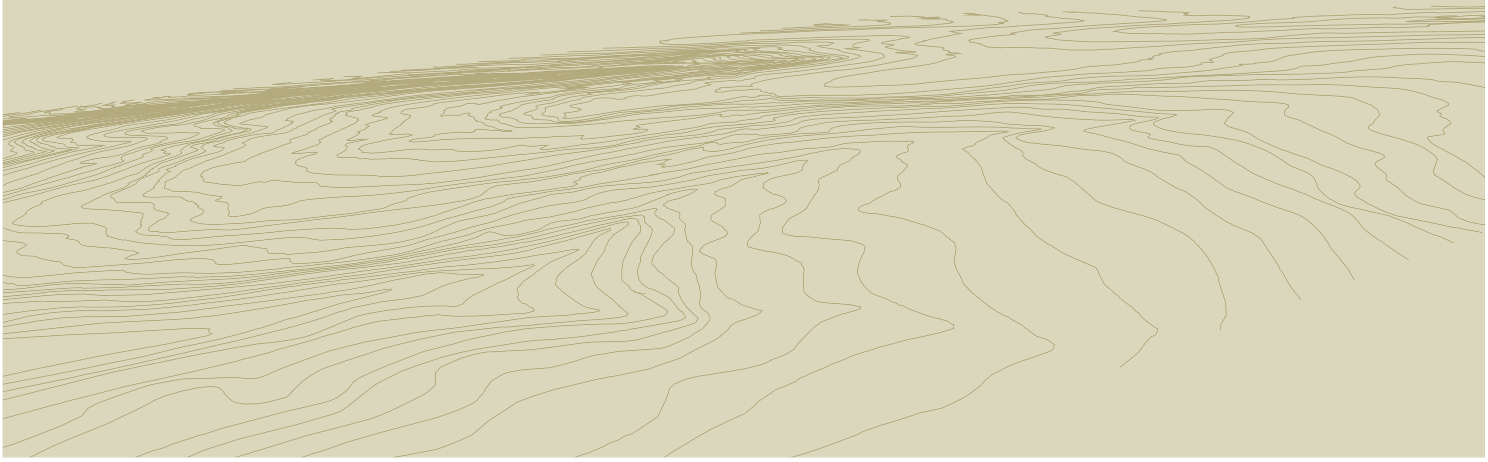
Appendix F

RCA Australia, 2007: Hydrogeological Investigation

ARMIDALE REGIONAL LANDFILL

Environmental Assessment



HYDROGEOLOGICAL INVESTIGATION

PROPOSED ARMIDALE LANDFILL

Prepared for

MAUNSELL AUSTRALIA PTY LTD

On behalf of

Armidale Dumaresq Council

Prepared by

RCA AUSTRALIA

RCA ref 5929-004/2

August 2007

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RCA ref 5929-004/2
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Engineering Geology

Environmental Engineering

Hydrogeology

Construction Materials Testing

10 August 2007

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HYDROGEOLOGICAL INVESTIGATION
PROPOSED ARMIDALE LANDFILL

1 INTRODUCTION

This report describes a hydrogeological investigation carried out for Maunsell Australia Pty Ltd on behalf of Armidale-Dumaresq Council at the site of the proposed Armidale landfill.

The work was commissioned by Mr Jamon Pool of Maunsell Australia Pty Ltd in March, 2007.

The proposed landfill is situated approximately 12 km east of Armidale, off the Waterfall Way. The site location is indicated on the location plan and included on Drawing 1, Appendix A.

The proposed site features and the data provided have previously been detailed in the RCA report 5929-002/1, Geotechnical and Hydrogeological Investigation, Proposed Armidale Landfill, January, 2007 (Ref [1]).

This report contains descriptions of the surface and subsurface conditions at the site and provides discussion on:

- hydrogeological conditions across the site; and
- groundwater level and quality.

The factual data on which this report is based is presented in the attached appendices.

Data from previous reports listed above is cross-referenced where relevant.

The report has been prepared for the purpose of providing additional baseline hydrogeological data, to that provided in the January, 2007 report (Ref [1]), to allow detailed design of the proposed landfill facility to progress and to plan for subsequent ongoing groundwater monitoring of the proposed facility.

2 FIELD AND LABORATORY INVESTIGATIONS

Fieldwork was undertaken over the period 16 to 20 April, 2007 and consisted of the following:

- Drilling of seven (7) bores (two abandoned) to depths ranging from 22m (BH13) to 60m (BH9):
    - The two abandoned bores were both attempts to drill BH9, in both cases confining pressure was lost due to a subsurface void, possibly a fault in the rock structure, and the drilling could not continue at that location:
        - Location 1 reached a depth of 41m;
        - Location 2 reached a depth of 33m;
        - Groundwater was not encountered in either location;
- Groundwater monitoring wells were installed in five (5) bedrock bores (BH9 - 13).
- All newly installed groundwater monitoring wells were developed and allowed to stablise prior to sampling to ensure that all samples collected were representative of the groundwater conditions at each location.
- Permeability tests were conducted in two (2) monitoring wells (BH5 and BH11).
- Groundwater samples were collected from a total of seven (7) wells comprising the existing wells BH4 and BH5 and the newly installed wells (BH9 – 13).

