Appendix D

EA Systems, 2006: Hydro-Geological Assessment

ARMIDALE REGIONAL LANDFILL

Environmental Assessment

Hydro-Geotechnical Assessment

FINAL REPORT

Armidale Dumaresq Council Landfill Facility Hydro-Geotechnical Assessment

Report Number 20969.13861

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This document provides information to address the intent of Project Number 20969 as agreed to by Armidale Dumaresq Council.

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1. Introduction

E.A. Systems Pty Limited has been commissioned by Maunsell Australia to complete a limited hydro-geotechnical investigation for a proposed landfill site for Armidale. This investigation is a component of the Environmental Assessment prepared on behalf of Armidale Dumaresq Council.

The proposed landfill is located 12 kilometres east of Armidale off the Waterfall Way. The site is located approximately one kilometre west of the Gara River.

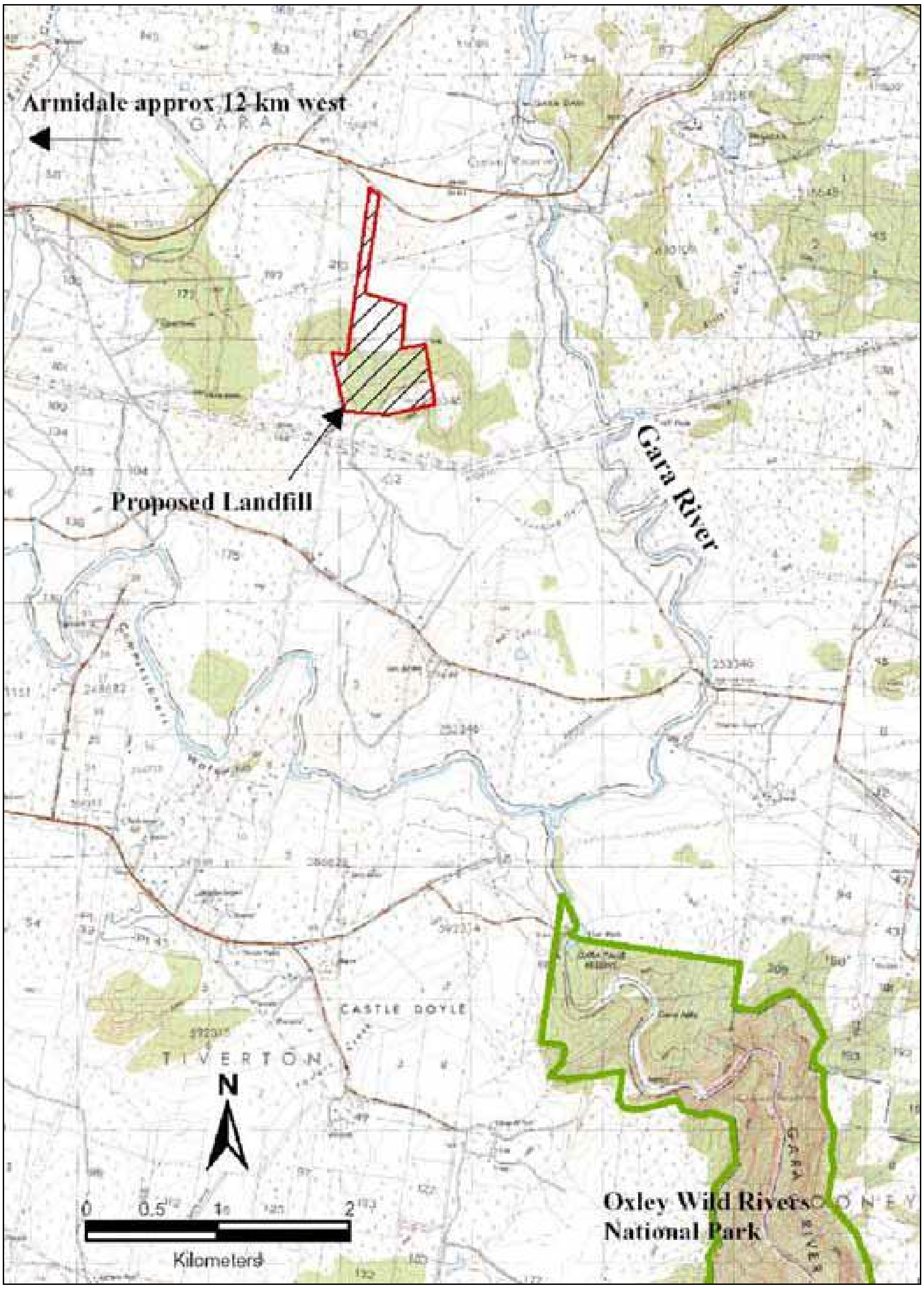


Figure 1. Proposed landfill location

1.1 Scope of Works

This geotechnical investigation follows the landfill site selection study by Maunsell Australia. This investigation was prepared to:

- describe soil and groundwater conditions on site;
- identify potential effects which these conditions may impose on the construction of the landfill; and,
- identify the potential impacts that the landfill may have on localised soil and groundwater conditions.

The project scope had limited sampling and did not include any in-field infiltration or soil strength/penetration tests. Bulk soil samples have been retained should further laboratory testing be required. A detailed geotechnical assessment is required to fully characterise the site and determine resource extents. This is not included in this assessment.

2. Description of Existing Environment – Regional Geology

The proposed landfill site is located on an undulating landscape on the New England plateau. The 1:250 000 geological map of the region (Gilligan et al., 1992) shows the proposed landfill site is underlain by Late Paleozoic deep marine sedimentary rocks of the Girrakool Beds. The site is also close to the contact with the nearby Sandon Beds, also largely deep marine sedimentary in nature. These two rock units are composed largely of low grade metamorphosed greywacke, mudstone and chert and have been folded (Gilligan *et al.*, 1992). Folding can cause the rock sequence to be steeply dipping (Ashley, 2005). The effects of weathering in the New England plateau can be found to depths of tens of meters (Ashley, 2005).

3. Investigations

3.1 EM survey

Electromagnetic surveys (EM31 and EM38) of the proposed landfill site were undertaken (Figure 2 and Figure 3). Electromagnetic surveying measures the soils' apparent electrical conductivity which is influenced by a number of soil factors including porosity, soil moisture, the concentration of dissolved electrolytes, and the amount and type of clay. An EM31 survey has a maximum recording depth of six metres, with the greatest zone of influence for measurement being between two and four metres. The EM38 survey has a maximum depth of 1.5 metres with the greatest zone of influence between 0.2 metres and one metre. The generated maps were used to identify trends across the site, and target locations where variability may be more pronounced.

