PLATE 2 View at BH5/SP5 looking west

PLATE 3: View of BH4 looking east.

PLATE 4 Hillside rising immediately from road shoulder on south side of Piggabeen Road.

3 INVESTIGATION WORK

3.1 Fieldwork

Fieldwork for the investigation was carried out on the 8th and 9th October 2009, and included the drilling of a total of 10 boreholes at the locations shown on the attached site plan, Figure 1. The material encountered at each location is described on borehole log sheets included in Annex A.

Dynamic Cone Penetrometer tests were carried out beside each borehole and at 1 additional location, and these tabulated test results are included on the borehole logs.

Standard Penetration Tests and undisturbed tube sampling were carried out in the deep borehole at the proposed pump station.

Soil samples were collected for the assessment of acid sulfate soil conditions.

Three standpipes were installed for the collection of groundwater, and 2 surface water samples were also taken (Cobaki Creek, and gully/drain).

Fieldwork was carried out in general accordance with Australian Standard, AS1726-1993 *'Site Investigation Code'* and NSW ASSMAC guidelines, and discussions with Tweed Shire Council's Environmental Officer, Mr Brad Pearce.

3.2 Laboratory Testing

Samples of representative strata were recovered and returned to our NATA accredited soils laboratory. The following tests were carried out on selected samples;

- pH and pHfox
- SCR chromium reducible suite
- Groundwater baseline screening (subcontracted)

Laboratory test results are included in Annex B, and summarised and discussed in Section 6.

4 SUBSURFACE CONDITIONS

4.1 Subsurface Strata

The investigation work indicated that significantly variable subsurface conditions existed at the borehole locations.

Broadly, on the low lying sides of Piggabeen Road, alluvial/marine sands, silty sands and silty clays were encountered, typically of medium dense consistency in the lowlying sections, with some very loose to loose sections. At the pump station borehole location, very soft to soft marine clays were encountered to a depth of 8.5m below ground surface level. Where boreholes were located near rising ground, (i.e. generally on the south side of the road in the central part of the alignment, and on both sides of the road towards the east end of the alignment), stiff/medium dense residual clay/sand soils were encountered over weathered rock.

The borehole logs in Annex A should be referred to for the detailed description of material encountered at each investigation location. A summary is given in the table below.

Groundwater was encountered in the following boreholes at the given depths:

BH2….2.5m

BH3…2.0m

BH4…1.8m

BH7…1.6m

BH8…1.5m

However, these depths could be expected to vary with tidal and weather influences.

On the southern side of the road, free groundwater was not encountered by the borehole termination depths of 2.5m in BH1, BH5 or BH6, however the low permeability clay soils at these locations were very moist, and seepage would probably occur if holes were left open for an extended period. Free groundwater was similarly not encountered within the boreholes on the southern side of the road, BH9 and BH11, by termination depths of 2.1m and 3.0m. These 2 boreholes were in a stronger, residual type soil profile, close to the toe of the hillslope.

4.2 Laboratory Test Results

Laboratory tests are included in Annex B and are discussed in Section 6.

Table 1: Summary of Subsurface Strata

Soil Descriptions/Depth (m)														
BH No	Chainage	Fill			Clays				Clayey Sandy Gravel	Sand	Clayey or Silty Sand	Weathered Rock	Water Level	TD
		Gravelly	Sands	Clays	Soft	Firm	Stiff	Very stiff to hard		Loose	Medium Dense			
1	1200	0.0-06	-	-	-	0.6-1.5	1.5-TD	-	-	-	-	-	NE	2.5
2	1080	0.0-0.3	0.3-1.1	-	-	1.1-1.75 2.0-2.5	2.5-TD	-	1.75-2.0	-	-	-	2.5 seepage	3.0
3	790	0.0-0.45	-	0.45-1.3	-	1.3-2.2	2.2-2.4	-	-	2.4-TD	-	-	2.0 seepage	2.5
4	605	0.0-1.15	1.15-2.1	-	-	2.1-2.3	2.3-TD	-	-	-	-	-	1.8-2.3 Seepage	2.5
5	480	0.2-0.6	0.0-0.2	0.6-0.8	0.8-TD	-	-	-	-	-	-	-	NE	2.5
6	280	0.0-0.6 1.2-1.3	0.6-1.2	-	1.2-TD	-	-	-	-	-	-	-	NE	2.5
7	140	0.0-0.6	0.6-0.95	-	0.95-1.2 1.6-TD	1.2-1.4	-	-	-	1.4-1.6	-	-	1.6 (hole collapsed)	2.5
8	0.0	0.0-0.8(1)	-	-	0.8-8.5	-	8.5-TD	-	-	-	-	-	1.5	10.9
9	620(9)	0.0-0.5	-	-	-	-	-	-	-	-	0.5-1.8(3)	1.8-TD	NE	2.1(2)
11	1180(9)	0.1-0.9	0.0-0.1	-	-	-	-	1.9-TD	-	-	0.9-1.6(4) 1.6-1.9	-	NE	3.0

NOTES:

(1) Clayey /Gravel Mix
(2) T/C bit Refusal
(3) Some sandy clay mix
(4) Fill?
(5) NE = Not encountered
(6) Location 11 was just a DCP test, no borehole
(7) TD = Total depth
(8) Depths = below existing ground surface level
(9) Locations BH9 and BH11 carried out on south side of road, along watermain alignment. All other locations on north side of road.

5 GEOTECHNICAL ASSESSMENT

5.1 Earthworks

Excavatability

Based on the proposed invert levels of predominantly between 0.9m and 1.5m, no problems should be encountered in excavating the near surface material encountered at the majority of the tested locations on site. However, allowance should be made for some potential variability along the alignment, particularly for the trunk watermain on the south side of Piggabeen Road, in the vicinity of chainage CH625 (BH9), as the rock layer encountered in this area can rise/fall and the rock strength can increase or decrease. Most soils encountered on site should be within the excavation limits of a small dozer (eg Cat D6 or similar) in bulk excavations or medium size backhoe (eg Case 580 or similar) in trench excavations, for the nominated excavation depths.

It is understood that a 30 tonne excavator is the most likely machine to be used. Whilst this machine is expected to be able to excavate the majority of the soils encountered, some allowance for localised difficulties should be made.

TC' bit refusal was encountered using a Quickdrill 3000, at a depth of 2.1m at location BH9. While there is no direct reliable relationship between drilling resistance and excavatability, as a rule of thumb the limit of the *'TC'* bit may be taken as indicative of the limit of excavation of a medium sized dozer in bulk excavation (Cat D7E, D8) or a large excavator in trench excavation (Kato or Hymac).

Generally below the *'TC'* bit limit, larger excavation equipment, explosives, compressor driven pneumatic tools, or hydraulic rock breakers would be required for excavation.

Excavation batter stability

The proposed construction methodology for the trenches is to excavate short sections of trench at a time, and to take all excavated soils from the trench to a dedicated treatment pad area within the Cobaki Lakes site for lime neutralisation and validation testing. . This treated material will then be used within the Cobaki Lakes site at a later date, while the trenches will instead be backfilled with select material from an alternative (non-ASS) source. This methodology has been proposed to minimise the difficulties and risks associated with treating acid sulphate soils along a narrow road alignment.

Even though only short sections of trench are to be open at any given time, due to the marginal strength nature of many of the upper level soils encountered, particularly along the sewer alignment, it is anticipated that a trench shoring system may be required at some locations to prevent collapse of trench sides and to limit the amount of water seepage/infiltration into the trench. Shoring of the sides of the pump station excavation may also be required, due to the very soft nature of the marine clays encountered to a depth of 8.5m below ground surface. Shoring is less likely to be required for the trunk water main in areas immediately adjacent to the hillside on the southern side of the road, between chainages CH500 and CH1170, however local variations could occur and final determination for this requirement will need to be made during construction works.

Where sections of trench for the trunk water main are located within very stiff or stronger residual clays or weathered rock, with trench depths of less than 1.0m, shoring may be unnecessary. Inspection by a qualified geotechnical engineer/geologist during construction would be required to confirm these areas on site.

It is recommended that the placement of all trench backfilll be inspected, tested and certified by Cardno Bowler, during the earthworks operations to ensure that all fill is placed in accordance with Tweed Shire Council specifications.

5.2 Building Footings

Based on the fieldwork results, very poor foundation strata were present at the proposed pump station location.

Insufficient bearing capacities would be available for high level footings.

Based on the nature of the proposed structure and the subsurface conditions encountered, it is suggested that deep level footings be adopted for the pump station.

Alternative deep level footing types include bored piles, grout injected piles, driven piles, push piles and screw in steel piles.

For a piled structure, with piles taken to competent founding strata, settlements should be limited. These may be assessed by the pile designer when a pile design is being determined.

Bored Piles

Using the Australian Standard AS2159-1995 *'Piling - Design and Installation'*, the design of a bored or grout injected pile footing system may be based on the following formulae:

$S^* \leq R_g^*$

where $R^*_g = \phi_g R_{ug}$
R^*_g = Design Geotechnical Strength
S^* = design action effect (design load as the combination of factored loads which produce the most adverse effect on the pile).
ϕ_g = Geotechnical Reduction Factor
R_{ug} = Ultimate Geotechnical Strength
$R_{ug} = f_s A_s + f_b A_b$
f_s = Ultimate skin friction pressure
f_b = Ultimate base bearing pressure
A_b = Plan area of pile base
A_s = Surface area of pile

For piles founding into clay or weathered rock:
$f_s = S \alpha$
$f_b = S N_c$
where α = Adhesion factor
N_c = Bearing capacity factor which varies between 5 and 9 depending on the depth of the pile
S = Undrained shear strength

For piles founding into sands or gravels:

$f_s = K_s\,\sigma'_v \tan\delta$

$f_b = \sigma'_{vb} N_q$

where σ'_v = vertical effective stress at relevant depth

σ'_{vb} = vertical effective stress at the base of pile or at limiting depth

N_q = Bearing capacity factor due to overburden pressure

K_s = Earth pressure co-efficient

δ = Angle of sidewall friction

The parameters shown in Table 2 may be used for footing design purposes. However, if bored piles are adopted, the base of the piles must be inspected during construction to ensure that material of adequate capacity supports each pile. It is essential that the base of each pile is free from any water-softened materials and any debris. Pile bases should be **cleaned using a clean out bucket or cleaning plate**. This instruction should be made **explicit** to the piling contractor.

However, due to the presence of a high water table, there may be a need for pumps to be utilised and/or a full casing sealed into the rock or an impermeable layer to maintain the integrity of the pile base, depending on the water influx into the pile hole.

If the pumping of water is not considered a satisfactory method to keep the water influx low, other possibilities include drilling the bore under bentonite suspension to the end bearing strata. Concrete is placed into the bore by tremie, and the bentonite suspension is displaced by the concrete. The major disadvantages with the method is that, unless the waste suspension is collected, the site can become very wet. There are also difficulties with checking of base cleanliness.

If may be prudent to drill a test pile on this site if bored pier construction methods are to be utilised to assess the suitability of this method and to determine if water inflow can be controlled.

Grout injected piles are another construction type that may be suitable. However, this piling technique is not favoured as some difficulties with base cleanliness and end resistance can occur with grout injected piles socketted through clay into rock.

Table 2: Geotechnical Parameters for Bored Piles

Material Type	Design Equivalent Skin Friction $\phi_g f_s$ (kPa)	Design Equivalent Base Bearing Capacity $\phi_g f_b$ (kPa)
Soft Marine clays	NR	NR
Stiff clays	20	150
Very stiff clays	24	250

Notes:

a) NR = Not Recommended

b) Ignore top 1.5m of profile in pile capacity calculations.

c) The above values were compiled assuming that the pile depth will be at least 5 times that of its pile diameter.

d) A geotechnical strength reduction factor (ϕ_g) of 0.4 has been applied to the ultimate parameters in the calculation of the above design equivalent capacities.

e) The geotechnical strength reduction factor could be increased should dynamic or static pile testing be carried out. If this is the case, then Cardno Bowler should be contacted.

Screw Piles

This deep foundation method is performed by screwing in a compression auger head which has a hollow steel tube connected to a hollow helix.

When the bearing strata is reached the steel cage is placed down the hollow tube and the tube filled with concrete. The auger head and steel tube are then unscrewed. The auger head is slowly withdrawn and concrete pumped out the end of the head under pressure filling the bore with concrete whilst being removed.

Nominal screw pile sizes are shown in Table 3.

Table 3: Nominal Screw Pile Sizes

Minor Diameter (mm)	Maximum Helix Diameter (mm)
410	550
460	510
510	660
560	700

In the calculation of allowable base bearing and allowable skin friction capacity, the following shaft sizes may be adopted:

- Base bearing = minor diameter + 150mm
- Skin friction = minor diameter + 100mm

The major advantage with this form of pile installation is that high ground water levels have no effect on pile construction.

The disadvantage with this piling technique is that subsurface materials, including the founding stratum can not be visually assessed during the construction process.

Driven Piles

Driven precast concrete or timber piles are a possible foundation type where the founding stratum is at depth. These have the advantage of not being effected by groundwater during construction.

Piles driven to near refusal into weathered rock can generally be designed based on the pile section capacity rather than on a consideration of the soil properties. Typical precast concrete pile sizes and nominal capacities are provided in Table 4 below.

Table 4: Indicative Pile Sizes and Capacities

Pile Size (mm square)	Nominal Capacity (kN)
235	600-700
275	1000-1200
300	1400-1500
350	1600-1800

The range in capacity for a given size reflects variation between individual piling contractors.

Piles would be expected to refuse in weathered rock with consecutive SPT 'N' values of about 50 or greater. Piling depths significantly deeper than 11m would be expected.

Vibrations and the pile cap associated with this type of installation are the major drawbacks related to driven pile construction. The vibrations of a driven pile drop hammer may potentially cause structural damage to existing pipes etc, and this must be considered carefully if this technique is to be utilised.

Cast insitu concrete driven piles with enlarged bases are another piling option. This is a method where a withdrawable tube containing a plug of gravel or dry concrete is driven down by blows from an internal drop hammer to founding depth. When the founding depth is reached the concrete is placed and the concrete plug hammered out to form a bulb end. A reinforcing cage and concrete are then placed and the tube is withdrawn.

Nominal pile capacities for this type of construction are displayed in Table 5

Table 5: Cast – Insitu (Enlarged Base) Driven Pile Capacities

Shaft Diameter	Working Load (kN)
400	1000
500	1500
600	2500

Loads are based on a base diameter of at least 1.5 times the shaft diameter.

A specialist piling contractor should be consulted to confirm pile capacities.

The advantage of the alternative deep level footing types (driven piles, push piles, screw in steel piles) is that they can be installed under a performance specification and they can be installed when there is a high water table or where drilled shafts would collapse without support.

6 ACID SULFATE SOIL ASSESSMENT

The following information was used to assess the presence of acid sulfate soils (ASS) at the site:

- Brief desktop study.
- On site indicators.
- Chemical tests including:
  - pH field tests.
  - S_{CR} analysis.
  - Groundwater quality assessment.

6.1 Desktop Study and On Site Indicators

Based on the Geological Map of Murwillumbah (Sheet 9541, 1978) the expected subsurface material on site bordered between Cainozoic alluvial strata including clay, silt, sand and gravel, and undifferentiated Neranleigh Fernvale beds comprising greywacke, argillite, quartzite, chert, shale, sandstone and greenstone.

The universal grid reference as indicated from the above geological map for the proposed development was 476817 to 483815.

The site was identified as being substantially below RL5.0m, and including recent Holocene estuarine deposits, which commonly contain ASS.

The adjoining swampy and low-lying terrain is also typical of conditions where acid sulfate soils are present.

The section of pipeline near the intersection with Anconia Street, is located within a higher ground (hillslope) area, and proposed invert levels are predominantly above RL5. Testing was not considered necessary for this section.

6.2 pH Tests

A total of 48 samples were recovered with a pH_F and pH_{FOX} test carried out on each sample. The field tests provided an indication as to the likelihood of the tested soils being actual or potential ASS. The results of the reactions are detailed on the field pH reports attached to Annex A.

pH_F Indicator

Premise: If the field pH is below pH4, the material is likely to contain Actual ASS (AASS).