All fieldwork was carried out by and in the presence of RCA personnel. Test locations are shown on the attached site plan (Drawing 1, Appendix A).

Bore locations were specified by Maunsell Australia Pty Ltd and were located in the field by hand held GPS unit. Subsequent to testing, the locations were surveyed by Hawkins Hook Surveyors.

Engineering logs of bores are presented in Appendix B, together with explanation sheets. Groundwater conditions have been noted on the bore logs at the time of fieldwork. Fluctuations in groundwater conditions may be expected due to variations in site conditions and rainfall. Groundwater levels were measured with a dip meter.

Water samples were obtained from the groundwater monitoring bores for the purpose of water quality testing. Seven (7) water samples (BH4, BH5, BH9 – 13) were collected using a specialised Bennett deep sampling pump. Samples were collected after purging indicated that water quality parameters (pH, conductivity, salinity, dissolved oxygen, turbidity and temperature) had stabilised by monitoring with a Horiba water quality meter. The values at the time of sampling have been recorded on the groundwater sampling sheets, Appendix G.

3 SITE DESCRIPTION

The regional geology, surface and subsurface conditions of the site have been discussed in detail in RCA report 5929-002/1 (Ref [1]) which should be read in conjunction with any findings or recommendations made in this report.

4 ASSESSMENT CRITERIA

4.1 LABORATORY ANALYSIS

Australian Laboratory Services (ALS) was chosen as the primary laboratory. This laboratory is NATA accredited and is experienced in the analytical requirements for testing groundwater.

ALS undertook internal quality assurance testing. Results are contained within the laboratory report sheets, Appendix D. A review of the results shows that sufficient internal QA sampling was undertaken by ALS. The results for all internal laboratory duplicates, laboratory control samples, method blanks and matrix spikes met the acceptance criteria as detailed on the ALS Quality Control Report, ES0705128, attached in Appendix C, except for the matrix spike recovery for the halogenated aliphatic compound 1, 1-dicloroethene. The recovery for the matrix spike for this compound was outside the acceptance criteria by less than 1%. Therefore any uncertainty associated with the reported results for this compound is not considered significant.

A matrix spike is an internal laboratory sample which is ‘spiked’ with a known concentration of a contaminant. The sample is then analysed and the recovery reported. The purpose of the spike is to determine whether the sample is strongly adsorbing the contaminant and preventing complete extraction which reduces the accuracy of the analysis.

4.2 Acceptance Criteria – Groundwater

4.2.1 NSW DEC Groundwater Guidelines 2007

The 2007 Groundwater Guidelines (Ref [2]) require that groundwater contaminant concentrations be compared to existing generic groundwater investigation levels (GIL's). The guidelines cite the following documents as appropriate sources of GIL's for contaminant assessment of groundwater:

- drinking water - NHNRC and NRMMC 2004 (Ref [3]); and
- Aquatic Ecosystems - ANZECC & ARMCANZ 2000a (Ref [4]).

For the protection of aquatic ecosystems, the GIL for 95% protection (ANZECC 2000a) should be used. Where the existing generic GIL is below the naturally occurring background concentration of a particular contaminant, the background concentration becomes the default.

Where the existing generic GIL for a particular contaminant is below the practical limit of reporting or below the detection limit, the quantitative limit of reporting or the detection limit should be used instead of the existing generic GIL.

Where a generic GIL does not exist for a particular contaminant or if the generic GIL's are not considered stringent enough to protect the ecology or human health, guidance from the DEC is recommended.

4.2.2 ANZECC and ARMCANZ 2000a

These water quality guidelines have been endorsed by the NSWEPA (Ref [2]). They consider not only the level of protection (eg, 99% or 95%) but also the state of the receiving water (eg, moderately disturbed). Additional allowances are also made for the bioaccumulation of some chemicals. These guidelines replace the NEPC NEPM 1999 guidelines for water (Ref [5]). As the 2007 Groundwater Guidelines (Ref [2]) require that only the 95% level of protection is to be adopted for groundwater assessment, the state of the receiving water is not required to be classified for groundwater assessments.

4.2.3 NHNRC and NRMMC 2004

These are the Australian Drinking Water Guidelines and have been endorsed by the NHNRC (Ref [2]). They provide guidance values for both the physical and chemical characteristics of drinking water. The guideline values provided are based on both human health and aesthetic considerations.