3.1.1 EM survey results

The EM surveys showed considerable variation in conductivity across the site. Conductivity across the site was measured at values ranging from 0 to 47 mS/m for the EM38 survey (Figure 3) and between 15 to 70 mS/m for the EM31 survey (Figure 2). Generally the southern end of the site, which corresponded with the existing wooded area on slopes of approximately 6% to 10%, showed values ranging between 0 to 15 mS/m up to 1.5 metres deep and between 15 to 30 mS/m up to six metres deep.

Below the tree line in the northern half of the site, the slope levelled out to less than 3% below the toe of the hill. At a depth to 1.5 metres below ground surface, the average conductivity ranged from approximately 19 to 29 mS/m, with small areas recording values as low as nine and as high as 47 mS/m. On average, conductivity values to six metres were higher than the shallower depth and average values from 31 to 52 mS/m, with peaks as high as 70 mS/m and as low as 15 mS/m.

3.1.2 EM survey discussion

As is confirmed by the drilling investigation (discussed in section 3.2), the EM survey results indicate that the site can be broadly divided into four areas. The division of these areas across the site can be attributed to the movement of clays. As was confirmed by the drilling investigation, areas of shallow or deeper clay soils were indicated by lower or higher conductivity rates respectively.

In the southwest and southeast corners of the site, the low conductivity values correspond to the hill tops where soil was shallow. The toe of the slopes show higher rates of conductivity, indicated by the blue areas. Soil that has been eroded from the hill tops has been deposited in this area where there is a reduction in slope. Greater areas of higher conductivity are shown in the EM31 survey, which suggests that clay may be found at depth. The flats and the hill slopes correspond to the green colouring where soils are shallower then the toe of the slope, yet deeper than the hill crests.

The pattern of soil depth shown by the EM surveys indicates the physical movement of soils down slope by natural processes of weathering and erosion. The clays and topsoils have been transported downslope, with colluvium present in areas where there is a decrease in slope.