Result: The field pH readings for most samples were above the threshold of pH 4. This indicated that actual ASS were unlikely to be present at the tested locations.

pH_{FOX} Indicators

Premise: If the pH_{FOX} result is lower than 3 (the extremely acid range), this is a strong indication of Potential Acid Sulfate Soils (PASS).

Results: The pH_{FOX} results for several samples were below the threshold of 3 which indicates PASS were likely to be present.

Premise: The stronger the reaction with peroxide in the pH_{FOX} test (in terms of gentle fizzing versus violent effervescing) the more likely the material contains PASS.

Results: A visual assessment on the severity of the reaction that occurred immediately after adding hydrogen peroxide to the insitu material was recorded. This reaction was quite variable across the tested samples. This indicated that PASS were likely to be present at several locations.

Premise: If the pH_{FOX} differs by more than 1pH unit below the pH_F, the material is likely to be PASS, with the greater the difference the stronger the indication.

Results: Several of the pH_{FOX} readings were greater than 1pH unit from the field pH reading, indicating PASS material may be present.

Overall, the pH_{FOX} results and the other indicators showed a likelihood of PASS at the tested locations.

These indicator test results were assessed in conjunction with more definitive laboratory testing.

6.3 S_{CR} Analysis

The more definitive full S_{CR} (chromium reducible) suite of laboratory tests were carried out on samples recovered at 0.5m intervals from all boreholes. A total of 58 tests were used to determine levels of acidity.

Full laboratory test results are included in Annex B. Table 6 below provides a summary of determined net acidity values for each tested sample. The net acidity has been based on the following equation:

Net Acidity = Potential Sulfidic Acidity
plus Actual Acidity *
plus Retained Acidity *
minus Acid Neutralising Capacity/Fineness Factor *

* (not all components are included - depends on pH_{KCl} results).

Table 6: Calculated Net Acidity Results

Test Location	Depth (m)	Approx RL (m)	Net Acidity, (eq%S)
BH1	0.0-0.25	2.1-1.85	0.029
	0.5-0.75	1.6-1.35	**0.093**
	1.0-1.25	1.1-0.85	**0.136**
	1.5-1.75	0.6-0.35	**0.043**
	2.0-2.25	0.1 - (-0.15)	**0.080**
	2.5-2.75	(-0.4) – (-0.65)	**0.075**
BH2	0.5-0.75	2.9-2.65	0.018
	1.0-1.25	2.4-2.15	**0.040**
	1.5-1.75	1.9-1.65	**0.033**
	2.0-2.25	1.4-1.15	**0.033**
	2.5-2.75	0.9-0.65	**0.037**

Table 6 continued

Test Location	Depth (m)	Approx RL (m)	Net Acidity, (eq%S)
BH3	0.5-0.75	3.15-2.9	**0.087**
	1.0-1.25	2.65-2.4	**0.043**
	1.5-1.75	2.15-1.9	**0.146**
	2.0-2.25	1.65-1.4	**0.174**
	2.5-2.75	1.15-0.9	**0.036**
BH4	0.5-0.75	3.0-2.75	**0.094**
	1.0-1.25	2.5-2.25	0.027
	1.5-1.75	2.0-1.75	**0.164**
	2.0-2.25	1.5-1.25	**0.155**
	2.5-2.75	1.0-0.75	**0.079**
BH5	0.0-0.25	0.52-0.27	0.025
	0.5-0.75	0.02 - (-0.23)	**0.073**
	1.0-1.25	(-0.48) - (-0.73)	**0.125**
	1.5-1.75	(-0.98) - (-1.23)	**4.01**
	2.0-2.25	(-1.48) - (-1.73)	**1.53**
	2.5-2.75	(-1.98) - (-2.23)	**0.46**
BH6	0.5-0.75	1.1 - 0.85	**2.99**
	1.0-1.25	0.6 - 0.35	**0.182**
	1.5-1.75	0.1 - (-0.15)	**0.366**
	2.0-2.25	(-0.4) – (-0.65)	**0.076**
	2.5-2.75	(-0.9) – (-1.15)	**1.14**
BH7	0.5-0.75	0.6 - 0.35	**0.051**
	1.0-1.25	0.1 - (-0.15)	**0.133**
	1.5-1.75	(-0.4) - (-0.65)	**0.031**
	2.0-2.25	(-0.9) - (-1.15)	**1.02**
	2.5-2.75	(-1.4) - (-1.65)	**1.41**
BH8	0.0-0.25	0.7-0.45	**0.057**
	0.5-0.75	0.2 - (-0.05)	**0.157**
	1.0-1.25	(-0.3) - (-0.55)	**0.139**
	1.5-1.75	(-0.8) - (-1.05)	**0.157**
	2.0-2.25	(-1.3) - (-1.55)	**0.131**
	2.5-2.75	(-1.8) - (-2.05)	**1.82**
	3.0-3.25	(-2.3) - (-2.55)	**1.95**
	3.5-3.75	(-2.8) - (-3.05)	0.004

Table 6 continued

Test Location	Depth (m)	Approx RL (m)	Net Acidity, (eq%S)
BH8 (cont'd)	4.0-4.25	(-3.3) - (-3.55)	**1.53**
	4.5-4.75	(-3.8) - (-4.05)	**0.572**
	5.0-5.25	(-4.3) - (-4.55)	**0.056**
BH9	0.0-0.25	2.2-1.95	**0.039**
	0.5-0.75	1.7-1.45	**0.088**
	1.0-1.25	1.2-0.95	**0.062**
	1.5-1.75	0.7-0.45	**0.044**
BH11	0.0-0.25	2.7-2.45	0.011
	0.5-0.75	2.2-1.95	0.025
	1.0-1.25	1.7-1.45	Nil
	1.5-1.75	1.2-0.95	0.021
	2.0-2.25	0.7-0.45	0.017
	2.5-2.75	0.2 – (-0.05)	0.009

Note: Numbers in bold indicated net acidity values greater than the action criteria of 0.03%.

As the soils have net acidity values greater than the action criteria of 0.03% (some significantly higher), a detailed acid sulfate soil management plan is required to manage the potential harm to the environment. This is detailed in section 7.

6.4 Management Options

6.4.1 Avoidance

The preferred management option where acid sulfate soils are present on a development site is avoidance. This means avoiding disturbing the ASS by planning the project layout around ASS areas and depths. This could include planning service trenches either to be shallow enough so that they do not reach the layers of ASS or selecting their locations so that they will not involve excavating into ASS. As this is not possible for this project, and ASS layers will be disturbed by the proposed excavations, then neutralising of the expected acid production is the most common solution. This is detailed in Section 6.4.2 below.

6.4.2 Liming Rates

Although the net acidity (and therefore the required neutralization rate) varies with depth at each tested location, rather than attempting to differentiate between soil types given the limited volumes that will be excavated from each section of trench, it is recommended that the liming rates be based on the maximum net acidity values that have been encountered along each linear section of trench.

It has been proposed to take all excavated soils to a dedicated treatment area within the Cobaki Lakes site, and to backfill the trench with a select material from an alternative (non-ASS) source. This is considered to be a practical methodology for trenching in such restricted site conditions (narrow road). As such, spoil from each section of excavated trench is to be neutralised with the liming rates as detailed below.

The estimated liming rates to neutralise the acid sulfate soils for each section of alignment are summarised in Table 7 below. Liming rates have been calculated from the maximum Net Acidity values for each segment.

Table 7: Liming Rates

Location	Typical Depths (m)	Liming Rate (1)	
		kg/tonne (2)	kg/m^3 (2)
CH00-CH550 on both mains BH5-BH8	Full depth of trench (and pump station) excavation	190	300
CH550-CH1150 on sewer main and CH550 – CH900 on trunk water main. BH1-4 & BH9	Full depth of trench excavation	9	13
CH900-CH1170 on trunk water main BH11	Full depth of trench excavation	NIL	NIL

Notes:

1. The indicated liming rates have included a safety factor of 1.5 to compensate for the possible effects of poor mixing and the reactivity of lime.
2. The conversion of liming rates from tonnes to cubic metres have been made as follows:
   - Fine texture soft to firm clay – 1.5t/m^3 bulk density
   - Coarse texture loose to medium dense sands – 1.5t/m^3 bulk density

6.5 Groundwater Analysis

The groundwater quality results have been summarised in Table 8 below. Full details are included in Annex B.

Table 8: Groundwater Quality

Description	Units	Result				
		CREEK 1	D1	BH2	BH5	BH8
pH	-	8.1	8.0	6.0	7.3	6.9
Electrical Conductivity	mS/cm	34.7	0.8	6.4	14.3	33.3
Dissolved Oxygen	mg/L	11.3	5.0	7.7	7.0	5.1
Colour	PCU	9	67	11	83	46
Calcium	mg/L	265	21	122	106	237
Magnesium	mg/L	456	8.0	139	228	422
Carbonate	mg/L	NP	NP	NP	NP	NP
Bicarbonate	mg/L	71	92	43	476	269
Sulfate	mg/L	1773	29	802	157	1267
Chloride	mg/L	21600	60	1470	4550	13500
Soluble Iron	mg/L	0.14	1.94	22.0	0.12	6.26
Total Iron	mg/L	0.36	5.57	23.0	1.35	17.0
Soluble Aluminium	mg/L	0.01	0.08	0.02	0.01	<0.01
Soluble Manganese	mg/L	0.02	0.04	0.65	0.33	0.72

NP = Not Present

The pH of the groundwater at BH2 was slightly acidic (6.0) but the other 4 samples recorded pH results within the guidelines (ANZECC Water Quality Guidelines for Fresh and Marine Water, 1992) allowable range of 6.5 to 8.5.

QASSIT Guidelines require that any disturbance to actual or potential ASS and groundwater levels, which results in groundwater with pollutants (eg acid, water soluble iron, aluminium and sometimes heavy metals), must be contained and managed within the boundary lines of the site.

Hence, the groundwater located on site will need to be managed by collecting any dewaterings from the trenches into a portable dosage/treatment tank. The retained water can be monitored and treated to acceptable levels prior to being slowly discharged back on the site. At the treatment pad location, to contain and manage any potential stormwater runoff, the treatment pad shall be bunded and drainage directed into a retention basin for management.

7 SITE MANAGEMENT

Based on the amount of acid sulfate soil being disturbed and the laboratory test results, the site has been identified as requiring substantial treatment. The proposed site management is therefore to include:

- Treatment of disturbed soils with neutralising agent (aglime).
- Validation of the effectiveness of the lime treatment.
- Monitoring of the pH of collected water.
- Prevention, or treatment of any infiltration passing through ASS into groundwater.

Each of the above items has been described in more detail in the following sections. Also, Table 9 summarises the details of ASMP and Table 10 summarises monitoring requirements.

7.1 Treatment of Disturbed Soils

The required method for handling excavated materials which contain acid sulfate soils is to stockpile the excavated soils at the nominated location within the Cobaki Lakes site and treat with lime. The treated material may then be used as desired. The lime treatment must occur within 18 hours for sandy soils, and within 60 hours for predominantly clay soils.

Liming of the soils shall take place with the following requirements:

- The location of the spoil stockpile will be as specified within the Cobaki Lakes site.
- The ground below the base of the stockpile shall be protected by a *'guard layer'* of lime placed at a rate of 60kg of agricultural lime per square metre for each 1m height of stockpile (i.e. 30 kg/m^2 if a 0.5m high stockpile was planned) when spoil from CH00-CH550 is being processed, or a minimum rate of 5kg of agricultural lime per square metre for each 1m height of stockpile (i.e. 2.5kg/m^2 if a 0.5m high stockpile was planned) when spoil from CH550 onwards is being processed. This will neutralise acidic leachate generated within the stockpiles.
- The bases of the excavated trenches shall be treated with a precautionary rate of 60kg of agricultural lime per square metre from CH00-CH550, and 5kg of agricultural lime per square metre from CH550 onwards.
- The excavated trenches are to be backfilled with non-ASS imported select fill.
- Retention bunds (made of non-ASS material) are to be constructed around the treatment stockpile areas to collect and contain surface runoff and leachate. The material used to construct any bund walls is to be treated with lime with the insitu material at the base of the bund treated with lime to a depth of 0.3m.
- Soils excavated and stockpiled shall be blended with fine-grained agricultural lime at the rate determined by the results of the S_{CR} test per dry tonne of soil, using a safety factor of 1.5. The liming rates have been provided in Table 7.
- Lime shall be fine-grained agricultural lime of at least 90% purity.
- The most effective method for mixing the material is by rotary hoe, disk plough or similar. The process shall involve placing thin layers (200mm – 300mm) of acid sulfate soils over the pre treated designated stockpile area, dosing the material at the determined lime rate, and ploughing again to make a homogeneous mix.
- All stockpiles are to be tested to confirm the liming and mixing process has effectively neutralised the acid sulfate soils. Validation testing requirements are outlined in Section 7.2.
- The stockpiled material shall not be used on site or removed from site until the validation testing confirms the stockpile has been treated successfully.

- The lime is to be stored at an on site depot. The contractor shall keep in storage approximately 500kg of agricultural lime at any one time to allow for any potential non-conformances to the ASSMP.

7.2 Validation Testing

Once the lime treatment of acid sulfate soils (which have been stockpiled at the specified treatment site) has been carried out, the treated soils will then be sampled and tested to ensure that the stockpile treatment has been successful. S_{CR} tests are used to determine this. Because of the high rates of net acidity encountered, validation testing will include one S_{CR} test carried out on every $100m^3$ of treated stockpile. The treated soils shall not be removed from site until validation tests have confirmed successful liming. This will take approximately 2 days.

7.3 Water Quality Management

The investigation to date has indicated that groundwater was encountered at depths of between 1.6m and 2.5m. In accordance with the guidelines, any disturbance to actual or potential ASS and groundwater levels, must be contained and managed within the boundary lines of the site.

When groundwater, stormwater etc, is encountered during excavation and treatment works, consideration shall be given to the following:

- Onsite runoff and any excavation dewatering shall be contained and managed within the boundaries of the site. These waters shall be directed into an on site portable treatment/dosage tank.
- For any treatment stockpile run off, these waters shall be directed into a retention basin. The retention basin base and sides shall be pretreated with lime to minimise acid leachate
- No water from the dosage tank or retention basin shall be released until acceptable test results are achieved (discussed below).
- The existing groundwater may require adjustment/treatment prior to re-release after dewatering (i.e. if the existing pH is low).
- Groundwater samples and Cobaki Creek samples have been tested prior to the commencement of earthworks to determine a benchmark for water analyses.
- During trench excavations, the testing of in situ groundwater shall include pH and EC and the water level every second day, from installed standpipes. If the pH falls below 6.5, additional tests will be required as described in the section below.
- During trench excavations, water is to be sampled every second day at 2 locations in the nearby Cobaki Creek, one upstream and one downstream, and tested for pH, EC and DO. If the pH falls below 6.5, additional tests will be required as described in the section below.
- During trench excavations, the stored dosage tank water is to be monitored for pH on a continuous basis, in accordance with the manufacturer's specifications. If the pH falls below 6.5, treatment is required to return the pH to an acceptable level prior to the release of the stored water.
- During the treatment pad operations, retention pond water is to be monitored on a weekly basis for pH, EC and DO. If the pH falls below 6.5, additional tests will be required as described in the section below.
- Detailed testing, when required, is to be as follows:
  - Total & dissolved iron
  - Filtered aluminium
  - Chloride
  - Calcium
  - Magnesium
  - Dissolved Manganese

- Sulfate
- Colour
- Carbonate
- Bicarbonate

- Treatment of the retained water is dependent on the initial water quality results. However, treatment of the water can be carried out by very careful use of hydrated lime, magnesium hydroxide or similar.
- These materials should be used carefully during treatment and a calibration process shall be determined to calculate the appropriate amount of lime needed for each basin. Relevant OH & S procedures for the handling of hydrated lime shall be followed.

When water quality results are analysed, consideration will be given to the existing water quality prior to the commencement of works.

7.4 Non Conformance Procedure and Contingencies

If a non conformance occurs during the monitoring of the management plan for acid sulfate material, the non conformance shall be immediately logged and reported to the superintendent responsible for the project. The appropriate corrective action as specified shall then be carried out. This action would require advice from Cardno Bowler.