4.2.4 APPROPRIATENESS OF THE GUIDELINES

The endorsed NSW DEC groundwater guidelines require that the ANZECC and ARMCANZ 2000a water guidelines for the protection of aquatic ecosystems based on the protection of the receiving waters (for groundwater assessments 95% level of protection is adopted) and the NHNRC and NRMMC 2004 drinking water guidelines based on human health and aesthetic considerations be used for groundwater assessment. Therefore they are considered to be the most appropriate guidance available.

4.2.5 LIMITATIONS OF THE GUIDELINES

Regardless of the guidelines adopted for the site, any groundwater assessment is likely to be conservative when applying the ANZECC and ARMCANZ 2000a water guidelines for the protection of aquatic ecosystems. This is due to the distance the site is situated from the nearest significant receiving water body, the Gara River (approx 1km), natural attenuation processes and the relatively small area of the site when compared to the total river catchment. Therefore the concentrations detected in the site groundwater do not necessarily represent the final concentration of the contaminants potentially reaching the river.

4.3 QUALITY ASSURANCE/QUALITY CONTROL

No duplicate samples were undertaken as part of this assessment.

Two (2) holding time outliers occurred from two (2) analytes in all wells, nitrate as N and pH. These holding times could not be met due to the period between on site sampling and delivery to the laboratory based in Newcastle. The delay was predominantly due to the need to remain at the site to install and develop the five (5) additional monitoring wells. As a result, the sampling of the wells was staggered over several days. Subsequent sampling events which do not require wells to be installed should not be subject to similar delays. Holding times for nitrate analyses associated with these events would be expected to be met.

The analysis of pH outside of holding time is not considered to create a significant level of uncertainty, as the pH of the wells was also measured in the field with a calibrated pH meter. Given that the laboratory holding time for pH is between six and 24 hours, it is unlikely that samples could be transported to the laboratory and analysed within holding time even if forwarded immediately after sampling.

As a result of the nitrate analyses being out of holding time, the reported results are conservative and may overstate the concentrations. Nitrate is stable for at least twenty eight (28) days, under the appropriate preservation and handling. Nitrite is stable for only two (2) days under the same conditions. Nitrate concentrations are not directly measured by the laboratory. The method for nitrate analysis involves analysing for NOx (nitrate + nitrite), then subtracting the nitrite concentration from the NOx result to calculate the nitrate result. If the analyses are undertaken after more than two (2) days, nitrite can begin to convert to nitrate, increasing the nitrate result reported.

All NOx analyses were undertaken within holding times (28 days). The NOx results associated with this assessment are considered to be accurate.

5 RESULTS

Results of the groundwater analyses are attached in Appendix C. In summary:

- Three (3) results are in excess of the 95% Fresh water ANZECC guidelines (Ref [4]):
    - BH9 Nitrate
    - BH10 Nitrate
    - BH4 Iron
- Two (2) results are in excess of the Health based criteria of the NHNRC Drinking water Guidelines (Ref [3]):
    - BH4 Manganese
    - BH5 Manganese, Sulfate
- Six (6) results are in excess of the Aesthetic based criteria of the NHNRC Drinking Water Guidelines (Ref [3]):
    - BH4 Iron, Manganese
    - BH5 Sodium, Manganese, Ammonia, Sulfate, Chloride
    - BH9 Manganese, Chloride
    - BH10 Chloride.

Results from BH4 and BH5 have also been compared to the previous sampling round (October, 2006) in Appendix C. Generally the results were consistent between sampling rounds except for the following:

- Chloride in BH4 decreased by approximately 50%.
- Nitrate in BH4 increased significantly (over ten fold), whereas it decreased significantly in BH5 (to less than 10% of previous result). These results therefore affected the Nitrite + Nitrate calculation.
- Iron increased ten fold in BH4.
- Ammonia increased by 1.6 times in BH4 and over six times in BH5.

Other chemical indicators which were detected in the wells included:

- Chloroform;
- Total Organic Carbon; and
- Phenols.

6 FIELD TEST RESULTS

Tests for hydraulic conductivity (permeability) were undertaken at two (2) bore locations. Due to the conditions encountered and project constraints, only one (1) test was undertaken in each bore. The result and analysis sheets for these tests are attached in Appendix E. Hydraulic conductivity test results are summarised in Table 1.

Table 1 *Hydraulic Conductivity/Permeability Test Result Summary*

Bore Number	Test Method	Permeability (m/s)
BH11	Falling Head Piezometer Test (Hvorslev method)	3.8×10^{-6}
BH5 [1]	Rising Head Test (Hvorslev method)	4.4×10^{-8}

1 The falling head test was conducted over a relatively short period and has required extrapolation to interpret the permeability.