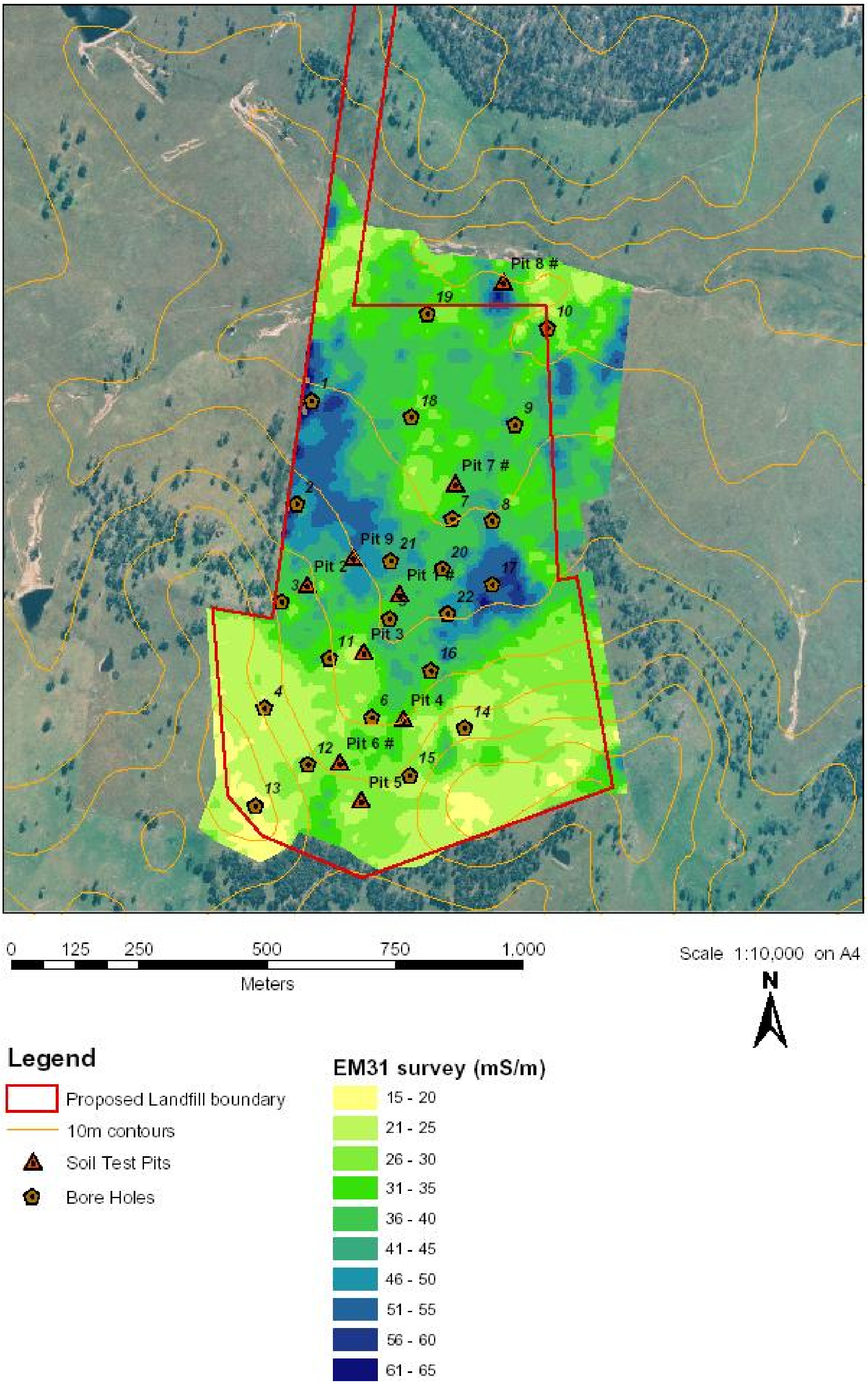


Figure 2. EM31 survey results

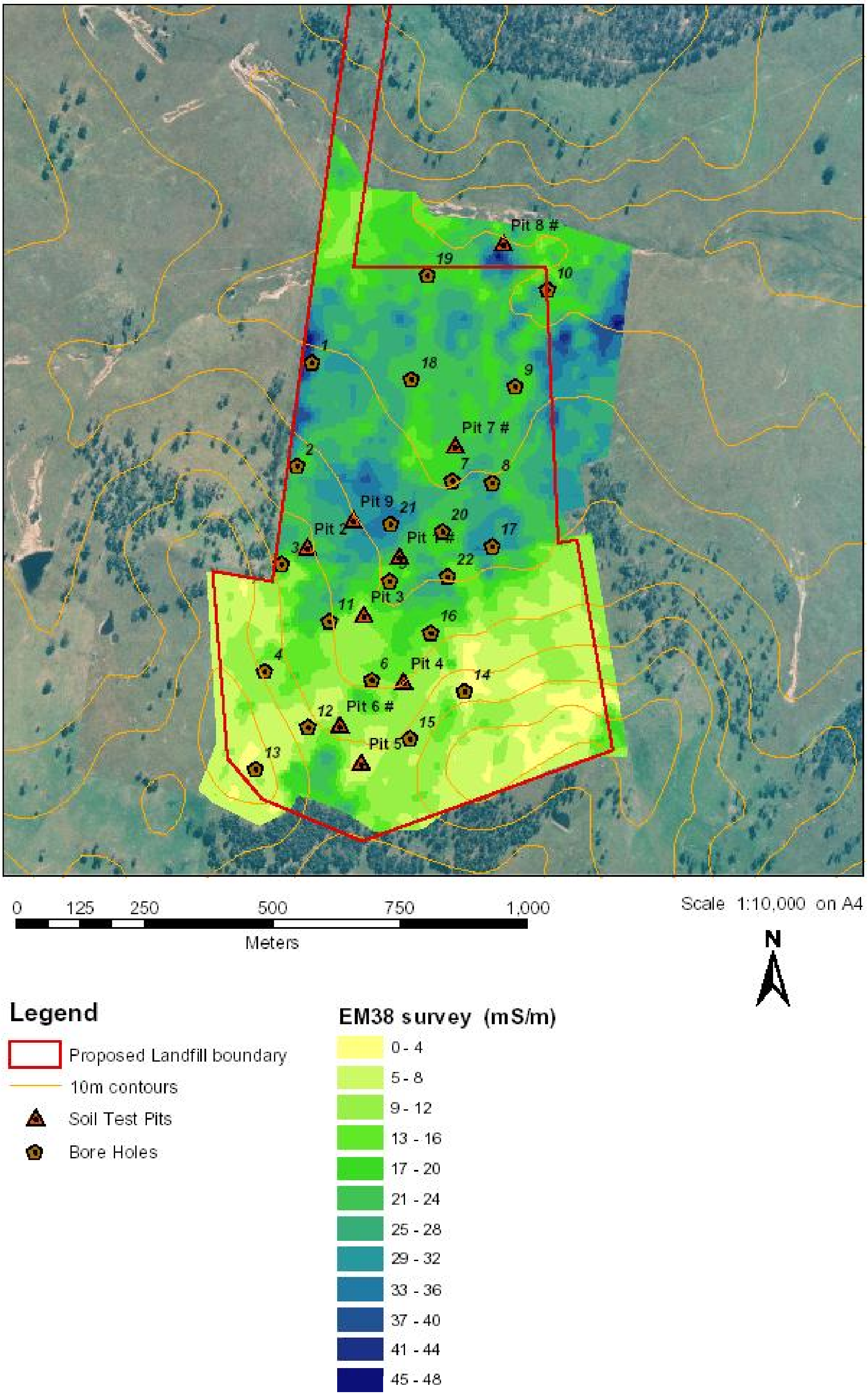


Figure 3. EM38 survey results

3.2 Soils Investigation

3.2.1 Methods

A soils investigation was completed across the site. The investigation included two components, the drilling of 22 bore holes and the excavation of nine (9) test pits. This investigation aimed to ground-truth the results of the EM survey, and to provide a more accurate indication of soil conditions across the site. Initial bore holes were completed on a grid pattern, with remaining bore holes and test pits completed to determine variations in the landscape as well as concentrating on the the landfill area proper.

The bore holes were dug using a light, trailer mounted drill rig (Plate 1). Most holes were drilled to a depth of approximately four metres, or until refusal. Several deeper pilot holes were drilled to a depth of 5.5 metres.

The nine test pits were excavated with a backhoe to a depth of approximately 1.5 metres (Plate 2). The pits were excavated to allow the collection of bulk samples and to gain a greater understanding of the soil profile.

The location of bore holes and test pits is shown in Figure 4 below.

Plate 1. The E.A. Systems light drill rig at Bore Hole 1.