Table 9: Summary Acid Sulfate Management Plan

Element	Acid Sulfate Soils Management
Objective	The prime objective for this acid sulfate soil environmental management plan is to control and neutralise exposed/disturbed acid sulfate soils to minimise the potential for any on site or off site degradation of the surrounding environment.
Management Strategy	Any excavated acid sulfate soils encountered on site will be treated by applying agricultural lime (min 90% purity) at the specified liming rate. Liming rates have been given in Table 7. Drainage waters from the excavation area, treatment areas and stormwater shall be directed to an on site portable dosage/treatment tank on Piggabeen Road, or retention basin within the Cobaki Lakes treatment area, then tested and treated, if required, using neutralising agents. No water from these storage tanks/basins can be released until acceptable tests results are achieved. These retention systems would not be required after acid sulfate soil disturbances and treatments have ceased.
Tasks & Monitoring	**The following actions shall be carried out before the bulk excavations commence;** › The earthmoving contractor shall be familiar with the treatment plan and prepare to implement the plan. **The following actions shall be carried out during the trench excavations;** › The liming rate shall be as given in Table 7, which has been determined from the S_{CR} net acidity result times a factor of 1.5 to allow for any deficiency in mixing techniques. › Treatment of the acid sulfate soil is to be implemented by mixing at least 90% pure agricultural lime with the soil using a rotary hoe, disk plough or similar methods that will successfully mix the lime through the soil (the contractor will nominate the most appropriate method). Excavated soils must be placed at the nominated stockpile locations. These must have been pretreated with a *'guard layer'* of lime. › Bunding shall be constructed around the treatment pad stockpile to divert any water runoff into a retention basin. › As lime treatment is progressively carried out, soil samples shall be collected from the stockpile at a frequency of one sample per 100m^3 for validation testing. The S_{CR} method will be used. If the test results are below the action criteria level, the soil contained in the stockpile is considered neutralised and can be removed reused or left in place as desired. If not, further liming will be required with more mixing of the stockpile and retesting. › Drainage water collected in the dosage tanks will be tested and treated continually in accordance with the manufacturer's specifications, prior to release. If the pH test results are outside the performance threshold limits, then the water shall be treated in accordance with the specifications. › Drainage water collected in the retention basin at the treatment pad area will be tested at 3 locations prior to release to determine the quality of the water. If the water quality test results are outside the performance threshold limits, then the water shall be treated using either hydrated lime, calcined magnesia or magnesium hydroxide. The retention basin would not be required after completion of the stockpile treatment.
Performance Indicators	The excavation or exposure of any acid sulfate soils on site will trigger this management plan. The lowering of the water table will trigger this management plan.

Table 9 continued

Element	Acid Sulfate Soils Management
Responsible Person/Company	› The contractor is to excavate, stockpile and treat acid sulfate soils with lime as per the above requirements, supply dosage tanks for trench dewatering collection, construct retaining bunds around stockpiles and to develop retention basins for stockpile runoff. › Cardno Bowler can ensure that the required number of samples have been collected and tested as specified. Cardno Bowler will carry monitoring requirements. Cardno Bowler will need to be informed of plans to commence construction at least 3 weeks in advance. › The Superintendent shall be notified immediately of any non conformance to the ASMP.
Reporting	Results for validation S_{CR} testing, a description of the treatment method, and a description of the materials excavated are to be reported & submitted to the superintendent. Water quality laboratory results will be reported. The results shall be submitted to the Superintendent prior to the material being reused or removed.
Corrective Action	Refer Section 7.4 in text.

Table 10: Monitoring Schedule and Performance Objectives

Situation	Parameter	Monitoring Schedule	Performance Criteria
SOILS **CONSTRUCTION PHASE** **Post Lime Treatment** › All treated material	› S_{CR}	1 test per 100m^3 stockpile	Net Acidity<0.03%
WATER MONITORING			
CONSTRUCTION PHASE › Groundwater standpipes	Full water quality as per Sec 7.3 pH, EC	If pH<6.5 Every second day	Various 6.5<pH<8.5
› Dosage tanks, (For reuse on site or released from site)	Full water quality as per Sec 7.3 pH, EC	If pH<6.5 continuous	Various 6.5<pH<8.5
› Retention basin at treatment pad area	Full water quality as per Sec 7.3 pH, EC	If pH<6.5 Every second day	Various 6.5<pH<8.5
› Cobaki Creek, upstream and downstream	Full water quality as per Sec 7.3 pH, EC, DO	If pH<6.5 Every second day	Various 6.5<pH<8.5

8 CONSTRUCTION INSPECTIONS AND ASSMP IMPLEMENTATION

It is recommended that the implementation of this management plan be monitored by Cardno Bowler to ensure that the plan is properly followed. Cardno Bowler cannot be held responsible for failures of the plan if we are not called upon to monitor it, and to check that any deviations from the plan are appropriate or necessary to minimise the potential for harm to the environment.

The ASSMP is to be reviewed and updated regularly to reflect what is learned on site during the operation of the project.

It is recommended that placement of all structural fill and footing excavations be inspected, tested and certified where necessary, by Cardno Bowler Pty Ltd to ensure recommendations made in this report have been adhered to.

Should subsurface conditions other than those described in this report be encountered, Cardno Bowler Pty Ltd should be consulted immediately and appropriate modifications developed and implemented if necessary.

9 CONCLUSIONS AND RECOMMENDATIONS

The following is a summary of the conclusions and recommendations in regard to the geotechnical and acid sulphate soil investigation for the proposed water and sewer mains at Piggabeen Road Package 2, Cobaki. However, the preceding sections of this report should be read for a full description of the conclusions and recommendations.

1. The subsurface conditions at the site showed significant variability, with soft marine clays extending to 8.5m at the west end of the site, and weathered rock at some locations at the east/central section of alignment.

2. The site preparation work should generally be carried out in accordance with Tweed Shire Council requirements.

3. Very soft marine clays were encountered at the proposed pump station location. A deep level piled system will be required to support the structure.

4. Groundwater/seepage was encountered at depths between 1.5m and 2.5m at several locations. Seepage could be expected at most locations (except possibly around BH9 and BH11) if excavations are left open for any length of time.

5. A series of field pH (pH_F) and pH oxidised (pH_{FOX}) tests, as well as the more definitive S_{CR} laboratory tests were carried out on samples recovered from all boreholes, with the results indicating that net acidity levels of most locations exceeded the action criteria levels with particularly high values in the soft marine clays.

6. As net acidity results have exceeded the guidelines a detailed acid sulfate soil management plan (ASSMP) is deemed necessary to manage the potential harm to the environment. This ASSMP is included as Section 7 of this report.

7. The estimated liming rates to neutralise the potential acid sulfate soils range up to 300kg/m3 for both trenches from CH00 to CH550. The liming rate is reduced to 13kg/m3 for both the sewer main trench from CH550 to CH1150, and the water trench from CH550 to CH900. For the remaining section of water main, CH900 to CH1170, liming has been deemed unnecessary. However, on site monitoring during construction may consider any variability in the subsurface strata with the required treatment area categorised.

8. Groundwater samples were recovered from 5 locations, and only 1 sample (BH2) showed a pH lower than required.

9. The groundwater can be managed on site by sending any trench dewaterings to a portable dosage/treatment tank. Any stormwater runoff over the treatment pad area, which is to be located at the nominated Cobaki Lakes site, can be managed by introducing lime treated water retention basins and the runoff directed into the retention basin. The waters collected must be contained and managed within the boundary lines of the site and treated, as necessary, to acceptable levels prior to discharge.

Yours faithfully

CLAUDIA GIBNEY
SENIOR GEOTECHNICAL ENGINEER
for **Cardno Bowler**

DAVID BOWLER
SENIOR PRINCIPAL

KEY:

APPROX BOREHOLE LOCATION

APPROX SURFACE WATER COLLECTION POINT

BH = BOREHOLE LOCATION
DCP = DYNAMIC CONE PENETROMETER TEST
SP = STANDPIPE
CR = CREEK WATER COLLECTION POINT
D =GULLY DRAIN WATER COLLECTION POINT

SCALE APPROX 1 : 3500

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INVESTIGATION LOCATION PLAN

PROPOSED TRUNK WATER AND SEWER MAINS

PIGGABEEN ROAD, FOR COBAKI LAKES

JOB NO.: **8768CG**

FIGURE 1

KEY:

APPROX BOREHOLE LOCATION

APPROX SURFACE WATER COLLECTION POINT

BH = BOREHOLE
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SCALE APPROX 1 : 3500……

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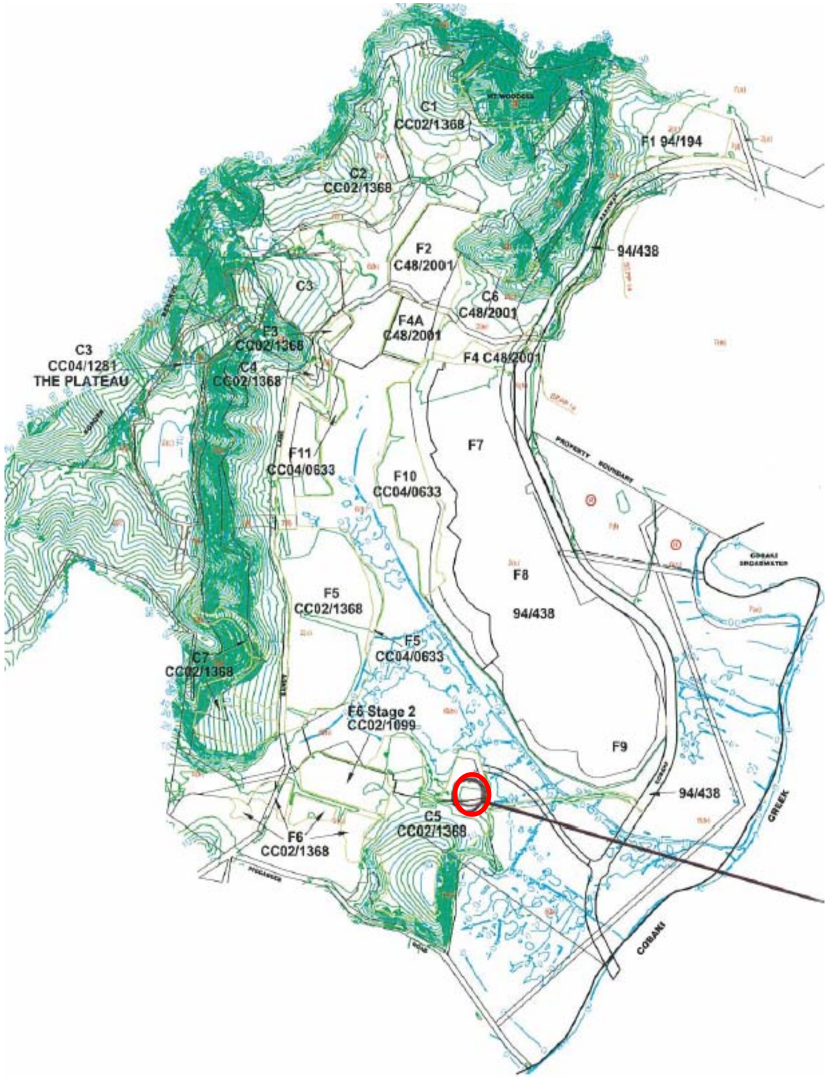
INVESTIGATION LOCATION PLAN

PROPOSED TRUNK WATER AND SEWER MAINS

PIGGABEEN ROAD, FOR COBAKI LAKES

JOB NO.: **8768CG**

FIGURE 2



NOTE: PLAN AND PHOTO SUPPLIED BY CLIENT

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TREATMENT PAD LOCATION PLAN

PROPOSED TRUNK WATER AND SEWER MAINS

PIGGABEEN ROAD, COBAKI

JOB NO.: **8768**

FIGURE 3

GENERAL NOTES

April 2005

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GENERAL

This report comprises the results of an investigation carried out for a specific purpose and client as defined in the introduction section(s) of the document. The report should not be used by other parties or for other purposes as it may not contain adequate or appropriate information.

TEST HOLE LOGGING

The information on the Test Hole Logs (Boreholes, Backhoe Pits, Exposures etc.) has been based on a visual and tactile assessment except at the discrete locations where test information is available (field and/or laboratory results).

Reference should be made to our standard sheets for the definition of our logging procedures (Soil and Rock Descriptions).

GROUNDWATER

Unless otherwise indicated the water levels given on the test hole logs are the levels of free water or seepage in the test hole recorded at the given time of measuring. The actual groundwater level may differ from this recorded level depending on material permeabilities. Further variations of this level could occur with time due to such effects as seasonal and tidal fluctuations or construction activities. Final confirmation of levels can only be made by appropriate instrumentation techniques and programmes.

INTERPRETATION OF RESULTS

The discussion and recommendations contained within this report are normally based on a site evaluation from discrete test hole data. Generalised or idealised subsurface conditions (including any cross-sections contained in the report) have been assumed or prepared by interpolation/extrapolation of these data. As such these conditions are an interpretation and must be considered as a guide only.

CHANGE IN CONDITIONS

Local variations or anomalies in the generalised ground conditions used for this report can occur, particularly between discrete test hole locations. Furthermore, certain design or construction procedures may have been assumed in assessing the soil structure interaction behaviour of the site.

Any change in design, in construction methods, or in ground conditions as noted during construction, from those assumed in this report should be referred to this firm for appropriate assessment and comment.

FOUNDATION DEPTH

Where referred to in the report, the recommended depth of any foundation (piles, caissons, footings, etc.) is an engineering estimate of the depth to which they should be constructed. The estimate is influenced and perhaps limited by the fieldwork method and testing carried out in connection with the site investigation, and other pertinent information as has been made available. The depth remains, however, an estimate and therefore liable to variation. Footing drawings, designs and specifications based upon this report should provide for variations in the final depth depending upon the ground conditions at each point of support.

REPRODUCTION OF REPORTS

Where it is desired to reproduce the information contained in this report for the inclusion in the contract documents or engineering specification of the subject development, such reproduction should include at least all the relevant test hole and test data, together with the appropriate standard description sheets and remarks made in the written report of a factual or descriptive nature.

This report is the subject of copyright and shall not be reproduced either totally or in part without the express permission of this firm.

IMPORTANT INFORMATION
ABOUT YOUR
GEOTECHNICAL ENGINEERING REPORT

More construction problems are caused by site subsurface conditions that any other factor. As troublesome as subsurface problems can be, their frequency and extent have been lessened considerably in recent years, due in large measure to programs and publications of ASFE / The Association of Engineering Firms Practicing in the Geosciences.

The following suggestions and observations are offered to help you reduce the geotechnical-related delays cost-overruns and other costly headaches that can occur during a construction project.

A GEOTECHNICAL ENGINEERING REPORT IS BASED ON A UNIQUE SET OF PROJECT-SPECIFIC FACTORS

A geotechnical engineering report is based on subsurface exploration plan designed to incorporate a unique set of project-specific factors. These typically include the general nature of the structure involved, its size and configuration; the location of the structure on the site and its orientation; physical concomitants such as access roads, parking lots and underground utilities, and the level of additional risk which the client assumed by virtue of limitations imposed upon the exploratory program. To help avoid costly problems, consult the geotechnical engineer to determine how any factors which change subsequent to the date of the report may affect its recommendations.

Unless your consulting geotechnical engineer indicates otherwise, *your geotechnical engineering report should not be used:*

- When the nature of the proposed structure is changed, for example, if an office building will be erected instead of a parking garage, or if a refrigerated warehouse will be built instead of an unrefrigerated one;
- when the size or configuration of the proposed structure is altered;
- when the location or orientation of the proposed structure is modified;
- when there is a change of ownership, or
- for application to an adjacent site.

Geotechnical engineers cannot accept responsibility for problems which may develop if they are not consulted after factors considered in their report's development have changed.

