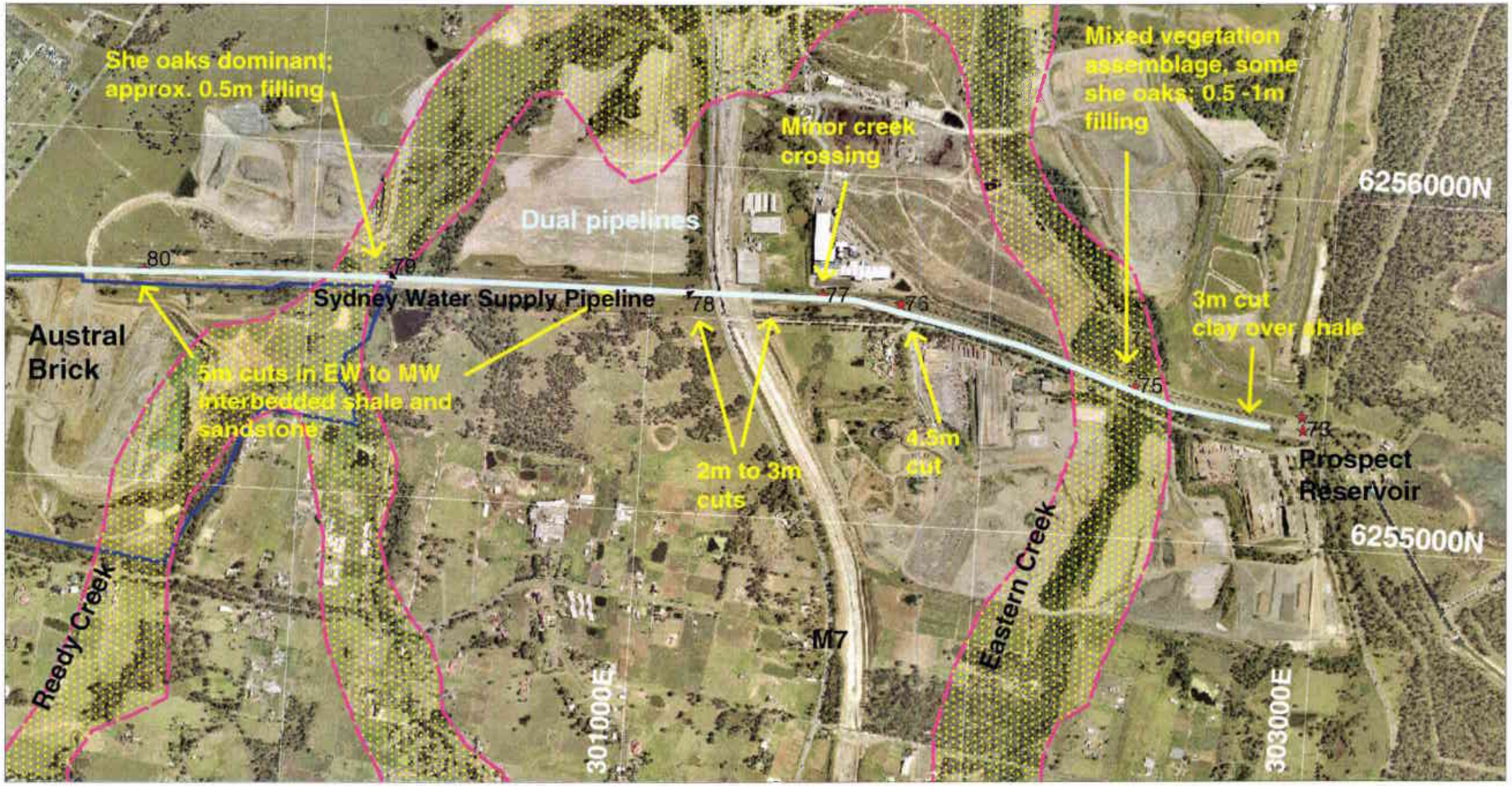
Title: **PROPOSED PIPELINES FOR WATER HARVESTING**
OAKDALE CONCEPT PLAN
EASTERN CREEK AND ERSKINE PARK

Client: GOODMAN INTERNATIONAL LTD			Office: Sydney
Drawn by: GRW	Scale: 1:40000 @A4	Project Number: 44711	Drawing No: 6
Approved by: GRW		Date: July 2007	



SCALE
0 500 1000m

LEGEND

(white box)	ALLUVIUM
(pink line)	SOIL LANDSCAPE BOUNDARY
sc	SOUTH CREEK SOIL LANDSCAPE
★	MAPPING REFERENCE POINT
(blue line)	SITE BOUNDARY
(red dashed line)	VERY SALINE AREA BOUNDARY
(light blue dashed line)	MODERATELY SALINE AREA BOUNDARY

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Sydney, Newcastle, Brisbane, Wollongong, Campbelltown, Melbourne, Perth, Wyong, Townsville, Cairns, Darwin, Canberra
Gold Coast, Sunshine Coast

Title: **PROPOSED PIPELINES FOR WATER HARVESTING**
OAKDALE CONCEPT PLAN
EASTERN CREEK AND ERSKINE PARK

Client: GOODMAN INTERNATIONAL LTD			Office: Sydney
Drawn by: GRW	Scale: 1:40000 @A4	Project Number: 44711	Drawing No: 7
Approved by: GRW		Date: July 2007	