Plate 2. Pit excavation with a backhoe at Test Pit 2

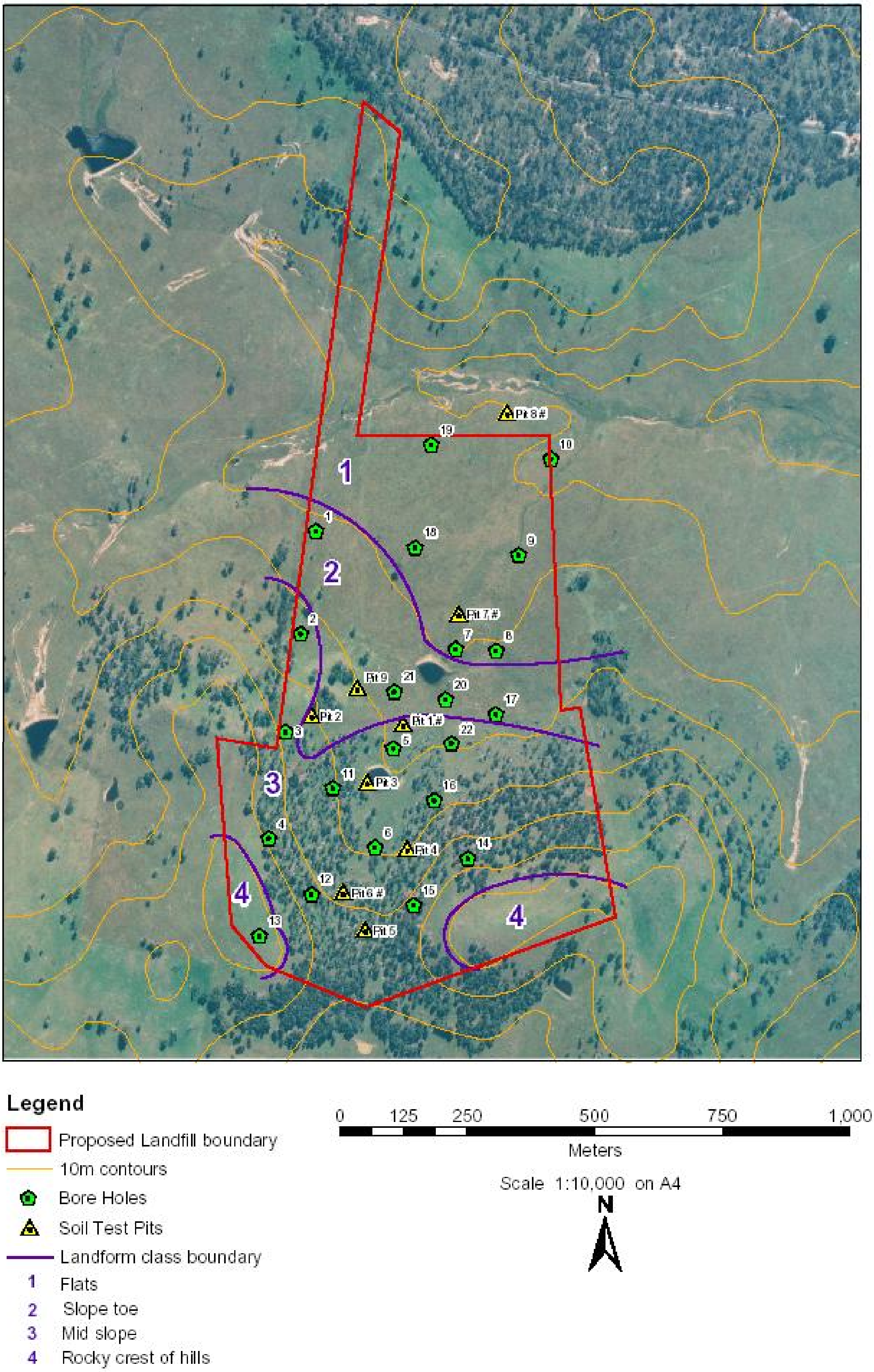


Figure 4. Bore hole and test pit locations

3.2.2 Results

The site can be broadly broken down into four areas based on the EM survey, landform and soil profiles; the 'flats' running out to the creek line (Plate 3), the toe of the slope, the wooded midslope (Plate 4) and the rocky crests of the hill (Plate 5). Figure 4 shows the delineation of each of these areas and how they relate to site topography and the location of the bore holes and test pits. With the exception of the hill crest where the profile was generally shallower and contained more rock and bedrock outcrops, the soils were relatively uniform across the site.

Complete soil logs for the bore holes and test pits are shown in Appendix A and Appendix B respectively. Typical photos showing the soil profiles on the midslope (pit 1 and 6) are shown in Plate 6. Typical profiles of the soils across each of the four broad categories are described below in Table 1. These are typical profiles only that include the range of each horizon. Variations do occur between individual bore holes and pits.

Table 1. Typical soil profiles across the site

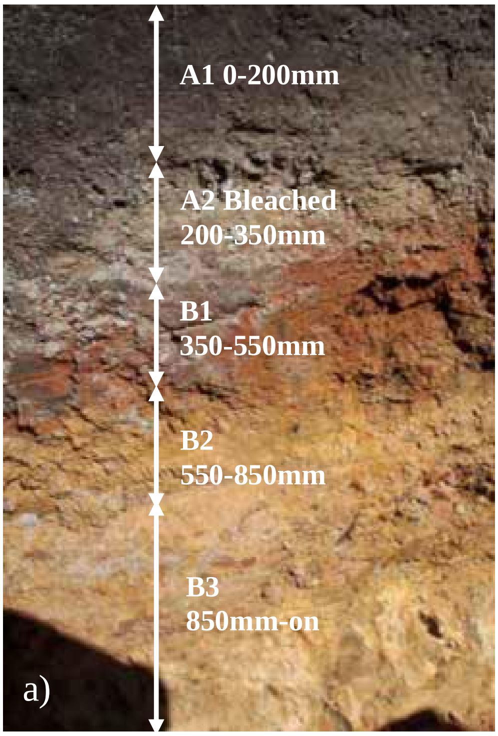
	Creek Flats		Slope Toe		Midslope		Hill Crests	
Bore holes	7, 8, 9, 10, 18, 19		1, 17, 20, 21		2, 3, 4, 5, 6, 11, 12, 14, 15, 16, 22		13	
Test pits	7, 8		2, 9		1, 3, 4, 5, 6			
Ranges of Typical Horizon Depths	0 – 0.3	Brown clay loam (SC – CI)	0 – 0.15	Brown clay loam (SC – CI)	0 – 0.15	Brown-grey clay loam (SC – CI) with some surface gravel	0 – 0.3	Brown rocky loam
	0.15 – 0.75	Grey-brown clay with sand (SC – CI) and some gravel	0.15 – 0.45	Grey-white sandy loam (CI – CL, SM – SC) with some gravel	0.15 – 0.3	BH2, 4, 5, 11 & TP1 – grey-white clay loam (CI – CL) that may indicate transient flow	0.3 – 0.4	Brown gravel
	0.3 – 3.3	Orange-yellow medium to heavy clay with fine sand (CL – CH) and gravel occurring in horizons 0.1 – 1.0 thick	0.25 – 1.5	Orange-red silty medium to heavy clay (CL – CH) with gravel	0.15 – 1.6	Orange heavy clay with some sand and gravel (GC, SC, CI - CH)	0.4 – 0.8	Yellow silty gravel
	1.5 – 4.3	Yellow sandy clayey silt (ML) material likely to be extremely weathered mudstone-argillite	1.2 – 5.5	Yellow sandy clayey silt (ML) material likely to be extremely weathered mudstone-argillite	1.2 – 5.5	Yellow sandy clayey silt (ML) material likely to be extremely weathered mudstone-argillite	0.8 – 1.0	Orange silty gravel
	0.3 – 2.8	Bore holes 18 – 19, medium clay with fine sand (SC – CL)					1.0 – 2.0	Yellow silty gravel
							2.0 – 2.5	Orange gravely clay
Termination and Refusal Details	2.0 – 3.8	Bore hole refusal* (except BH7- termination)	3.0 – 5.5	Bore hole termination*	1.7 – 4.2	Bore hole refusal in 4, 5, 6, 12, 14, 22	2.5	Refusal
					4.0 - 5.5	Bore hole termination* in 2, 3, 11, 15, 16		
	1.2 – 1.35	Backhoe refusal on decomposed mudstone-argillite	1.2 – 1.3	Backhoe refusal on decomposed mudstone-argillite	1.2 – 1.7	Backhoe refusal on decomposed mudstone-argillite		

* Note the augers used on the light drill rig are able to penetrate through hard materials, and the grindings brought to the surface may present as fines.

Plate 3. The 'flats' running down to the creek line (photo taken from across the main drainage line looking south up towards the proposed landfill.