MOST GEOTECHNICAL "FINDINGS" ARE PROFESSIONAL ESTIMATES

Site exploration identifies actual subsurface conditions only at those points where samples are taken, when they are taken. Data derived through sampling and subsequent testing are extrapolated by geotechnical engineers who then render an opinion about overall subsurface conditions, their likely reaction to proposed construction activity and appropriate foundation design. Even under optimal circumstances actual conditions may differ from those inferred to exist, because no geotechnical engineer, no matter how qualified, and no subsurface exploration program, no matter how comprehensive, can reveal what is hidden by earth, rock and time. The actual interface between materials may be far more gradual or abrupt than a report indicates. Actual conditions in areas not sampled may differ from predications. *Nothing can be done to prevent the unanticipated, but steps can be taken to help minimise their impact.* For this reason, *most experienced owners retain their geotechnical consultants through the construction stage,* to identify variances, conduct additional tests which may be needed, and to recommend solutions to problems encountered on site.

SUBSURFACE CONDITIONS CAN CHANGE

Subsurface conditions may be modified by constantly changing natural forces. Because a geotechnical engineering report is based on conditions which existed at the time of subsurface exploration, *construction decisions should not be based on a geotechnical engineering report whose adequacy may have been affected by time.* Speak with the geotechnical consultant to learn if additional tests are advisable before construction starts.

Construction operations at or adjacent to the site and natural events such as floods, earthquakes or groundwater fluctuations may also affect subsurface conditions and thus, the continuing adequacy of a geotechnical report. The geotechnical engineer should be kept apprised of any such events, and should be consulted to determine if additional test are necessary.

GEOTECHNICAL SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES AND PERSONS

Geotechnical engineers' reports are prepared to meet the specific needs of specific individuals. A report prepared for a consulting civil engineer may not be adequate for a construction contractor, or even some other consulting civil engineer. Unless indicated otherwise, this report was prepared expressly for the client involved and expressly for purposes indicated by the client. Use by any other persons for any purpose, or by the client for a different purpose, may result in problems. *No individual other than the client should apply this report for its intended purpose without first conferring with the geotechnical engineer. No person should apply this report for any purpose other than that originally contemplated without first conferring with the geotechnical engineer.*

A GEOTECHNICAL ENGINEERING REPORT IS SUBJECT TO MISINTERPRETATION

Costly problems can occur when other design professionals develop their plans based on misinterpretations of a geotechnical engineering report. To help avoid these problems, the geotechnical engineer should be retained to work with other appropriate design professionals to explain relevant geotechnical findings and to review the adequacy of their plans and specifications relative to geotechnical issues.

BORING LOGS SHOULD NOT BE SEPARATED FROM THE ENGINEERING REPORT

Final boring logs are developed by geotechnical engineers based upon their interpretation of field logs (assembled by site personnel) and laboratory evaluation of field samples. Only final boring logs customarily are included in geotechnical engineering reports. *These logs should not under any circumstances be redrawn* for inclusion in architectural or other design drawings, because drafters may commit errors or omissions in the transfer process. Although photographic reproduction eliminates this problem, it does nothing to minimize the possibility of contractors misinterpreting the logs during bid preparation. When this occurs, delays, disputes and unanticipated costs are the all-too-frequent result.

To minimize the likelihood of boring log misinterpretation, *give contractors ready access to the complete geotechnical engineering report* prepared or authorized for their use*. Those who do not provide such access may proceed under the *mistaken* impression that simply disclaiming responsibility for the accuracy of subsurface information always insulates them from attendant liability. Providing the best available information to contractors helps prevent costly construction problems and the adversarial attitudes which aggravate them to disproportionate scale.

* For further information on this aspect reference should be made to "Guidelines for the Provision of Geotechnical Information in Construction Contracts" published by The Institution of Engineers Australia, National Headquarters, Canberra, 1987.

READ RESPONSIBILITY CLAUSES CLOSELY

Because geotechnical engineering is based extensively on judgment and opinion, it is far less exact than other design disciplines. This situation has resulted in wholly unwarranted claims being lodged against geotechnical consultants. To help prevent this problem, geotechnical engineers have developed model clauses for use in written transmittals. These are *not* exculpatory clauses designed to foist geotechnical engineers' liabilities onto someone else. Rather, they are definitive clauses which identify where geotechnical engineers' responsibilities begin and end. Their use helps all parties involved recognize their individual responsibilities and take appropriate action. Some of these definitive clauses are likely to appear in your geotechnical engineering report, and you are encouraged to read them closely. Your geotechnical engineer will be pleased to give full and frank answers to your questions.

OTHER STEPS YOU CAN TAKE TO REDUCE RISK

Your consulting geotechnical engineer will be pleased to discuss other techniques which can be employed to mitigate risk. In addition, ASFE has developed a variety of materials which may be beneficial. Contact ASFE for a complimentary copy of its publications directory.

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Cardno BOWLER

Shaping the Future

IMPORTANT INFORMATION ABOUT ACID SULFATE SOILS

How are acid sulfate soils formed?

Acid sulfate soils (ASS) are soils rich in iron sulfides, such as pyrite. When exposed to air by drainage or excavation, the pyrite reacts with oxygen. This results in the release of copious quantities of sulfuric acid together with high levels of heavy metals, such as iron and toxic aluminum.

Releases of acid and metals can cause significant harm to the environment, engineering structures and even human health. Areas of acid sulfate soils should be identified before disturbance to ensure that appropriate measures can be taken to minimise potently problems.

In Australia, the sediments that are of most concern are those which formed within the last 10000 years (Holocene era), after the last major sea level rise. When the sea level rose and inundated the land, sulfate in the sea water mixed with land sediments containing iron oxides and organic matter. The resulting chemical reaction produced large quantities of iron sulfides in waterlogged environments.

Identification of ASS - Maps indicating acid sulfate soils in key coastal areas from the NSW border to Noosa are available from the Department of Natural Resources. Mapping projects are continuing in key areas. A number of landscape features can indicate the presence of acid sulfate soils and highlight areas which may require further investigation. Laboratory analysis of soil samples is necessary to confirm the presence of acid sulfate soils.

Elevation - Acid sulfate soils are commonly found less than 5 metres above sea level, particularly in low-lying coastal areas. Mangroves, salt marshes, floodplains, swamps, estuaries, and brackish or tidal lakes, are ideal for acid sulfate soil formation.

Vegetation - Species that commonly indicate acid sulfate soil areas include mangroves, marine couch, tea-trees (Melaleuca spp), Phragmites spp., and she-oaks (Casuarina spp). Stunted or dead vegetation, acid scalds and poor vegetation regrowth in previously disturbed areas are all indicative of the impacts of acid production due to the exposure of acid sulfate soils (salinity may cause similar problems).

Soils - In their undisturbed, waterlogged state, acid sulfate soils may range from dark grey muds to grey sands and sometimes peats. Initially, they have a pH close to neutral (6.5-7.5), but may became very acidic when exposed to air (pH<3). When disturbed, the soils may smell of 'rotten eggs' (hydrogen sulfide gas). **Jarosite** is a straw-yellow mineral and is the most conclusive indicator that the iron sulfides in acid sulfate soils are oxidising and forming sulfuric acid. Jarosite requires very acidic conditions (pH<3.7) to form.

Iron Staining - A by-product of the acidification of acid sulfate soils is the production of rust-coloured iron stains and oil-looking bacterial scums. When acid water mixes with water of a higher pH, the dissolved iron in the water precipitates as a rust-red scum, which can smother and kill vegetation and aquatic organisms. During iron scum formation, oxygen is removed from the water, resulting in low dissolved oxygen levels which can be a potential cause of fish kills.

Water quality – When sulfuric acid (from iron sulfide oxidation) reaches a water body, the water can become highly acidic (pH<4). Clear blue-green water indicates the presence of soluble aluminium and soluble iron in acid water. When the aluminium from the soil moves into the water, it can cause particles suspended in the water to clump together and drop to the bottom of the water body. This results in clear blue-green water with a deceivingly healthy looking appearance.

Fish kills – Fish kills may be associated with exposure of acid sulfate soils. Sudden changes in acid, aluminium, iron or oxygen levels in the aquatic environment can kill fish and may also kill less obvious aquatic organisms, including bottom-dwelling crustaceans and oysters. Diseases such as 'red spot' may also be trigged by acid water.

The above information are extracts from fact sheets provided by the DNR (Reference LC60, LC61 and LC62). A full extract of these fact sheets can be found at the DNR web site www.dnr.qld.gov.au

Bowler Geotechnical will be pleased to discuss any issues regarding acid sulfate soils. For further information contact our engineering department on 07 38006446 or visit our website on www.bowlergeotechnical.com.au

Annex A

Fieldwork Results

September, 2001

SOIL DESCRIPTION

This procedure involves the description of a soil in terms of its visual and tactile properties, and relates to both laboratory samples and field exposures as applicable. A detailed soil profile description, in association with local geology and experience, will facilitate the initial (and often complete) site assessment for engineering purposes.

The method involves an evaluation of each of the items listed below and is in general agreement with the Site Investigation Code AS1726-1993.

SOIL TYPE
The soil is described on the basis of the grain size composition of the constituent particles, and the plasticity of the fraction of material passing the 425μm sieve.

Furthermore, as most natural soils are part combinations of various constituents, the primary soil is described and modified by minor components. In brief, the system is as follows;

SILT OR CLAY AS MINOR COMPONENT		GRAVEL OR SAND AS MINOR COMPONENT	
% Fines	**Modifier**	**% Coarse**	**Modifier**
≤5 >5 ≤12 >12	omit, or use "trace" describe as "with clay/silt" as applicable prefix soil as "silty/clayey" as applicable	≤15 >15 ≤30 >30	omit, or use "trace" describe as "with sand/gravel" as applicable prefix soil as "sandy/gravelly' as applicable

Note: For soils containing both sand and gravel the minor coarse fraction is omitted if less than 15%, or described as "with sand/gravel" as applicable when greater than 15%.

The appropriate classification group symbol for soil classification is also given before the soil type description in accordance with AS1726-1993, Table A1.

For granular soils, an assessment of grading (well, uniform, gap or poor), particle size (fine, medium etc), angularity, shape and particle composition may also be given.

COLOUR
Colour is important for correlation of data between test holes and for subsequent excavation operations. The prominent colour is noted, followed by (spotted, mottled, streaked etc.) secondary colours as applicable. Colour should be described in the "moist" condition, though both wet and dry colours may also be appropriate.

MOISTURE
The moisture condition of the soil is described by the appearance and feel of the soil using one of the following terms:
Dry cohesive soils - hard, friable or powdery; granular soils - cohesionless, free funning.
Moist soil cool, darkened colour: cohesive soils - can be moulded; granular soils - tend to cohere.
Wet soil cool, darkened colour: cohesive soils - usually weakened, free water on hands when handling; granular soils - tend to cohere.

In addition, the presence of any seepage or free water is noted on all test hole logs.

CONSISTENCY/RELATIVE DENSITY
Granular soils are generally described in terms of relative density (density index) as listed in Table A5 AS1726. These soils are inherently difficult to assess and normally a penetration test procedure (SPT, DCP or CPT) is used in conjunction with published correlation tables. Alternatively, insitu density tests can be conducted in association with minimum and maximum densities performed in the laboratory.

Cohesive soils can be assessed by direct measurement (shear vane), or estimated approximately by tactile means and/or the aid of a geological pick as given on the following table. It is emphasised that a "design shear strength" must take cognisance of the insitu moisture content and the possible variations of moisture with time.

Term	Tactile Properties	Undrained Shear Strength (kPa)
Very Soft	Exudes between the fingers when squeezed in the hand.	≤12
Soft	Easily penetrated by thumb about 30-40mm. Pick head can be pushed in up to shaft. Moulded by light finger pressure.	>12 ≤25
Firm	Penetrated by thumb 20-30mm with moderate effort. Sharp end of pick pushed in some 30-40m. Moulded by strong finger pressure.	>25 ≤50
Stiff	Indented by thumb about 4mm with moderate effort. Pick pushed in up to 10mm. Cannot be moulded in fingers.	>50 ≤100
Very Stiff	Readily indented by thumb nail. Slight indentation produced by pushing pick into soil.	>100 ≤200
Hard	Difficult to indent with thumb nail. Requires power tools for excavation.	>200

STRUCTURE/OTHER FEATURES
The structure of the soil may be described with reference to: zoning, where soils consist of separate zones differing in colour, grain size or other properties; defects, including fissures, cracks, root-holes and the like; cementing, with the strength (weakly to strongly), and nature of the cementing agent; additional observations including geological origin, odour and the like. In addition, the presence of other features (ferricrete nodules, organic inclusions) should also be noted as applicable.

DYNAMIC CONE PENETROMETER

TEST METHOD: AS1289.6.3.2

Client:	**LEDA DEVELOPMENTS PTY LTD**				**Date Tested:**		
Project:	**TRUNK WATER & SEWER PACKAGE 2 ALIGNMENTS**				**Report No:**		
Location:	**PIGGABEEN ROAD, COBAKI**				**Job No:**	**8768**	
TEST NO							
POSITION	**BH1**	**BH2**	**BH3**	**BH4**	**BH5**	**BH6**	**BH7**
DEPTH (m)	**BLOWS**	**BLOWS**	**BLOWS**	**BLOWS**	**BLOWS**	**BLOWS**	**BLOWS**
0.1	8	8		7	3		
0.2	10	20		11	17		
0.3	13	Drilled		>20	7		
0.4	12	7			2		
0.5	6	16			4		8
0.6	5	11	1		4	4	8
0.7	3	4	1		4	7	9
0.8	2	2	Drilled 2		5	6	8
0.9	3	2	2		4	6	7
1.0	5	2	2		3	3	7
1.1	6	2	1		3	5	5
1.2	8	5	2		2	3	5
1.3	12	5	1		3	2	4
1.4	12	5	2		3	3	5
1.5	13	6	1		2	2	8
1.6	17	7	1		3	2	8
1.7	>20	7	2		3	3	5
1.8		9	2		4	3	5
1.9		13	4		3	4	5
2.0		15	4		3	3	5
2.1		>20	4		3	3	6
2.2			5		3	3	5
2.3			6		4	3	6
2.4			10		4	4	5
2.5			12		3	3	6
2.6			11		4	3	5
2.7			10		4	3	3
2.8			12		4	3	3
2.9			14		5	4	3
3.0							

CARDNO BOWLER

7/98 Anzac Ave
HILLCREST QLD 4118
Ph: 3800 6446 Fax: 3800 0816

BOREHOLE LOG SHEET

Client: Leda Developments Pty Ltd
Project: Trunk Water & Sewer Package 2 Alignments
Location: Piggabeen Road, Cobaki

Job No: 8768

Hole No: BH8

Sheet: 1 of 4

Position:	Angle from Horizontal: 90°	Surface Elevation:
Rig Type: Quickdrill 3000	Bit:	Driller: DL
Casing Diameter:	Contractor: Cardno Bowler Pty Ltd	
Date Started : Date Completed:	Logged By: DL	Date Logged:

Depth (m)	Drilling: Auger 'V' Bit	Auger 'TC' Bit	Washbore	Casing	Coring	Groundwater (m)	Sample or Field Test	Recovered	DCP	RL (m AHD)	Graphic Log	USCS Symbol	Description (SYMBOL, SOIL NAME, plasticity/particle characteristics, colour, minor components, moisture, consistency, structure, ORIGIN)
0.0 – 0.8												GC-CI	CLAYEY GRAVEL/SILTY CLAY, medium plasticity, fine to coarse grained sand, fine to coarse gravel, pale brown yellow, dry, hard, (roadbase), FILL Cobbles
0.8 – 1.0							D 0.80 - 0.90 m					CI	SILTY CLAY, medium plasticity, fine to coarse grained sand, black, some vegetation, dry to moist, firm to stiff, NATURAL? (MARINE)
1.0 –						▶ 1.5	U 1.50 - 1.80 m U50; PPT=20 D 2.50 - 2.60 m					CH	SILTY CLAY, high plasticity, fine to coarse grained sand, green grey, moist to wet, stiff, NATURAL (MARINE)

Depth scale: 0.5, 1.0, 1.5, 2.0, 2.5

See Standard Sheets for details of abbreviations & basis of descriptions

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BOREHOLE LOG SHEET

Client: Leda Developments Pty Ltd Project: Trunk Water & Sewer Package 2 Alignments Location: Piggabeen Road, Cobaki	Job No: 8768		**Hole No: BH8** Sheet: 2 of 4
Position:	Angle from Horizontal: 90°		Surface Elevation:
Rig Type: Quickdrill 3000	Bit:		Driller: DL
Casing Diameter:	Contractor: Cardno Bowler Pty Ltd		
Date Started :	Date Completed:	Logged By: DL	Date Logged:

Depth (m)	Drilling: Auger 'V' Bit	Auger 'TC' Bit	Washbore	Casing	Coring	Groundwater (m)	Sample or Field Test	Recovered	DCP	RL (m AHD)	Graphic Log	USCS Symbol	Description (SYMBOL, SOIL NAME, plasticity/particle characteristics, colour, minor components, moisture, consistency, structure, ORIGIN)
							U 3.00 - 3.40 m U50; PPT=000						SILTY CLAY, high plasticity, fine to coarse grained sand, green grey, moist to wet, stiff, NATURAL (MARINE)
3.5													With shells (Stand pipe)
4.0													
4.5							U 4.50 - 4.90 m U50; PPT=000					CH	
5.0													Not much shell Marine clay
5.5													

See Standard Sheets for details of abbreviations & basis of descriptions

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BOREHOLE LOG SHEET

Client: Leda Developments Pty Ltd			**Hole No: BH8**
Project: Trunk Water & Sewer Package 2 Alignments			
Location: Piggabeen Road, Cobaki		**Job No: 8768**	**Sheet: 3 of 4**
Position:		**Angle from Horizontal: 90°**	**Surface Elevation:**
Rig Type: Quickdrill 3000		**Bit:**	**Driller: DL**
Casing Diameter:		**Contractor: Cardno Bowler Pty Ltd**	
Date Started :	**Date Completed:**	**Logged By: DL**	**Date Logged:**

Depth (m)	Drilling: Auger 'V' Bit	Auger 'TC' Bit	Washbore	Casing	Coring	Groundwater (m)	Sample or Field Test	Recovered	DCP	RL (m AHD)	Graphic Log	USCS Symbol	Description (SYMBOL, SOIL NAME, plasticity/particle characteristics, colour, minor components, moisture, consistency, structure, ORIGIN)
							U 6.00 - 6.50 m U50; PPT=20						SILTY CLAY, high plasticity, fine to coarse grained sand, green grey, moist to wet, stiff, NATURAL (MARINE)
6.5													
7.0													
7.5							U 7.50 - 8.00 m U50; PPT=40					CH	
8.0													
8.5													Firms up; tending away from marine mud

See Standard Sheets for details of abbreviations & basis of descriptions

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BOREHOLE LOG SHEET

Client: Leda Developments Pty Ltd			**Hole No: BH8**
Project: Trunk Water & Sewer Package 2 Alignments			
Location: Piggabeen Road, Cobaki		**Job No: 8768**	**Sheet: 4 of 4**
Position:		**Angle from Horizontal: 90°**	**Surface Elevation:**
Rig Type: Quickdrill 3000		**Bit:**	**Driller: DL**
Casing Diameter:		**Contractor: Cardno Bowler Pty Ltd**	
Date Started :	**Date Completed:**	**Logged By: DL**	**Date Logged:**

Depth (m)	Drilling: Auger 'V' Bit	Drilling: Auger 'TC' Bit	Drilling: Washbore	Drilling: Casing	Drilling: Coring	Groundwater (m)	Sample or Field Test	Recovered	DCP	RL (m AHD)	Graphic Log	USCS Symbol	Description (SYMBOL, SOIL NAME, plasticity/particle characteristics, colour, minor components, moisture, consistency, structure, ORIGIN)
							U 9.00 - 9.40 m U50; PPT=100					CH	SILTY CLAY, high plasticity, fine to coarse grained sand, green grey, moist to wet, stiff, NATURAL (MARINE)
9.5													
10.0													
10.5							U 10.50 - 10.90 m U50; PPT=240						
													BOREHOLE TERMINATED AT 10.90 m
11.0													
11.5													

See Standard Sheets for details of abbreviations & basis of descriptions

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BOREHOLE LOG SHEET

Client: Leda Developments Pty Ltd
Project: Trunk Water & Sewer Package 2 Alignments
Location: Piggabeen Road, Cobaki

Hole No: BH9

Job No: 8768 | **Sheet:** 1 of 1

Position:	**Angle from Horizontal:** 90°	**Surface Elevation:**
Rig Type: Quickdrill 3000	**Bit:**	**Driller:** DL
Casing Diameter:	**Contractor:** Cardno Bowler Pty Ltd	
Date Started : **Date Completed:**	**Logged By:** DL	**Date Logged:**

Depth (m)	Drilling: Auger 'V' Bit	Auger 'TC' Bit	Washbore	Casing	Coring	Groundwater (m)	Sample or Field Test	Recovered	DCP	RL (m AHD)	Graphic Log	USCS Symbol	Description (SYMBOL, SOIL NAME, plasticity/particle characteristics, colour, minor components, moisture, consistency, structure, ORIGIN)
									7			SM	SILTY SAND, fine to coarse grained sand, grey brown, with trace of fine gravel, dry, medium dense, FILL
									11			GC-SM	CLAYEY GRAVEL/SILTY CLAY, medium plasticity, fine to coarse grained sand, fine to coarse gravel, pal ebrown yellow, dry, hard, (roadbase), FILL
									15				
									12				
									13				
0.5									6			SC	CLAYEY SAND, fine to coarse grained sand, pale grey cream, with some root matter, moist to dry, medium dense, NATURAL?
									7				
									5				
									5				
									4			SC-CL	SILTY CLAY/CLAYEY SAND, low plasticity clay, fine to carse grained sand, cream black dark grey, moist, medium dense to stiff, NATURAL
1.0									5				
									5				
									6				
									6				
									8				
1.5									6				
									12			SC-SM	CLAYEY SAND/SILTY SAND, fine to coarse grained sand, cream pale green, molist to dry, firm to stiff, NATURAL
									>20				
												XW	SANDSTONE
2.0							D 2.00 - 2.10 m						
													TC BIT REFUSAL BOREHOLE TERMINATED AT 2.10 m
2.5													

See Standard Sheets for details of abbreviations & basis of descriptions

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BOREHOLE LOG - DCP ONLY SHEET

Client: Leda Developments Pty Ltd **Project:** Trunk Water & Sewer Package 2 Alignments **Location:** Piggabeen Road, Cobaki	**Job No:** 8768	**Hole No: BH10** **Sheet:** 1 of 1
Position:	**Angle from Horizontal:** 90°	**Surface Elevation:**
Rig Type: Quickdrill 3000	**Bit:**	**Driller:** DL
Casing Diameter:	**Contractor:** Cardno Bowler Pty Ltd	
Date Started : **Date Completed:**	**Logged By:** DL	**Date Logged:**

Depth (m)	Drilling: Auger 'V' Bit	Auger 'TC' Bit	Washbore	Casing	Coring	Groundwater (m)	Sample or Field Test	Recovered	DCP	RL (m AHD)	Graphic Log	USCS Symbol	Description (SYMBOL, SOIL NAME, plasticity/particle characteristics, colour, minor components, moisture, consistency, structure, ORIGIN)
									9				
									10				
									14				
									10				
									4				
0.5									6				
									4				
									7				
									9				
									11				
1.0									11				
									13				
									>20				
1.5													
2.0													
2.5													

See Standard Sheets for details of abbreviations & basis of descriptions

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BOREHOLE LOG SHEET

Client: Leda Developments Pty Ltd			**Hole No: BH11**
Project: Trunk Water & Sewer Package 2 Alignments			
Location: Piggabeen Road, Cobaki		**Job No: 8768**	**Sheet: 1 of 1**
Position:		**Angle from Horizontal: 90°**	**Surface Elevation:**
Rig Type: Quickdrill 3000		**Bit:**	**Driller: DL**
Casing Diameter:		**Contractor: Cardno Bowler Pty Ltd**	
Date Started :	**Date Completed:**	**Logged By: DL**	**Date Logged:**

Depth (m)	Drilling: Auger 'V' Bit	Auger 'TC' Bit	Washbore	Casing	Coring	Groundwater (m)	Sample or Field Test	Recovered	DCP	RL (m AHD)	Graphic Log	USCS Symbol	Description (SYMBOL, SOIL NAME, plasticity/particle characteristics, colour, minor components, moisture, consistency, structure, ORIGIN)
									9			SM	SILTY SAND, fine to coarse grained sand, grey brown, with trace of fine gravel, dry, medium dense, FILL
									12, 17, 15, 11, 8, 12, 7, 10			GM-SM	SILTY SAND/SILTY GRAVEL, fine to coarse grained sand, fine to medium grained gravel, pale brown blue gravel, dry to moist, medium dense to dense, FILL
0.5													
1.0									7, 7, 5, 5, 4, 4			SM	SILTY SAND, fine to coarse grained, creamy, with some sh4lls and fine gravel, dry to moist, medium dense, FILL?
1.5							D 1.50 - 1.60 m		3				
									4, 5, 4			CL-SC	SILTY CLAY/CLAYEY SAND, low plasticity clay, fine to carse grained sand, cream black dark grey, moist, medium dense to stiff, NATURAL
2.0									7, 11, 11			CH-CI	SANDY SILTY CLAY, medium to high plasticity, fine to medium grained sand, black dary grey, dry to moist, very stiff, NATURAL
							D 2.20 - 2.30 m		12, 12				
2.5									15, 20			CH	CLAY, high plasticity, fine to coarse grained sand, red grey, with trace fine to medium gravel, dry to moist, hard, NATURAL
							D 2.80 - 2.90 m						
3.0													BOREHOLE TERMINATED AT 3.00 m

See Standard Sheets for details of abbreviations & basis of descriptions

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ABN 44 334 849 724 ACN 109 324 370

33B Machinery Dve
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NSW 2486

PO Box 3218
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NSW 2486

Phone: 07 5523 9922
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Email: mazlab@bigpond.com.

CLIENT: Cardno Bowler	**DATE:** 8/10/2009		**BH#:** 01
MAZLAB JOB NO: CBB 1953	**PROJECT:** Cnr Piggabeen Rd & Skyline Dr, Tweed Heads West- 8768		
Depth	**Description**	**Tests**	**Sampling**
0.00m	Silty SAND(SM) fine grained, grey-brown, dry		D/Sample @0.50m Intervals
0.20m FILL	Clayey Silty GRAVEL(GP) fine to medium sized, orange-brown & grey, with fine sand, j/moist		
0.60m	Silty CLAY(CL) firm, low plasticity, grey, with fine sand (WF>WP)		
1.10m	Silty Sandy CLAY(CH) just firm, high plasticity, grey, traces of orange-brown, with fine sand (WF>WP)		
1.30m	Silty Sandy CLAY(CH) just firm, high plasticity, orange, red-brown and grey, traces of fine gravel		
1.50m	Silty Sandy CLAY(CH) stiff, high plasticity, orange, red-brown and grey, traces of fine gravel		
1.70m	Sandy CLAY(CH) very stiff, light grey with some orange and red-brown, fine to medium grained sand (WF>WP)		
2.50m	Hole Terminated – No water encountered		
Drilled:	Equipment: Jacmaz 500		

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CLIENT: Cardno Bowler	**DATE:** 8/10/2009	**BH#:** 02
MAZLAB JOB NO: CBB 1953	**PROJECT:** Cnr Piggabeen Rd & Skyline Dr, Tweed Heads West-8768	

Depth	**Description**	**Tests**	**Sampling**
0.00m	Pavement GRAVEL		Stand Pipe Installed @ 3.00m
0.30m	SAND(SP) light brown, fine to medium grained, moist		
0.75m	SAND(SP) grey light-grey, fine to medium grained, v/moist		
FILL			
1.10m	Silty Sandy CLAY(CL) just firm, grey, fine grained sand (WF>WP)		
1.40m	Silty Sandy CLAY(CH) just firm, grey with some light grey and orange-brown, fine grained sand (WF>WP)		
1.75m	Clayey Sandy GRAVEL(GP) orange-red brown, traces of grey, predominantly fine sized sand, fine to medium grained (WF>WP)		
2.00m	Sandy CLAY(CH) firm, light grey with some orange and red-brown, fine to medium grained sand, v/moist (WF>WP)		
2.50m	Sandy CLAY(CH) stiff, light grey with some orange and red-brown, fine to medium grained sand, v/moist (WF>WP)		
3.00m	Hole Terminated – Minor Seepage – Above stiff clay layer @ 2.50m		

Drilled:	Equipment: Jacmaz 500	

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CLIENT: Cardno Bowler	**DATE:** 8/10/2009		**BH#:** 03
MAZLAB JOB NO: CBB 1953	**PROJECT:** Cnr Piggabeen Rd & Skyline Dr, Tweed Heads West - 8768		
Depth	**Description**	**Tests**	**Sampling**
0.00m	Pavement GRAVEL		
0.45m	Sandy CLAY(CL) firm, brown, traces of orange-brown, fine to medium grained sand with coarse sand, v/moist (WF>WP)		
0.70m FILL	Silty Sandy CLAY(CH) soft, grey with traces of orange-brown, fine grained sand, v/moist (WF>WP)		
1.30m	Sandy CLAY(CH) soft-firm, grey and green grey, traces of orange-brown, fine grained sand with silt and pockets of fine gravel, v/moist (WF>WP)		
1.70m	Silty Sandy CLAY(CH) just firm, grey, fine grained sand v/moist (WF>WP)		
2.20m	Silty Sandy CLAY(CH) firm-stiff, grey, fine grained sand v/moist (WF>WP)		
2.40m	SAND(SP) loose, grey light-grey, fine to medium grained, wet		
2.50m	Hole Terminated – Water/Seepage @ 2.00m		
Drilled:	Equipment: Jacmaz 500		

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CLIENT: Cardno Bowler		**DATE:** 8/10/2009	**BH#:** 04
MAZLAB JOB NO: CBB 1953		**PROJECT:** Cnr Piggabeen Rd & Skyline Dr, Tweed Heads West - 8768	

Depth	**Description**	**Tests**	**Sampling**
0.00m	Bitumen		
0.04m	Pavement GRAVEL		
1.15m	SAND(SP) loose, light grey and orange-brown, fine to medium grained, pockets of fine to medium size gravel, moist		
1.80m	Gravelly SAND(SP) loose, light grey and orange-brown, fine to medium size gravel, v/moist		
FILL			
2.10m	Silty Sandy CLAY(CH) just firm, grey, fine grained sand v/moist (WF>WP)		
2.30m	Silty Sandy CLAY(CH) stiff, light grey, some orange-brown (WF>WP)		
2.50m	Hole Terminated – Some Seepage @ 1.80-2.30m		

Drilled:	Equipment: Jacmaz 500	

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CLIENT: Cardno Bowler	**DATE:** 8/10/2009		**BH#:** 05
MAZLAB JOB NO: CBB 1953	**PROJECT:** Cnr Piggabeen Rd & Skyline Dr, Tweed Heads West - 8768		
Depth	**Description**	**Tests**	**Sampling**
0.00m	Silty SAND(SM) grey-brown, fine grained, j/moist		
0.20m	Sandy GRAVEL(GP) brown orange-brown, fine to medium sized, fine to medium grained sand, with clay fines, j/moist		
0.60m FILL	Sandy CLAY(CH) just firm, orange, yellow-brown and grey, fine grained sand, with silt (WF>WP)		
0.80m	Silty Sandy CLAY(CH) soft, grey and green grey, fine grained sand, v/moist (WF>WP)		
1.20m	Silty Sandy CLAY(CH) soft, grey, fine grained sand, with organics, v/moist (WF>WP)		
2.10m	MARINE CLAY(CH) very soft, grey, fine grained sand, with organics, traces of fine shell grit, v/moist (WF>WP)		
2.50m	Hole Terminated – No water encountered		
Drilled:	Equipment: Jacmaz 500		

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CLIENT: Cardno Bowler		**DATE:** 8/10/2009	**BH#:** 06
MAZLAB JOB NO: CBB 1953		**PROJECT:** Cnr Piggabeen Rd & Skyline Dr, Tweed Heads West - 8768	
Depth	**Description**	**Tests**	**Sampling**
0.00m	Bitumen		
0.35m	Pavement GRAVEL		
0.60m	Clayey Silty SAND(SC/SM) grey-green grey, fine to medium grained, traces of fine gravel, with organic matter (root fibers etc), moist		
FILL	(GRAVEL – 1.20-1.30m)		
1.30m	Organic Sandy Silty CLAY(CL) soft, grey dark-grey, fine grained sand, v/moist (WF>WP)		
1.50m	Silty Sandy CLAY(CH) soft, grey, fine grained sand, distinct organic odour, v/moist (WF>WP)		
1.80m	MARINE CLAY(CH) very soft, grey, fine grained sand, v/moist (WF>WP)		
2.50m	Hole Terminated – No water encountered		
Drilled:	Equipment: Jacmaz 500		

MAZLAB Pty Ltd
Environmental Testing, Sampling and Drilling (Vibracore)
ABN 44 334 849 724 ACN 109 324 370

33B Machinery Dve
Tweed Heads South
NSW 2486

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Phone: 07 5523 9922
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Email: mazlab@bigpond.com.