Plate 4. Typical area of the wooded midslope area.

Plate 5. Typical hill crest (near Bore Hole 13).



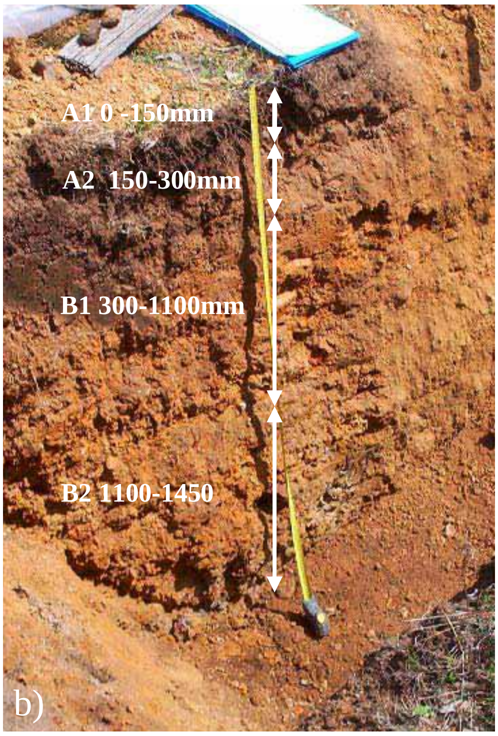


Plate 6. Typical soil profile a) mid-way down the site in Pit 1, and b) near to top of the site at Pit 6.

It appears that the site is underlain by a common substrate rock, most likely mudstone-argillite and chert. Medium to coarse grained greywacke is also common in the area. These substrate rocks are part of the Sandon Beds.

No standing groundwater was encountered during the investigation. Some soil moisture was observed at depths of less than 0.5 metre in bore holes 1, 5, 7, 9, 10, 17, 18 and 21. These bore holes all corresponded with lower slopes at the north of the site or on the main drainage line that runs from the saddle through the middle of the site. The moist layer in bore holes 1, 5, 9, 10 and 17 were bleached (white, grey or pale brown) and overly a stiff orange clay. These profiles suggest water moving down the profile and then moving laterally at the top of the clay layer. It is possible that this groundwater movement is transient only.

At the crests, the soil profile was generally shallower with more rock. The shallow, rocky soils that occur on the hill crests may act as recharge areas for transient groundwater flow during high rainfall events. Lateral movement of this groundwater may then occur through the bleached clay loam layer above the orange clay.

A graphical representation of the likely underlying soil and sub-surface conditions are shown in Figure 5 below.

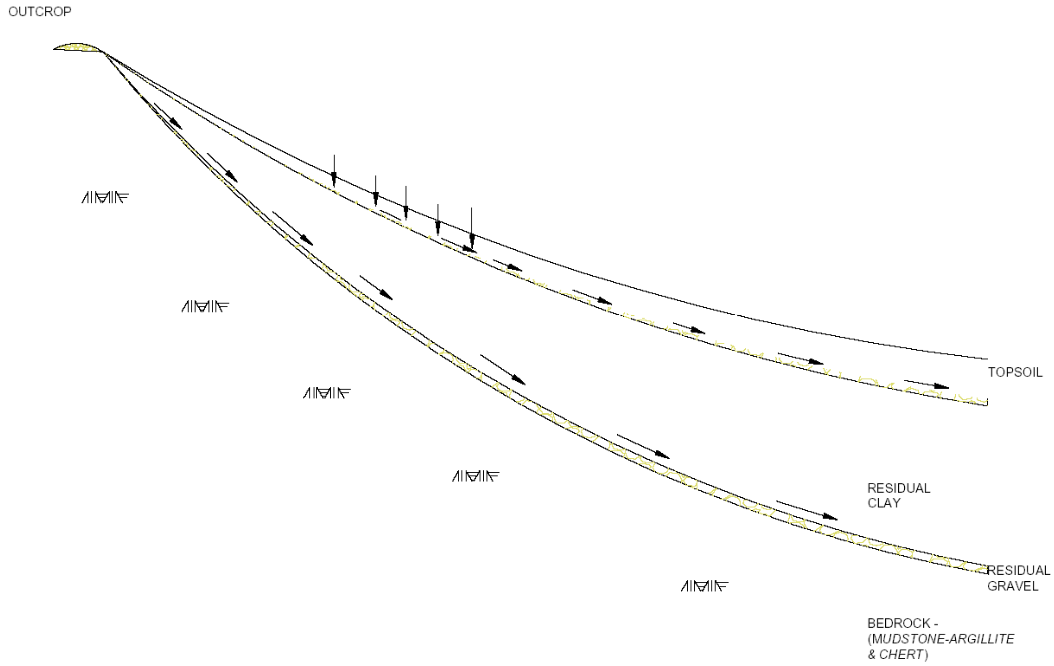


Figure 5. Possible cross-section of the site showing direction of sub-surface flow (Not to Scale; vertically exaggerated)

Refusal was typically reached on bedrock at around 1.2- 1.7m when using the backhoe. Where deeper profiles were achieved using an auger, weathered rock (ranging from slightly weathered to extremely weathered and grading to 'fresh' bedrock) was encountered from about 1.5m until refusal (or termination at 5.5m).

Laboratory Results

Six (6) typical bulk samples from the site were submitted to a NATA accredited laboratory for geotechnical laboratory testing to confirm soil classification and also determine the suitability of materials likely to be used in construction of the landfill. Tests completed on these samples were Particle Size Distribution (or grading), Atterberg Limits and Falling Head Permeability on a remoulded sample. The analysis undertaken and the laboratory description of each of these soils are shown in Table 2. The complete set of the laboratory results is presented in Appendix C.

Table 2. Geotechnical laboratory analysis undertaken

Laboratory Report No.	Laboratory Soil Description	Sample location	Analysis Undertaken: Grading > 0.075mm	Grading with Hydrometer	Atterberg Limits	Falling Head Permeability on remoulded sample AT 98% (m/s)
1	Sandy clayey SILT (ML), medium plasticity, yellow grey, fine to coarse sand.	BH 3	Appendix C	Appendix C	LL 38% PL 22% PI 16% LS 8.0%	6 X 10^{-10}
2	Sandy silty CLAY (CI) medium plasticity, yellow grey & orange, fine to coarse sand, trace fine gravel.	Pit 5, >600	Appendix C	Appendix C	LL 48% PL 25% PI 23% LS 11.0%	5 X 10^{-10}
3	Clayey silty gravely SAND (SC) fine to coarse grained, red orange & grey, fine to coarse gravel, medium plasticity clay.	Pit 4, 800 – 1,200	Appendix C	Appendix C	LL 38% PL 22% PI 16% LS 8.0%	5 X 10^{-9}
4	Sandy clayey GRAVEL (GC) fine to coarse grained, light brown, medium plasticity clay, fine to coarse sand.	Pit 1, approx 1500	Appendix C	-	LL 37% PL 16% PI 21% LS 10.5%	-
5	Silty sandy clayey GRAVEL (GC) fine to coarse grained, brown, medium plasticity clay, fine to coarse sand.	Pit 1, 600 – 900	Appendix C	Appendix C	LL 42% PL 17% PI 25% LS 12.5%	-
6	Silty CLAY (CH) high plasticity, yellow grey & orange, some fine to coarse sand.	Pit 2, 600 – 1,000	Appendix C	Appendix C	LL 69% PL 22% PI 47% LS 18.0%	1 X 10^{-10}

The orange/yellow grey clay (report number 6 in Table 2) is representative of the orange clay common across the site (excluding the hill crests). This layer typically occurred in layers of around 1.25m. This soil was identified as being an inorganic clay of high plasticity (group symbol CH). Soils of this type generally have a high to very high dry strength. The (remoulded) permeability of this soil is 1 x 10^{-10} m/s. This layer is also represented by report 5 (Table 2), material found higher up the slope in the midslope area. This material was described as a silty sandy clayey gravel (GC). The linear shrinkage for these two materials was determined to be 18 and 12.5% respectively.

Further up the slope the material between 0.8 – 1.2 metres in pit 4 is a clayey silty gravely sand (SC), and sandy silty clay (CI). This latter material had a permeability of 5 x 10^{-10} m/s.

Where weathered bedrock was exhibiting ‘soil’ properties (i.e. if it could be remoulded with wetting), a sample was also collected for laboratory testing. The fine fraction of the underlying decomposed mudstone was tested and found to be a sandy clayey gravel (GC), or a sandy clayey silt (ML) (reports 4 and 1 respectively). The latter material found on the mid-slopes, has a permeability of 6 x 10^{-10} m/s

3.2.3 Discussion

The results indicate, the soil profiles across the site can be split into four typical main groups, based on topography, soil depth and the results of the EM survey. With the exception of the hill crests towards the south of the site, the soils generally displayed similar conditions and properties. Below 0.15 metres of topsoil there was commonly a pale coloured silty clay layer that displayed bleached colouring. This bleaching is likely due to transient flow through the soil profile that over time has caused translocation of minerals.

Below this bleached layer, a yellow to orange, medium to heavy clay with some sand and small gravel was common between depths of 0.15 to 1.6 metres. Between 1.6 to 5.5 metres (the maximum bore hole depth reached before termination) a yellow clay with fine sand was common. This layer is most likely extremely weathered (XW) mudstone-argillite and exhibits soil properties.

Topsoil

The top 150mm (topsoil) should be stripped and stockpiled according to best practice guidelines. This material should be used for topsoiling at the completion of construction works.

Clay Lining Material

With the exception of the hill crests, the orange clay material found across the site is suitable for a lining/capping material and should be excavated and stockpiled separately. This material was found at depths from 0.3, 0.25 and 0.15 (from the creek flats, slope toes and midslope respectively), and varied in profile thickness from 3.0 down to less than 1.5m. The exception is bore holes 18 and 19 were only a small band of orange clay was identified.

This clay material, when placed with a suitable thickness and compacted, should provide a lining with an acceptable permeability limits ($< 1x10^{-9}$ m/s), as required by the Department of Environment and Conservation (DEC). The linear shrinkage of these materials is in the order of 15 to 18%. While the shrink-swell potential of this material is higher than ideal values, remoulding and compaction will assist in managing the shrink-swell to a degree. Furthermore, mixing this material with materials of lower shrink-swell potential will also assist. The bearing pressure of the proposed facility should be considered in light of the Atterberg Limits identified during this investigation.

While soils of group CH and CI are the most suitable material for lining, GC and SC may also be of low permeability provided adequate compaction (98% or greater) takes place at appropriate moisture conditions using suitable construction practices.

Clay material at the landfill site has been found to have a remoulded permeability (>98%) of around $1x10^{-8}$ m/s. Given the plasticity of the materials, the clay should be readily able to reach a permeability of $1x10^{-9}$ m/s, as required by the DEC, through satisfactory compaction. Suitable compaction testing will be required during the detailed design stage of the landfill to validation this permeability.

On-site assessment will need to be made during construction, as the quantity of gravel found in the profile varies across the site. Generally, more gravel is found higher in the slope. Should the concentration of gravel through the profile be higher than expected, this material should be removed and stockpiled separately to the clay material. Alternatively, the gravel material could be mixed with the clay to provide a homogenous material for lining.

Sub-soils

The underlying sub-soils of decomposed and mineralised clay and mudstone should provide a low permeability lining for the landfill, provided it is ripped, wetted and compacted to adequate standards. This may not be required if an adequate thickness of clay material is compacted above this layer. If any of this material is pulled from the ground, it should be stockpiled separately to other materials. This material could also be used for surfacing of roads and hardstand areas.

Summary

In summary, the outcome of the limited geotechnical assessment undertaken of the proposed site does not preclude the construction of a landfill facility. The site should be suitable if suitable construction specifications are adhered to. The soil properties of the underlying decomposed sandstone material should provide a suitable in-situ lining material, provided it is ripped and wetted to provide adequate compaction. The orange clay material found across the site in thickness from 1.3 up to 3.0m should provide a material suitable for capping purposes.

The limited nature of this investigation does not allow determination of material quantities. It is recommended that a detailed grid survey of soils be undertaken to define the contents of the required soil resources.

3.3 Groundwater Investigation

This study was limited to the drilling and logging of five (5) bore holes that were developed for piezometers. No standing groundwater was encountered during the shallow soil drilling investigation, although damp conditions were encountered in some bore holes and the soil profile had evidence of transient sub-surface flow. These factors are indicative of transient flow rather than standing groundwater.

Consequently, piezometers were installed to monitor the presence of (any) groundwater movement. No groundwater has been detected to date in any of the piezometers at the time of reporting, despite the seasonally wet conditions during September to December 2005. The presence and depth of groundwater should be monitored in the installed bores as part of the preliminary investigation, and as on going long term monitoring.

The deep diamond core was drilled using 'wet drill' methods, and hence made the accurate identification of groundwater difficult to determine. At the immediate completion of the diamond core drilling, standing groundwater was identified at a depth of 18.7 metres. This water may have been from either natural sources, or from the drilling operation.