CLIENT: Cardno Bowler		**DATE:** 8/10/2009	**BH#:** 07	
MAZLAB JOB NO: CBB 1953		**PROJECT:** Cnr Piggabeen Rd & Skyline Dr, Tweed Heads West - 8768		
Depth	**Description**		**Tests**	**Sampling**
0.00m	Bitumen			
0.45m	Pavement GRAVEL			
0.60m FILL	Clayey Silty SAND(SC/SM) grey-green grey, fine to medium grained, traces of fine gravel, with organic matter (root fibers etc), moist			
0.95m	Organic Sandy Silty CLAY(CL) soft, grey dark-grey, fine grained sand, v/moist (WF>WP)			
1.20m	Sandy Silty CLAY(CH) just firm, grey light-grey, traces of orange-brown, fine grained sand (WF>WP)			
1.40m	SAND(SP) loose, grey, fine to medium grained, trace of silt, v/moist – wet			
1.60m	MARINE SANDY CLAY(CH) soft, grey, fine grained sand, traces of fine shell grit, v/moist (WF>WP)			
2.50m	Hole Terminated – Water Encountered, Hole Collapsed @ 1.60m			
Drilled:	Equipment: Jacmaz 500			

Annex B

Laboratory Test Results

September, 2001

LABORATORY TESTING

GENERAL

Samples extracted during the fieldwork stage of a site investigation may be "disturbed" or "undisturbed" (as generally indicated on the test hole logs) depending upon the nature and purpose of the sample as well as the method of extraction. Nominally "undisturbed" samples may suffer a varying degree of disturbance during extraction, transportation, extrusion and testing. This aspect should be taken into account when assessing test results which must of necessity reflect the effects of such disturbance.

All soil properties (as measured by laboratory testing) exhibit inherent variability and thus a certain statistical number of tests is required in order to predict an average property with any degree of confidence. The site variability of soil strata, future changes in moisture and other conditions, and the discrete sampling positions must also be considered when assessing the representative nature of the laboratory programme.

Certain laboratory test results provide interpreted soil properties as derived by conventional mathematical procedures. The applicability of such properties to engineering design must be assessed with due regard to the site, sample condition, procedure and project in hand.

TESTING

Laboratory testing is normally carried out in accordance with Australian Standard 1289 as amended, or Queensland Transport Standards when specified. The routine Australian Standard tests are as follows:

Sample Preparation	Test 1
Moisture Content	Test 2.1.1
Liquid Limit	Test 3.1.1)
Plastic Limit	Test 3.2.1) collectively known as Atterberg Limits
Plasticity Index	Test 3.3.1)
Linear Shrinkage	Test 3.4.1
Particle Density	Test 3.5.1
Particle Size Distribution	Tests 3.6.1, 3.6.2, 3.6.3
Emerson Class Number	Test 3.8.1)
Percent Dispersion	Test 3.8.2) collectively, Dispersion Classification
Pinhole Dispersion Classification	Test 3.8.3)
Organic Matter	Test 4.1.1
Sulphate content	Test 4.2.1
pH Value	Test 4.3.1
Resistivity	Test 4.4.1
Standard Compaction	Test 5.1.1
Modified Compaction	Test 5.2.1
Dry Density Ratio	Test 5.4.1
Minimum/Maximum Density	Test 5.5.1
Density Index	Test 5.6.1
California Bearing Ratio	Tests 6.1.1, 6.1.2
Undrained Triaxial Shear	Test 6.4.1
One Dimensional Consolidation	Test 6.6.1
Constant Head Permeability	Test F7.1
Shrink Swell Index	Test 7.1.1

Where tests are used which are not covered by appropriate standard procedures, details are given in the report.

LABORATORY

Our laboratory is a Registered Laboratory with the National Association of Testing Authorities (NATA).

Cardno Bowler
Shaping the Future

Geotechnical Engineering Consultants
Construction Testing Services
Environmental Consultants

A.B.N. 74 128 806 735

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FIELD pH MEASUREMENTS

CLIENT: **LEDA** JOB No.: **GC2245/8768**

PROJECT: **COBAKI LAKES, PIGGABEEN ROAD PIPELINES** REPORT No.: **1**

DATE DELIVERED: **08/10/09 & 09/10/09** DATE TESTED: **13/10/09**

LOCATION: **Borehole # 1**

DEPTH m	pH_f	pH_{fox}	REACTION	SAMPLE No.
0.00 - 0.25	5.6	2.8	XXX	78916
0.25 - 0.50	-	-	-	-
0.50 - 0.75	4.4	3.5	X	78917
0.75 - 1.00	-	-	-	-
1.00 - 1.25	5.5	3.5	XXX	78918
1.25 - 1.50	-	-	-	-
1.50 - 1.75	4.5	3.4	XX	78919
1.75 - 2.00	-	-	-	-
2.00 - 2.25	4.3	3.6	XX	78920
2.25 - 2.50	-	-	-	-
2.50 - 2.75	4.3	4.1	X	78921

LOCATION: **Borehole # 2**

DEPTH m	pH_f	pH_{fox}	REACTION	SAMPLE No.
0.00 - 0.25	-	-	-	-
0.25 - 0.50	-	-	-	-
0.50 - 0.75	6.8	7.4	X	78922
0.75 - 1.00	-	-	-	-
1.00 - 1.25	7.0	6.8	X	78923
1.25 - 1.50	-	-	-	-
1.50 - 1.75	5.9	4.0	XX	78924
1.75 - 2.00	-	-	-	-
2.00 - 2.25	5.1	3.7	X	78925
2.25 - 2.50	-	-	-	-
2.50 - 2.75	4.9	3.9	X	78926

LOCATION: **Borehole # 3**

DEPTH m	pH_f	pH_{fox}	REACTION	SAMPLE No.
0.00 - 0.25	-	-	-	-
0.25 - 0.50	-	-	-	-
0.50 - 0.75	4.2	3.1	X	78927
0.75 - 1.00	-	-	-	-
1.00 - 1.25	4.4	3.0	XX	78928
1.25 - 1.50	-	-	-	-
1.50 - 1.75	5.1	3.0	XXX	78929
1.75 - 2.00	-	-	-	-
2.00 - 2.25	5.6	2.9	XXX	78930
2.25 - 2.50	-	-	-	-
2.50 - 2.75	5.6	3.5	X	78931

LOCATION: **Borehole # 4**

DEPTH m	pH_f	pH_{fox}	REACTION	SAMPLE No.
0.00 - 0.25	-	-	-	-
0.25 - 0.50	-	-	-	-
0.50 - 0.75	3.9	4.1	X	78932
0.75 - 1.00	-	-	-	-
1.00 - 1.25	4.4	3.8	X	78933
1.25 - 1.50	-	-	-	-
1.50 - 1.75	6.6	6.4	X	78934
1.75 - 2.00	-	-	-	-
2.00 - 2.25	6.7	6.5	X	78935
2.25 - 2.50	-	-	-	-
2.50 - 2.75	5.1	3.4	XX	78936

FIELD pH:

pH_f = pH of saturated soil with de-ionised water.

pH_{fox} = pH of saturated soil with 30% H_2O_2

REACTION & SEVERITY:

X = Slight, XX = Moderate, XXX = High, XXXX = Very Vigorous

Authorised Signature: A Thomas ....

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QUALITY ASSURED SUPPLIER
QUEENSLAND GOVERNMENT

FIELD pH MEASUREMENTS

CLIENT: **LEDA** JOB No.: **GC2245/8768**

PROJECT: **COBAKI LAKES, PIGGABEEN ROAD PIPELINES** REPORT No.: **2**

DATE DELIVERED: **08/10/09 & 09/10/09** DATE TESTED: **13/10/09**

LOCATION: **Borehole # 5**

DEPTH m	pH_f	pH_{fox}	REACTION	SAMPLE No.
0.00 - 0.25	3.3	2.6	XXX	78937
0.25 - 0.50	-	-	-	-
0.50 - 0.75	3.7	2.1	XXX	78938
0.75 - 1.00	-	-	-	-
1.00 - 1.25	6.1	2.7	X	78939
1.25 - 1.50	-	-	-	-
1.50 - 1.75	6.0	0.8	XXX	78940
1.75 - 2.00	-	-	-	-
2.00 - 2.25	6.5	1.3	XX	78941
2.25 - 2.50	-	-	-	-
2.50 - 2.75	6.8	2.1	XXX	78942

LOCATION: **Borehole # 6**

DEPTH m	pH_f	pH_{fox}	REACTION	SAMPLE No.
0.00 - 0.25	-	-	-	-
0.25 - 0.50	-	-	-	-
0.50 - 0.75	4.2	3.9	X	78943
0.75 - 1.00	-	-	-	-
1.00 - 1.25	5.2	4.1	X	78944
1.25 - 1.50	-	-	-	-
1.50 - 1.75	6.3	3.0	XXX	78945
1.75 - 2.00	-	-	-	-
2.00 - 2.25	6.1	3.2	XX	78946
2.25 - 2.50	-	-	-	-
2.50 - 2.75	6.3	3.4	X	78947

LOCATION: **Borehole # 7**

DEPTH m	pH_f	pH_{fox}	REACTION	SAMPLE No.
0.00 - 0.25	-	-	-	-
0.25 - 0.50	-	-	-	-
0.50 - 0.75	5.0	3.5	X	78948
0.75 - 1.00	-	-	-	-
1.00 - 1.25	5.0	2.9	X	78949
1.25 - 1.50	-	-	-	-
1.50 - 1.75	5.4	1.7	X	78950
1.75 - 2.00	-	-	-	-
2.00 - 2.25	5.5	1.9	XX	78951
2.25 - 2.50	-	-	-	-
2.50 - 2.75	6.4	3.2	XX	78952

LOCATION: **Borehole # -**

DEPTH m	pH_f	pH_{fox}	REACTION	SAMPLE No.
0.00 - 0.25				
0.25 - 0.50				
0.50 - 0.75				
0.75 - 1.00				
1.00 - 1.25				
1.25 - 1.50				
1.50 - 1.75				
1.75 - 2.00				
2.00 - 2.25				
2.25 - 2.50				
2.50 - 2.75				

FIELD pH:

pH_f = pH of saturated soil with de-ionised water.

pH_{fox} = pH of saturated soil with 30% H_2O_2

REACTION & SEVERITY:

X = Slight, XX = Moderate, XXX = High, XXXX = Very Vigorous

Authorised Signature: AThomas ....

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FIELD pH MEASUREMENTS

CLIENT: **LEDA** JOB No.: **GC2245/8768**

PROJECT: **COBAKI LAKES, PIGGABEEN ROAD PIPELINES** REPORT No.: **3**

DATE DELIVERED: **08/10/09 & 09/10/09** DATE TESTED: **13/10/09**

LOCATION: **Borehole # 8**

DEPTH m	pH_f	pH_{fox}	REACTION	SAMPLE No.
0.00 - 0.25	4.5	2.7	XX	78953
0.25 - 0.50	-	-	-	-
0.50 - 0.75	3.5	2.6	XX	78954
0.75 - 1.00	-	-	-	-
1.00 - 1.25	5.6	3.0	XX	78955
1.25 - 1.50	-	-	-	-
1.50 - 1.75	3.9	2.8	XX	78956
1.75 - 2.00	-	-	-	-
2.00 - 2.25	5.1	1.9	XXX	78957
2.25 - 2.50	-	-	-	-
2.50 - 2.75	5.5	1.3	XX	78958
2.75 - 3.00	-	-	-	-
3.00 - 3.25	6.0	1.3	XX	78959
3.25 - 3.50	-	-	-	-
3.50 - 3.75	6.6	3.1	XX	78960
3.75 - 4.00	-	-	-	-
4.00 - 4.25	6.5	2.0	XXX	78961
4.25 - 4.50	-	-	-	-
4.50 - 4.75	6.5	1.9	XXX	78962
4.75 - 5.00	-	-	-	-
5.00 - 5.25	5.7	1.5	XX	78963
5.25 - 5.50	-	-	-	-
5.50 -5.75	-	-	-	-
5.75 - 6.0	-	-	-	-

LOCATION:-

DEPTH m	pH_f	pH_{fox}	REACTION	SAMPLE No.
0.00 - 0.25				
0.25 - 0.50				
0.50 - 0.75				
0.75 - 1.00				
1.00 - 1.25				
1.25 - 1.50				
1.50 - 1.75				
1.75 - 2.00				
2.00 - 2.25				
2.25 - 2.50				
2.50 - 2.75				
2.75 - 3.00				
3.00 - 3.25				
3.25 - 3.50				
3.50 - 3.75				
3.75 - 4.00				
4.00 - 4.25				
4.25 - 4.50				
4.50 - 4.75				
4.75 - 5.00				
5.00 - 5.25				
5.25 - 5.50				
5.50 -5.75				
5.75 - 6.0				

FIELD pH:

pH_f = pH of saturated soil with de-ionised water.

pH_{fox} = pH of saturated soil with 30% H_2O_2

REACTION & SEVERITY:

X = Slight, XX = Moderate, XXX = High, XXXX = Very Vigorous

Authorised Signature: A Thomas

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QUALITY ASSURED SUPPLIER
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FIELD pH MEASUREMENTS

CLIENT: **LEDA** JOB No.: **GC2245/8768**

PROJECT: **COBAKI LAKES, PIGGABEEN ROAD PIPELINES** REPORT No.: **4**

DATE DELIVERED: **08/10/09 & 09/10/09** DATE TESTED: **13/10/09**

LOCATION: **Borehole # 9**

DEPTH m	pH_f	pH_{fox}	REACTION	SAMPLE No.
0.00 - 0.25	4.5	3.2	X	78964
0.25 - 0.50	-	-	-	-
0.50 - 0.75	3.8	3.2	XX	78965
0.75 - 1.00	-	-	-	-
1.00 - 1.25	4.8	2.8	X	78966
1.25 - 1.50	-	-	-	-
1.50 - 1.75	4.7	3.6	X	78967
1.75 - 2.00	-	-	-	-
2.00 - 2.25	-	-	-	-
2.25 - 2.50	-	-	-	-
2.50 - 2.75	-	-	-	-

LOCATION: **Borehole # 11**

DEPTH m	pH_f	pH_{fox}	REACTION	SAMPLE No.
0.00 - 0.25	6.0	6.4	X	78968
0.25 - 0.50	-	-	-	-
0.50 - 0.75	6.7	6.4	X	78969
0.75 - 1.00	-	-	-	-
1.00 - 1.25	7.0	6.6	X	78970
1.25 - 1.50	-	-	-	-
1.50 - 1.75	6.1	3.7	X	78971
1.75 - 2.00	-	-	-	-
2.00 - 2.25	4.4	3.4	X	78972
2.25 - 2.50	-	-	-	-
2.50 - 2.75	6.1	3.7	X	78973

LOCATION: **Borehole # -**

DEPTH m	pH_f	pH_{fox}	REACTION	SAMPLE No.
0.00 - 0.25				
0.25 - 0.50				
0.50 - 0.75				
0.75 - 1.00				
1.00 - 1.25				
1.25 - 1.50				
1.50 - 1.75				
1.75 - 2.00				
2.00 - 2.25				
2.25 - 2.50				
2.50 - 2.75				

LOCATION: **Borehole # -**

DEPTH m	pH_f	pH_{fox}	REACTION	SAMPLE No.
0.00 - 0.25				
0.25 - 0.50				
0.50 - 0.75				
0.75 - 1.00				
1.00 - 1.25				
1.25 - 1.50				
1.50 - 1.75				
1.75 - 2.00				
2.00 - 2.25				
2.25 - 2.50				
2.50 - 2.75				

FIELD pH:

pH_f = pH of saturated soil with de-ionised water.

pH_{fox} = pH of saturated soil with 30% H_2O_2

REACTION & SEVERITY:

X = Slight, XX = Moderate, XXX = High, XXXX = Very Vigorous

Authorised Signature: A Thomas ....