Although no standing groundwater was encountered during the shallow drilling operation (<10 metres), a total of five piezometers were installed in layers that were believed to carry transient flows. The screens were placed in those layers considered to be most permeable and those most likely to carry transient flows (Appendix F).

Four piezometers were installed on the site on the 13th October 2005 (Figure 6 and Table 3). Piezometers one, two and three were installed with interception screens ranging from depths of 0.35 to 2.0 metres. The screen depth indicated the depth at which shallow groundwater was most likely to move through the gravel layers, and also the layers that were most likely to be impacted by the proposed landfill site. Piezometer one was placed on the ridge at the southern end of the site to provide an indication of unaffected groundwater as it enters the site. Piezometer two is located on the flats at the lower end of the proposed site and will indicate the quality of groundwater leaving the proposed site. Piezometer three is located beside the gully north of the proposed site and will provide background data on any unaffected groundwater moving along the natural drainage line that enters the Gara River. Piezometer four was placed adjacent to the Gara River with screen at a depth of 1.1 to 2.6 metres. Piezometer four will provide an indication of any groundwater entering the potentially sensitive receptor of the Gara River.

An additional piezometer (piezo 5) was placed in the deep, diamond core bore hole on 17th November 2005. The screen of this piezometer was placed at a depth of 5.1 to 9.6 metres, and sealed with bentonite. This piezometer was placed immediately down slope of the proposed landfill site to provide an indication of deeper groundwater movement. This piezometer was placed at a greater depth than the other piezometers to provide an indication (if any) of groundwater movement at a greater depth through those soils considered more permeable. Bore logs and Form A details of each piezometer are shown in Appendix F.

Table 3. Piezometer Locations (MGA94 Zone 56) and Water Entry Screen Depths

Piezometer	Easting	Northing	Water entry from (m)	Water entry to (m)
1	383261.98	6618683.49	0.35	1.85
2	383490.08	6619462.43	0.5	2.0
3	383412.89	6619775.29	0.45	1.95
4	384608.59	6619877.89	1.1	2.6
5	383471.27	6619105.1	5.1	9.6

The presence and depth of groundwater in each of these piezometers should be monitored as part of an on-going, long-term monitoring program. An investigation of piezometer levels on the 17th November and 20th December 2005 showed no groundwater present in any of the four shallow piezometers. A check of the deep piezometer 5 on the 20th December 2005 showed no groundwater present. This followed a period of sustained above average rainfall in the New England Area. Total monthly rainfall (mm) during the period from September to December is compared to long term averages for Armidale in Table 4 below. Despite this rainfall no groundwater has passed through the interception depths of these piezometers in the period since they were installed.

Table 4. Actual Monthly Rainfall (September – December 21, 2005) compared to Long Term Monthly Rainfall Averages (BoM 2005)

Year	Month			
	September	October	November	December
2005	101.6	60.4	161.4	84.0
Long Term Averages (1857-1997)	51.6	67.8	80.4	89.2

Figure 6. Piezometer locations

3.4 Diamond Core Drilling

3.4.1 Methods

A vertical, deep diamond drill core was drilled to a depth of 26 metres in the location shown in Figure 6 (Piezo 5 Deep Rock Core). The drill core from five to 26 metres was collected and logged by Associate Professor Paul Ashley (Department of Earth Sciences, University of New England). The top five metres of the profile was discarded as recovery of the weathered material was poor.

A full copy of Professor Ashley's geological log is included in Appendix D. The following is a summary of this report.

3.4.2 Results

The core contains two primary rock types. The dominant rock type is the medium grained, rather massive greywacke (quartz-feldspar-lithic sandstone). Where fresh and unweathered, this rock is not porus. The second rock type, "mud chip greywacke" is similar, but contains abundant, larger lithic grains.

Much of the greywacke and mud chip greywacke is rather massive and homogenous, however weak foliation is evident in places. This is due to the tectonic effects imposed on the rock when it was deeply buried in the earths crust. Many of the structures in this core, including rare thin veins of quartz indicate a steeply dipping feature.

Planar to arcuate and irregular fractures are common throughout the core. These are slightly more abundant when weathering effects are stronger. This fracturing has occurred after the formation of foliations. Fractures lie in two orientations and are likely to have occurred during different geologic times. Intersections and weathering of these faults has resulted in narrow zones of rubble and clay.

Weathering of the core is prominent to a depth of around 19.5 metres. Below a depth of 19.5 metres, weathering effects tend to be more limited to zones of stronger fracturing. This illustrates the importance of fracturing to allow migration of shallow oxidising groundwater. These fracture sets commonly show the development of clay zones.

3.4.3 Implications

Fracturing and weathering effects observed in the drill core would have implications on the transmission of groundwater and potential leaching events. The weathering effects in the deeper sections of the core indicate that oxidising groundwater has penetrated to a depth of at least 26 metres. Strong fracturing and clay development in these weathered zones might have the potential for considerable groundwater transmission.

3.5 Fault Line Investigation

A fault line has been identified on the published geological map of the region which cuts across the southeast corner of the proposed landfill site (Figure 7). Although marked as 'position accurate' on the Geological map sheet, Jim Stroud, (Senior Geologist, Geological Survey of New South Wales, NSW Department of Primary Industries-Mineral Resources, pers comm., 16 September 2005) stated that the fault line shown is only in its approximate position. It actual location may vary within 500 meters of the position shown. All geological boundaries, including fault lines, have a significant possible error associated.

Following discussion with Jim Stroud (Department of Mineral Resources, Armidale) and Associate Professor Paul Ashley (Department of Earth Sciences, University of New England) (pers. comm., Sept. 2005), there is apparently little topographic or geophysical expression of the fault. The fault position may have been speculated from features such as air photo linears.

An investigation of the possible geological fault was conducted by Professor Paul Ashley (Appendix E). The investigation included detailed field mapping and structural measures, together with examination of remote sensing and map data. The investigation concluded that no evidence of a fault in the area of the planned landfill site could be found, and that the fault shown on the map sheet has no basis in the site under investigation.

3.6 Site Anomalies and Recommendations

Although groundwater was not encountered during the soils investigation, there is evidence of shallow sub-surface transient flow, (typically in the A2 horizon) noted by the presence of sedges (indicator species for moist and/or saturated conditions). This sub-surface flow may, particularly during or after periods of heavy rainfall, come to the surface at the base of the slope as seeps (which may be identifiable as springs or the presence of sedges and other plants which are common around water-logged sites). These seeps would most likely be due to two reasons:

i. As relatively high velocity sub-surface flow moves from the hill sides to the flats, the decrease in flow velocity will force groundwater to the surface; or
ii. The presence of a rock outcrop downslope, forcing the sub-surface flow to the surface.

These seeps are generally located below the proposed landfill void. Seeps can be prevented by upslope interception using clay lined earthen contour drains cut into the clay B horizon.

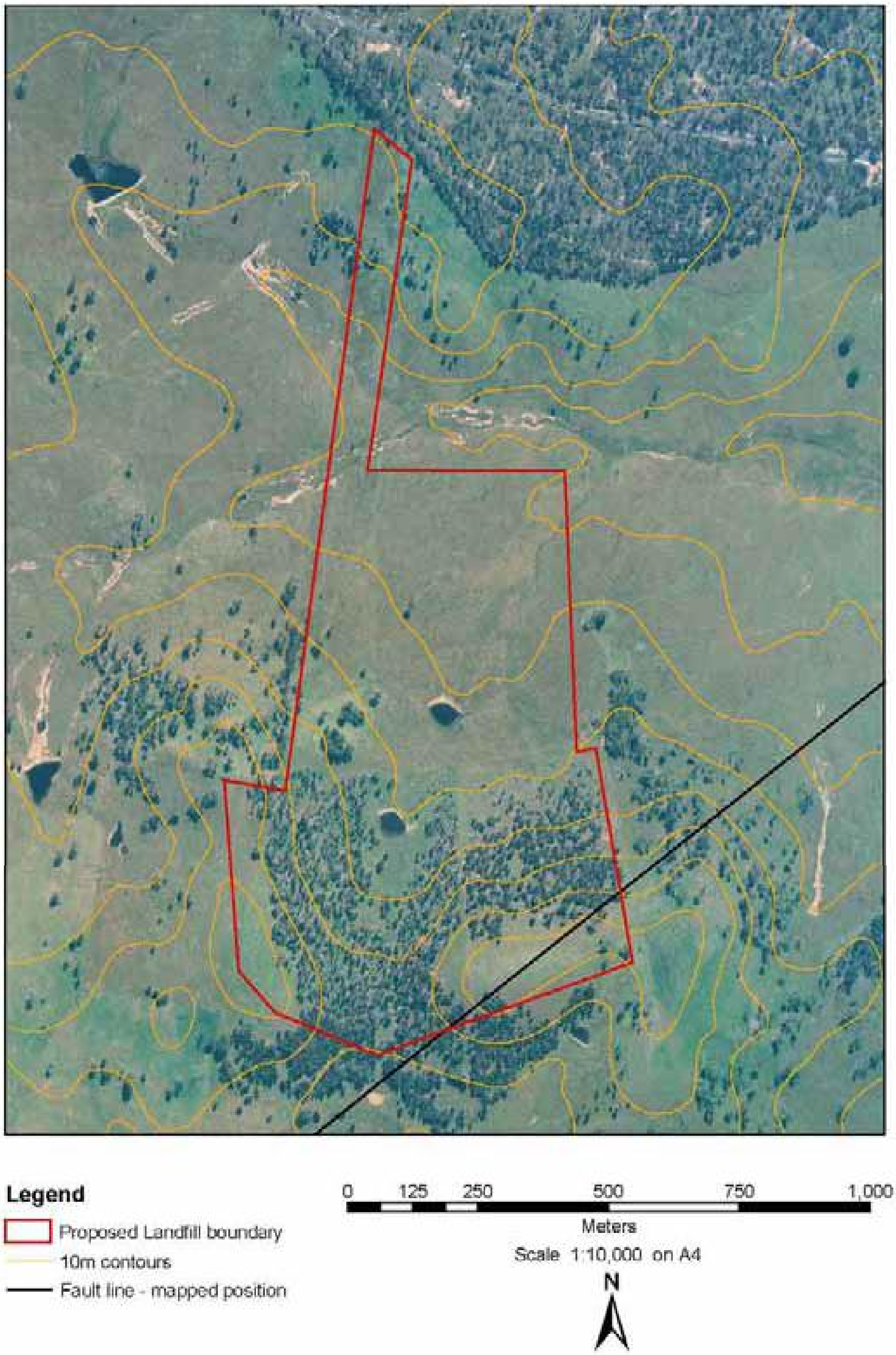


Figure 7. Fault line transecting the site (Dorrigo-Coffs Harbour 1:250,000 Geological Services Sheet SH 56-10 - SH 56-11)

4. Conclusions

Based on the information collated, initial outcomes of the geotechnical investigation have found that soil and groundwater conditions would be suitable for a landfill site, provided suitable detailed design and construction methodologies are adhered to.

The soil profile is relatively uniform throughout the site, although more rocks and gravel is present towards the crest of the slope where the soil profile is much shallower. The horizon of orange clay with sand and gravel (ranging in depth across the site from 1.3m to 3.0m in thickness) contains material suitable for lining and capping. Furthermore, the underlying decomposed parent material could provide a suitable in-situ lining material, provided that suitable ripping, wetting and compaction take place during construction. Given the duplex nature of the soil profile, it is recommended that each horizon of the profile be excavated and stockpiled separately.

The EM survey and the drilling investigation showed that the soil conditions across the site could be largely spilt into four areas – the flats, toe of slope, mid slope and crests of the hills. As suggested by the EM survey and later confirmed during the drilling investigation, the areas of higher conductivity contain greater depths of clay material. These areas are typically around the toe of the slopes where colluvial material has been deposited, and to a certain extent on the midslopes. The areas of low conductivity correspond to the hill tops where soil was shallow and weathered material has been washed downslope. The creek flats were also found to have shallower soils.

The pattern of soil depth shown by the EM surveys and geotechnical investigation indicates the physical movement of soils down slope by natural processes of weathering and erosion. The clays and topsoils have been transported downslope, with colluvium present in areas where there is a decrease in slope.

No standing groundwater was encountered during the investigation. However, the soil profile had evidence of transient sub-surface flow in the shallower soils. Consequently, piezometers were installed to monitor the presence of (any) groundwater movement. No groundwater has been detected during limited piezometer monitoring to date, despite the seasonally wet conditions during September to December 2005. The presence and depth of groundwater should be monitored in the installed bores as part of the preliminary investigation, and as on going long term monitoring.

A fault line is shown on the 1:250,000 geological map of the area. A detailed fault line investigation undertaken concluded that no evidence of a fault in the area of the planned landfill site could be found, and that the fault shown on the map sheet has no basis in the site under investigation.

5. References

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