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FINAL CERTIFICATE OF ANALYSIS

Client: Cardno Bowler Pty Ltd
Address: PO Box 2789
NERANG EAST
QLD 4211

		Lims1 Report No:	09/3175-C
Attention:	Peter Kenyon	**Client Reference:**	O/No 1747
Copy To:	Fax: 07 5596 4841	**Date of Report:**	23/10/2009

All pages of this Report have been checked and approved.
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Taken By:	Client	**No of Samples:**	5
Date Taken:	9/10/2009	**Date Testing Commenced:**	12/10/2009
Date Received:	12/10/2009	**Date Testing Completed:**	23/10/2009

Sample Description: Cobaki Lakes/Piggabeen Rd Pipe Lines - Chemical

Sample/Site No	Sample/Site Description
78860	Creek 1
78861	D1
78862	BH 2
78863	BH 5
78864	BH 8

COMMENTS:

Results refer to samples as received at the Laboratory.
* Tests not covered by NATA accreditation.
NP = Not Present.

NATA ACCREDITED FOR TECHNICAL COMPETENCE

This document is issued in accordance with NATA's accreditation requirements.
Accredited for compliance with ISO/IEC 17025.
Accreditation No: 12754 & 13538

Dr Paul J Wright
(Senior Technical Officer)
paulw@tweedlab.com.au

Client: Cardno Bowler Pty Ltd

Address: PO Box 2789

NERANG EAST
QLD 4211

Attention: Peter Kenyon

Lims1 Report No: 09/3175-C
Date Testing Completed: 23/10/2009
Date of Report: 23/10/2009

Sample Description: Cobaki Lakes/Piggabeen Rd Pipe Lines - Chemical

Sample Identification:			78860	78861	78862	78863	78864
Date Taken:			9/10/2009	9/10/2009	9/10/2009	9/10/2009	9/10/2009
Date Received:			12/10/2009	12/10/2009	12/10/2009	12/10/2009	12/10/2009
Date Testing Commenced:			12/10/2009	12/10/2009	12/10/2009	12/10/2009	12/10/2009
Test	Method	Units	09/3175-C/1	09/3175-C/2	09/3175-C/3	09/3175-C/4	09/3175-C/5
Calcium (Total)	M8	mg/L	265.0	21.0	122.0	106.0	237.0
Magnesium (Total)	M8	mg/L	456.0	8.0	139.0	228.0	422.0
Iron (Total)	M8	mg/L	0.36	5.57	23.00	1.35	17.00
Iron (Soluble)	M8	mg/L	0.14	1.94	22.00	0.12	6.26
Manganese (Soluble)	M8	mg/L	0.02	0.04	0.65	0.33	0.72
Aluminium (Soluble)	M8	mg/L	0.01	0.08	0.02	0.01	<0.01
Carbonate (CO3)	C10	mg/L	NP	NP	NP	NP	NP
Colour True	P10	Colour Units	9	67	11	83	46
Bicarbonate HCO_3	C10	mg/L	71	92	43	476	269
Chloride	C20	mg/L	21,600.0	60.0	1,470.0	4,550.0	13,500.0
Sulphur as Sulphate	M8	mg/L	1,773.0	29.0	802.0	157.0	1,267.0

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QUALITY ASSURED SUPPLIER
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MULTIPLE PARAMETER TESTING

CLIENT: **LEDA** *JOB No.:* **GC2245 / 8768**

PROJECT: **COBAKI LAKES, PIGGABEEN ROAD PIPELINES** *REPORT No.:* **13**

TEST ITEM: **WATER QUALITY**

LOCATION	SAMPLE NUMBER	pH	Ec (mS/cm)	Dissolved Oxygen (ppm)
CREEK 1	78860	8.1	34.7	11.3
D1	78861	8.0	0.8	5.0
BH 2	78862	6.0	6.4	7.7
BH 5	78863	7.3	14.3	7.0
BH 8	78864	6.9	33.3	5.1

REMARKS:

Approved Signature: ....
S. THOMAS

Form No.: GCR035b Rev.3 06/05

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QUALITY ASSURED SUPPLIER
QUEENSLAND GOVERNMENT

REPORT OF ANALYSIS OF SOILS FOR PRESENCE OF ACID SULFATES

CHROMIUM REDUCIBLE SULFUR SUITE

CLIENT: **LEDA**
PROJECT: **COBAKI LAKES, PIGGABEEN ROAD PIPELINES**
DATE SAMPLED: **08/10/09**
TEST ITEM: **DISTURBED**

JOB No.: **GC 2245-8768**
REPORT No: **5**
DATE ISSUED: **22/10/09**

Copy to:

SITE TEST No.	SAMPLE NUMBER	SAMPLE LOCATION	LEVEL (m)	SOIL DESCRIPTION	Bulk Density (t/m^3)	pH_F	pH_{FOX}	pH_{KCL} 23A	s-TAA (%) 23F	S_{CR} (%) 22B	s-ANC_{BT} (%) S 19A2	S_{HCL} (%) 20B	S_{KCL} (%) 23C	s-S_{NAS} (%) 20J	NET ACIDITY (%) S	Verification Pass / Fail	LIMING RATE REQUIRED (kg/m^3)	REMARKS
1 AS	78916	**BOREHOLE No. 1**	0.00 - 0.25	REFER TO BORELOG	1.300	5.6	2.8	5.7	0.015	0.014	NA	NA	NA	NA	0.029	**NA**	**NR**	
2 AS	78917	**BOREHOLE No. 1**	0.50 - 0.75	REFER TO BORELOG	1.300	4.4	3.5	4.0	0.077	0.016	NA	NIL	0.003	NIL	0.093	**NA**	**5.9**	
3 AS	78918	**BOREHOLE No. 1**	1.00 - 1.25	REFER TO BORELOG	1.300	5.5	3.5	4.5	0.093	0.043	NA	NA	NA	NA	0.136	**NA**	**8.6**	
4 AS	78919	**BOREHOLE No. 1**	1.50 - 1.75	REFER TO BORELOG	1.300	4.5	3.4	4.6	0.031	0.012	NA	NA	NA	NA	0.043	**NA**	**2.8**	
5 AS	78920	**BOREHOLE No. 1**	2.00 - 2.25	REFER TO BORELOG	1.300	4.3	3.6	4.5	0.063	0.017	NA	NA	NA	NA	0.080	**NA**	**5.1**	
6 AS	78921	**BOREHOLE No. 1**	2.50 - 2.75	REFER TO BORELOG	1.300	4.3	4.1	4.3	0.053	0.022	NA	NIL	0.065	NIL	0.075	**NA**	**4.8**	
7 AS	78922	**BOREHOLE No. 2**	0.50 - 0.75	REFER TO BORELOG	1.300	6.8	7.4	8.6	NA	0.018	NA	NA	NA	NA	0.018	**NA**	**NR**	
8 AS	78923	**BOREHOLE No. 2**	1.00 - 1.25	REFER TO BORELOG	1.300	7.0	6.8	8.0	NA	0.040	NIL	NA	NA	NA	0.040	**NA**	**2.5**	

Codes:

S	Sulfur	pH_{KCL}	pH of filtered 1:40 1M KCl extract (TAA)
TAA	Titratable Actual Acidity	ANC_{BT}	Acid Neutralising Capacity - back titration
CR	Chromium Reducible	S_{HCL}	Sulfur soluble in 4 M HCL
pH_F	Field pH of saturated soil sample	S_{NAS}	Net acid soluble sulfur
pH_{FOX}	Field pH of 30% peroxide reaction	NR	Not required - % Sulfur less than action limit

Action Limit for % Oxidisible Sulfur = 0.03

*** 1.5 factor of safety included in all liming rate calculations**

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QUALITY ASSURED SUPPLIER
QUEENSLAND GOVERNMENT

REPORT OF ANALYSIS OF SOILS FOR PRESENCE OF ACID SULFATES

CHROMIUM REDUCIBLE SULFUR SUITE

CLIENT: **LEDA**
PROJECT: **COBAKI LAKES, PIGGABEEN ROAD PIPELINES**
DATE SAMPLED: **08/10/09**
TEST ITEM: **DISTURBED**

JOB No.: **GC 2245/8768**
REPORT No: **6**
DATE ISSUED: **22/10/09**

Copy to:

SITE TEST No.	SAMPLE NUMBER	SAMPLE LOCATION	LEVEL (m)	SOIL DESCRIPTION	Bulk Density (t/m^3)	pH_F	pH_{FOX}	pH_{KCL}	s-TAA (%)	S_{CR} (%)	$s\text{-}ANC_{BT}$ (%) S	S_{HCL} (%)	S_{KCL} (%)	$s\text{-}S_{NAS}$ (%)	NET ACIDITY (%) S	Verification Pass / Fail	LIMING RATE REQUIRED (kg/m^3)	REMARKS
								23A	23F	22B	19A2	20B	23C	20J				
9 AS	78924	**BOREHOLE No. 2**	1.50 - 1.75	REFER TO BORELOG	1.300	5.9	4.0	5.9	0.012	0.021	NA	NA	NA	NA	0.033	**NA**	**2.1**	
10 AS	78925	**BOREHOLE No. 2**	2.00 - 2.25	REFER TO BORELOG	1.300	5.1	3.7	5.1	0.024	0.009	NA	NA	NA	NA	0.033	**NA**	**2.1**	
11 AS	78926	**BOREHOLE No. 2**	2.50 - 2.75	REFER TO BORELOG	1.300	4.9	3.9	4.7	0.028	0.009	NA	NA	NA	NA	0.037	**NA**	**2.3**	
12 AS	78927	**BOREHOLE No. 3**	0.50 - 0.75	REFER TO BORELOG	1.300	4.2	3.1	4.1	0.064	0.023	NA	NIL	0.037	NIL	0.087	**NA**	**5.5**	
13 AS	78928	**BOREHOLE No. 3**	1.00 - 1.25	REFER TO BORELOG	1.300	4.4	3.0	3.9	0.043	NIL	NA	NIL	0.214	NIL	0.043	**NA**	**2.8**	
14 AS	78929	**BOREHOLE No. 3**	1.50 - 1.75	REFER TO BORELOG	1.300	5.1	3.0	3.6	0.132	0.014	NA	NIL	0.158	NIL	0.146	**NA**	**9.3**	
15 AS	78930	**BOREHOLE No. 3**	2.00 - 2.25	REFER TO BORELOG	1.300	5.6	2.9	4.4	0.156	0.018	NA	NIL	0.211	NIL	0.174	**NA**	**11.1**	
16 AS	78931	**BOREHOLE No. 3**	2.50 - 2.75	REFER TO BORELOG	1.300	5.6	3.5	5.1	0.023	0.013	NA	NA	NA	NA	0.036	**NA**	**2.3**	

Codes:

S	Sulfur	pH_{KCL}	pH of filtered 1:40 1M KCl extract (TAA)
TAA	Titratable Actual Acidity	ANC_{BT}	Acid Neutralising Capacity - back titration
CR	Chromium Reducible	S_{HCL}	Sulfur soluble in 4 M HCL
pH_F	Field pH of saturated soil sample	S_{NAS}	Net acid soluble sulfur
pH_{FOX}	Field pH of 30% peroxide reaction	NR	Not required - % Sulfur less than action limit

Action Limit for % Oxidisible Sulfur = 0.03

*** 1.5 factor of safety included in all liming rate calculations**

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QUALITY ASSURED SUPPLIER
QUEENSLAND GOVERNMENT

REPORT OF ANALYSIS OF SOILS FOR PRESENCE OF ACID SULFATES

CHROMIUM REDUCIBLE SULFUR SUITE

CLIENT: **LEDA**
PROJECT: **COBAKI LAKES, PIGGABEEN ROAD PIPELINES**
DATE SAMPLED: **08/10/09**
TEST ITEM: **DISTURBED**

JOB No.: **GC 2245-8768**
REPORT No: **7**
DATE ISSUED: **22/10/09**

Copy to:

SITE TEST No.	SAMPLE NUMBER	SAMPLE LOCATION	LEVEL (m)	SOIL DESCRIPTION	Bulk Density (t/m^3)	pH_F	pH_{FOX}	pH_{KCL}	s-TAA (%)	S_{CR} (%)	$s\text{-}ANC_{BT}$ (%) S	S_{HCL} (%)	S_{KCL} (%)	$s\text{-}S_{NAS}$ (%)	NET ACIDITY (%) S	Verification Pass / Fail	LIMING RATE REQUIRED (kg/m^3)	REMARKS
								23A	23F	22B	19A2	20B	23C	20J				
17 AS	78932	**BOREHOLE No. 4**	0.50 - 0.75	REFER TO BORELOG	1.300	3.9	4.1	4.0	0.085	0.009	NA	NIL	0.008	NIL	0.094	**NA**	**5.9**	
18 AS	78933	**BOREHOLE No. 4**	1.00 - 1.25	REFER TO BORELOG	1.300	4.4	3.8	6.2	NIL	0.027	NA	NA	NA	NA	0.027	**NA**	**NR**	
19 AS	78934	**BOREHOLE No. 4**	1.50 - 1.75	REFER TO BORELOG	1.300	6.6	6.4	7.8	NA	0.164	NIL	NA	NA	NA	0.164	**NA**	**10.4**	
20 AS	78935	**BOREHOLE No. 4**	2.00 - 2.25	REFER TO BORELOG	1.300	6.7	6.5	8.2	NA	0.155	NIL	NA	NA	NA	0.155	**NA**	**9.8**	
21 AS	78936	**BOREHOLE No. 4**	2.50 - 2.75	REFER TO BORELOG	1.300	5.1	3.4	5.7	0.015	0.063	NA	NA	NA	NA	0.079	**NA**	**5.0**	
22 AS	78937	**BOREHOLE No. 5**	0.00 - 0.25	REFER TO BORELOG	1.300	3.3	2.6	4.6	0.012	0.013	NA	NA	NA	NA	0.025	**NA**	**NR**	
23 AS	78938	**BOREHOLE No. 5**	0.50 - 0.75	REFER TO BORELOG	1.300	3.7	2.1	3.6	0.051	0.021	NA	NIL	0.022	NIL	0.073	**NA**	**4.6**	
24 AS	78939	**BOREHOLE No. 5**	1.00 - 1.25	REFER TO BORELOG	1.300	6.1	2.7	4.4	0.016	0.109	NA	NIL	0.019	NIL	0.125	**NA**	**7.9**	

Codes:

S	Sulfur	pH_{KCL}	pH of filtered 1:40 1M KCl extract (TAA)
TAA	Titratable Actual Acidity	ANC_{BT}	Acid Neutralising Capacity - back titration
CR	Chromium Reducible	S_{HCL}	Sulfur soluble in 4 M HCL
pH_F	Field pH of saturated soil sample	S_{NAS}	Net acid soluble sulfur
pH_{FOX}	Field pH of 30% peroxide reaction	NR	Not required - % Sulfur less than action limit

Action Limit for % Oxidisible Sulfur = 0.03

*** 1.5 factor of safety included in all liming rate calculations**

Authorised Signature: ....

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QUALITY ASSURED SUPPLIER
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REPORT OF ANALYSIS OF SOILS FOR PRESENCE OF ACID SULFATES

CHROMIUM REDUCIBLE SULFUR SUITE

CLIENT: **LEDA**
PROJECT: **COBAKI LAKES, PIGGABEEN ROAD PIPELINES**
DATE SAMPLED: **08/10/09**
TEST ITEM: **DISTURBED**

JOB No.: **GC 2245/8768**
REPORT No: **8**
DATE ISSUED: **22/10/09**

Copy to:

SITE TEST No.	SAMPLE NUMBER	SAMPLE LOCATION	LEVEL (m)	SOIL DESCRIPTION	Bulk Density (t/m^3)	pH_F	pH_{FOX}	pH_{KCL}	s-TAA (%)	S_{CR} (%)	$s\text{-}ANC_{BT}$ (%) S	S_{HCL} (%)	S_{KCL} (%)	$s\text{-}S_{NAS}$ (%)	NET ACIDITY (%) S	Verification Pass / Fail	LIMING RATE REQUIRED (kg/m^3)	REMARKS
								23A	23F	22B	19A2	20B	23C	20J				
25 AS	78940	**BOREHOLE No. 5**	1.50 - 1.75	REFER TO BORELOG	1.300	6.0	0.8	5.3	0.082	3.923	NA	NA	NA	NA	4.005	**NA**	**254.0**	
26 AS	78941	**BOREHOLE No. 5**	2.00 - 2.25	REFER TO BORELOG	1.300	6.5	1.3	4.1	0.080	1.450	NA	NIL	0.031	NIL	1.530	**NA**	**97.0**	
27 AS	78942	**BOREHOLE No. 5**	2.50 - 2.75	REFER TO BORELOG	1.300	6.8	2.1	6.2	NIL	0.461	NA	NA	NA	NA	0.461	**NA**	**29.3**	
28 AS	78943	**BOREHOLE No. 6**	0.50 - 0.75	REFER TO BORELOG	1.300	4.2	3.9	4.2	0.027	2.963	NA	NIL	0.025	NIL	2.990	**NA**	**189.6**	
29 AS	78944	**BOREHOLE No. 6**	1.00 - 1.25	REFER TO BORELOG	1.300	5.2	4.1	5.6	0.159	0.023	NA	NA	NA	NA	0.182	**NA**	**11.5**	
30 AS	78945	**BOREHOLE No. 6**	1.50 - 1.75	REFER TO BORELOG	1.300	6.3	3.0	5.7	0.008	0.358	NA	NA	NA	NA	0.366	**NA**	**23.2**	
31 AS	78946	**BOREHOLE No. 6**	2.00 - 2.25	REFER TO BORELOG	1.300	6.1	3.2	4.8	0.023	0.053	NA	NA	NA	NA	0.076	**NA**	**4.8**	
32 AS	78947	**BOREHOLE No. 6**	2.50 - 2.75	REFER TO BORELOG	1.300	6.3	3.4	6.0	NIL	1.137	NA	NA	NA	NA	1.137	**NA**	**72.1**	

Codes:
S Sulfur
TAA Titratable Actual Acidity
CR Chromium Reducible
pH_F Field pH of saturated soil sample
pH_{FOX} Field pH of 30% peroxide reaction
pH_{KCL} pH of filtered 1:40 1M KCl extract (TAA)
ANC_{BT} Acid Neutralising Capacity - back titration
S_{HCL} Sulfur soluble in 4 M HCL
S_{NAS} Net acid soluble sulfur
NR Not required - % Sulfur less than action limit

Action Limit for % Oxidisible Sulfur = 0.03
*** 1.5 factor of safety included in all liming rate calculations**

Authorised Signature: ……………………………………

Form No.: GCR035b Rev.3 06/05

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QUALITY ASSURED SUPPLIER
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REPORT OF ANALYSIS OF SOILS FOR PRESENCE OF ACID SULFATES

CHROMIUM REDUCIBLE SULFUR SUITE

CLIENT: **LEDA**
PROJECT: **COBAKI LAKES, PIGGABEEN ROAD PIPELINES**
DATE SAMPLED: **08/10/09**
TEST ITEM: **DISTURBED**

JOB No.: **GC 2245/8768**
REPORT No: **9**
DATE ISSUED: **22/10/09**

Copy to:

SITE TEST No.	SAMPLE NUMBER	SAMPLE LOCATION	LEVEL (m)	SOIL DESCRIPTION	Bulk Density (t/m^3)	pH_F	pH_{FOX}	pH_{KCL}	s-TAA (%)	S_{CR} (%)	s-ANC_{BT} (%) S	S_{HCL} (%)	S_{KCL} (%)	s-S_{NAS} (%)	NET ACIDITY (%) S	Verification Pass / Fail	LIMING RATE REQUIRED (kg/m^3)	REMARKS
								23A	23F	22B	19A2	20B	23C	20J				
33 AS	78948	**BOREHOLE No.7**	0.50 - 0.75	REFER TO BORELOG	1.300	5.0	3.5	3.8	0.051	NIL	NA	NIL	0.031	NIL	0.051	**NA**	**3.2**	
34 AS	78949	**BOREHOLE No.7**	1.00 - 1.25	REFER TO BORELOG	1.300	5.0	2.9	3.9	0.072	0.061	NA	NIL	0.020	NIL	0.133	**NA**	**8.4**	
35 AS	78950	**BOREHOLE No.7**	1.50 - 1.75	REFER TO BORELOG	1.300	5.4	1.7	4.3	0.031	NIL	NA	NIL	0.018	NIL	0.031	**NA**	**1.9**	
36 AS	78951	**BOREHOLE No.7**	2.00 - 2.25	REFER TO BORELOG	1.300	5.5	1.9	5.7	0.008	1.014	NA	NA	NA	NA	1.022	**NA**	**64.8**	
37 AS	78952	**BOREHOLE No.7**	2.50 - 2.75	REFER TO BORELOG	1.300	6.4	3.2	6.8	NA	1.458	0.080	NA	NA	NA	1.405	**NA**	**89.1**	
38 AS	78953	**BOREHOLE No.8**	0.00 - 0.25	REFER TO BORELOG	1.300	4.5	2.7	4.6	0.040	0.017	NA	NA	NA	NA	0.057	**NA**	**3.6**	
39 AS	78954	**BOREHOLE No.8**	0.50 - 0.75	REFER TO BORELOG	1.300	3.5	2.6	3.4	0.139	0.018	NA	NIL	0.037	NIL	0.157	**NA**	**10.0**	
40 AS	78955	**BOREHOLE No.8**	1.00 - 1.25	REFER TO BORELOG	1.300	5.6	3.0	4.0	0.091	0.048	NA	NIL	0.031	NIL	0.139	**NA**	**8.8**	

Codes:

S	Sulfur	pH_{KCL}	pH of filtered 1:40 1M KCl extract (TAA)
TAA	Titratable Actual Acidity	ANC_{BT}	Acid Neutralising Capacity - back titration
CR	Chromium Reducible	S_{HCL}	Sulfur soluble in 4 M HCL
pH_F	Field pH of saturated soil sample	S_{NAS}	Net acid soluble sulfur
pH_{FOX}	Field pH of 30% peroxide reaction	NR	Not required - % Sulfur less than action limit

Action Limit for % Oxidisible Sulfur = 0.03

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Authorised Signature: .... Athomas

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REPORT OF ANALYSIS OF SOILS FOR PRESENCE OF ACID SULFATES

CHROMIUM REDUCIBLE SULFUR SUITE

CLIENT: **LEDA**
PROJECT: **COBAKI LAKES, PIGGABEEN ROAD PIPELINES**
DATE SAMPLED: **08/10/09**
TEST ITEM: **DISTURBED**

JOB No.: **GC 2245/8768**
REPORT No: **10**
DATE ISSUED: **22/10/09**

Copy to:

SITE TEST No.	SAMPLE NUMBER	SAMPLE LOCATION	LEVEL (m)	SOIL DESCRIPTION	Bulk Density (t/m^3)	pH_F	pH_{FOX}	pH_{KCL}	s-TAA (%)	S_{CR} (%)	$s\text{-}ANC_{BT}$ (%) S	S_{HCL} (%)	S_{KCL} (%)	$s\text{-}S_{NAS}$ (%)	NET ACIDITY (%) S	Verification Pass / Fail	LIMING RATE REQUIRED (kg/m^3)	REMARKS
								23A	23F	22B	19A2	20B	23C	20J				
41 AS	78956	**BOREHOLE No. 8**	1.50 - 1.75	REFER TO BORELOG	1.300	3.9	2.8	3.7	0.119	0.038	NA	NIL	0.018	NIL	0.157	**NA**	**10.0**	
42 AS	78957	**BOREHOLE No. 8**	2.00 - 2.25	REFER TO BORELOG	1.300	5.1	1.9	4.5	0.028	0.103	NA	NA	NA	NA	0.131	**NA**	**8.3**	
43 AS	78958	**BOREHOLE No. 8**	2.50 - 2.75	REFER TO BORELOG	1.300	5.5	1.3	3.5	0.210	1.606	NA	NIL	0.026	NIL	1.816	**NA**	**115.1**	
44 AS	78959	**BOREHOLE No. 8**	3.00 - 3.25	REFER TO BORELOG	1.300	6.0	1.3	5.0	0.076	1.876	NA	NA	NA	NA	1.952	**NA**	**123.8**	
45 AS	78960	**BOREHOLE No. 8**	3.50 - 3.75	REFER TO BORELOG	1.300	6.6	3.1	6.2	0.004	NIL	NA	NA	NA	NA	0.004	**NA**	**NR**	
46 AS	78961	**BOREHOLE No. 8**	4.00 - 4.25	REFER TO BORELOG	1.300	6.5	2.0	6.4	0.004	1.526	NA	NA	NA	NA	1.530	**NA**	**97.0**	
47 AS	78962	**BOREHOLE No. 8**	4.50 - 4.75	REFER TO BORELOG	1.300	6.5	1.9	6.4	0.004	0.568	NA	NA	NA	NA	0.572	**NA**	**36.2**	
48 AS	78963	**BOREHOLE No. 8**	5.00 - 5.25	REFER TO BORELOG	1.300	5.7	1.5	6.2	0.004	0.053	NA	NA	NA	NA	0.056	**NA**	**3.6**	

Codes:

S	Sulfur	pH_{KCL}	pH of filtered 1:40 1M KCl extract (TAA)
TAA	Titratable Actual Acidity	ANC_{BT}	Acid Neutralising Capacity - back titration
CR	Chromium Reducible	S_{HCL}	Sulfur soluble in 4 M HCL
pH_F	Field pH of saturated soil sample	S_{NAS}	Net acid soluble sulfur
pH_{FOX}	Field pH of 30% peroxide reaction	NR	Not required - % Sulfur less than action limit

Action Limit for % Oxidisible Sulfur = 0.03

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REPORT OF ANALYSIS OF SOILS FOR PRESENCE OF ACID SULFATES

CHROMIUM REDUCIBLE SULFUR SUITE

CLIENT: **LEDA**
PROJECT: **COBAKI LAKES, PIGGABEEN ROAD PIPELINES**
DATE SAMPLED: **08/10/09**
TEST ITEM: **DISTURBED**

JOB No.: **GC 2245/8768**
REPORT No: **11**
DATE ISSUED: **22/10/09**

Copy to:

SITE TEST No.	SAMPLE NUMBER	SAMPLE LOCATION	LEVEL (m)	SOIL DESCRIPTION	Bulk Density (t/m^3)	pH_F	pH_{FOX}	pH_{KCL}	s-TAA (%)	S_{CR} (%)	$s\text{-}ANC_{BT}$ (%) S	S_{HCL} (%)	S_{KCL} (%)	$s\text{-}S_{NAS}$ (%)	NET ACIDITY (%) S	Verification Pass / Fail	LIMING RATE REQUIRED (kg/m^3)	REMARKS
								23A	23F	22B	19A2	20B	23C	20J				
49 AS	78964	**BOREHOLE No. 9**	0.00 - 0.25	REFER TO BORELOG	1.300	4.5	3.2	4.2	0.039	NIL	NA	NIL	0.006	NIL	0.039	**NA**	**2.5**	
50 AS	78965	**BOREHOLE No. 9**	0.50 - 0.75	REFER TO BORELOG	1.300	3.8	3.2	3.6	0.067	0.020	NA	NIL	0.020	NIL	0.088	**NA**	**5.6**	
51 AS	78966	**BOREHOLE No. 9**	1.00 - 1.25	REFER TO BORELOG	1.300	4.8	2.8	4.0	0.062	NIL	NA	NIL	0.025	NIL	0.062	**NA**	**3.9**	
52 AS	78967	**BOREHOLE No. 9**	1.50 - 1.75	REFER TO BORELOG	1.300	4.7	3.6	4.8	0.027	0.017	NA	NA	NA	NA	0.044	**NA**	**2.8**	
53 AS	78968	**BOREHOLE No. 11**	0.00 - 0.25	REFER TO BORELOG	1.300	6.0	6.4	6.4	NIL	0.011	NA	NA	NA	NA	0.011	**NA**	**NR**	
54 AS	78969	**BOREHOLE No. 11**	0.50 - 0.75	REFER TO BORELOG	1.300	6.7	6.4	8.1	NA	0.025	NA	NA	NA	NA	0.025	**NA**	**NR**	
55 AS	78970	**BOREHOLE No. 11**	1.00 - 1.25	REFER TO BORELOG	1.300	7.0	6.6	8.7	NA	NIL	NA	NA	NA	NA	NIL	**NA**	**NR**	
56 AS	78971	**BOREHOLE No. 11**	1.50 - 1.75	REFER TO BORELOG	1.300	6.1	3.7	8.3	NA	0.021	NA	NA	NA	NA	0.021	**NA**	**NR**	

Codes:

S	Sulfur	pH_{KCL}	pH of filtered 1:40 1M KCl extract (TAA)
TAA	Titratable Actual Acidity	ANC_{BT}	Acid Neutralising Capacity - back titration
CR	Chromium Reducible	S_{HCL}	Sulfur soluble in 4 M HCL
pH_F	Field pH of saturated soil sample	S_{NAS}	Net acid soluble sulfur
pH_{FOX}	Field pH of 30% peroxide reaction	NR	Not required - % Sulfur less than action limit

Action Limit for % Oxidisible Sulfur = 0.03

*** 1.5 factor of safety included in all liming rate calculations**

Authorised Signature: ....

Form No.: GCR035b Rev.3 06/05

Cardno Bowler

Shaping the Future

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QUALITY ASSURED SUPPLIER
QUEENSLAND GOVERNMENT

REPORT OF ANALYSIS OF SOILS FOR PRESENCE OF ACID SULFATES

CHROMIUM REDUCIBLE SULFUR SUITE

CLIENT: **CARDNO BOWLER - HILLCREST**
PROJECT: **COBAKI LAKES, PIGGABEEN ROAD PIPELINES**
DATE SAMPLED: **08/10/09**
TEST ITEM: **DISTURBED**

JOB No.: **GC 2245**
REPORT No: **12**
DATE ISSUED: **22/10/09**

Copy to:

SITE TEST No.	SAMPLE NUMBER	SAMPLE LOCATION	LEVEL (m)	SOIL DESCRIPTION	Bulk Density (t/m^3)	pH_F	pH_{FOX}	pH_{KCL}	s-TAA (%)	S_{CR} (%)	$s\text{-}ANC_{BT}$ (%) S	S_{HCL} (%)	S_{KCL} (%)	$s\text{-}S_{NAS}$ (%)	NET ACIDITY (%) S	Verification Pass / Fail	LIMING RATE REQUIRED (kg/m^3)	REMARKS
								23A	23F	22B	19A2	20B	23C	20J				
57 AS	78972	**BOREHOLE No. 11**	2.00 - 2.25	REFER TO BORELOG	1.300	4.4	3.4	6.2	NIL	0.017	NA	NA	NA	NA	0.017	**NA**	**NR**	
58 AS	78973	**BOREHOLE No. 11**	2.50 - 2.75	REFER TO BORELOG	1.300	6.1	3.7	5.2	NIL	0.009	NA	NA	NA	NA	0.009	**NA**	**NR**	

Codes:

- S — Sulfur
- TAA — Titratable Actual Acidity
- CR — Chromium Reducible
- pH_F — Field pH of saturated soil sample
- pH_{FOX} — Field pH of 30% peroxide reaction
- pH_{KCL} — pH of filtered 1:40 1M KCl extract (TAA)
- ANC_{BT} — Acid Neutralising Capacity - back titration
- S_{HCL} — Sulfur soluble in 4 M HCL
- S_{NAS} — Net acid soluble sulfur
- NR — Not required - % Sulfur less than action limit

Action Limit for % Oxidisible Sulfur = 0.03

*** 1.5 factor of safety included in all liming rate calculations**

Authorised Signature: ....