The results indicate that the permeability of the sandstone bedrock tested in the vicinity of monitoring well, BH11 is in the order of 3.8×10^{-6}. The permeability of the argillite bedrock in the vicinity of well BH5 was in the order of 4.4×10^{-8} m/s. The permeability of the argillite bedrock tested in the vicinity of BH4 during the previous investigation (Ref [1]) was 4.8×10^{-9} m/s. This result is at odds with field observations made during the latest assessment.

Attempts were made to undertake a rising head test in the well BH11. However, due to the relatively high permeability of the strata encountered, the standing water level in the bore could not be lowered sufficiently to ensure an accurate test result. Therefore a falling head test was undertaken. The water used was pumped from the well following the completion of sampling. The standing water level was then allowed to stabilise before the re-introduction of the water for the permeability test. The aquifer in the well BH11was encountered and screened in sandstone. The permeability recorded is considered to be consistent with that expected in a highly fractured, sandstone strata.

The BH5 test was conducted over a relatively short period of time in comparison to the total recovery and did not achieve the recommended level of groundwater recovery. However, given the slow recovery time of the bore, it is not considered that shortfall in data collection would be likely to significantly alter the permeability test result calculated for this monitoring well. A review of the data collected indicated that the well recovery rate appeared to have largely stabilised at the time the test was ended. Therefore, extrapolation of the data is not considered to create significant uncertainty in the reported result. The limited period of the test was necessitated by equipment failure in the field, associated with faulty seals on the data logger employed. The aquifer in the well BH5 was encountered and screened in argillite bedrock. The permeability recorded is considered to be consistent with that expected in a slightly fractured, argillite strata.

Given the limitations associated with the permeability data collected to date, it is recommended that the above permeability results be used as indicative values only. If more accurate data is required for detailed design purposes, a more rigorous testing schedule for permeability should be adopted.

7 INTERPRETATION AND DISCUSSION

7.1 HYDROGEOLOGICAL CONDITIONS

7.1.1 SITE GEOLOGY

The geology of the site can be summarised from the Dorrigo – Coffs Harbour 1:250000 Geological Series Sheet SH 56-10 and 11 as follows:

- The site is in an geological zone predominantly classified as:

- Pl - Greywacke, slate, siliceous argillite, pebbly mudstone.

- Within this main classification is a small zone at the northern end of the site classified as;

  - Ts - Conglomerate, greybilly, sandstone and claystone.

The main geological feature associated with the site is the Mihi Fault which begins approximately 10km north-east of the site and extends diagonally past the eastern side of the site. The fault passes close to the south of the site, possibly crossing the site at the southern or upper extremity, in the vicinity of BH9.

7.1.2 SITE TOPOGRAPHY

The site topography can be divided into two (2) distinct sections. The southern or upper section which is steep and heavily vegetated, and the northern or lower section which is more gently sloping and consists of open paddock. The division between the sections is generally defined by the fence line in the vicinity of the location of BH12, running east-west approximately through the centre of the site. The lower or northern portion of the site is further defined by a ridge running east-west at the northern extremity.

An intermittent waterway (dry creek) flows from west to east through the site toward the Gara River, concentrating runoff from the site and the sites immediately to the north and west. The creek is located north of the position of BH5 at the toe of the ridge. No flow was noted in the creek and it was not sampled as part of this assessment.

The nearest permanent watercourse is the Gara River, which is a fresh water environment. The Gara River is located within the Macleay River Catchment Area. The Department of Natural Resources rates water source and cumulative stress as *high* within the river, with summer extraction demand regularly exceeding available flows in November (Ref [6]), indicating that minimal recharge from groundwater inflows is likely to be occurring.

7.1.3 GROUNDWATER SURVEY

Groundwater monitoring wells were installed into the bedrock aquifer in five (5) additional bores (BH9 - BH13) during this investigation. A summary of the details of the additional monitoring wells is presented in Table 2.

Table 2 *Piezometer Summary*

Bore No.	E	N	RL (m, AHD)	Screen Depth (m)
9	383128.77	6618697.86	1014.03	53.5-59.5
10	383470.84	6618809.06	993.78	41.0-47.0
11	383204.64	6619230.01	977.58	30.0-36.0
12	383558.08	6619122.94	969.79	34.0-40.0
13	383488.09	6619373.36	961.70	16.0-22.0

Details of the two (2) existing wells BH4 and BH5, monitored as part of this assessment are presented in the January, 2007 report (Ref [1]).

Standing groundwater was encountered in all bores and the results are presented in Table 3.

Table 3 *Gauged Groundwater Depths*

Bore No.	RL (m AHD)	Stickup (m)	GW Depth from top of pipe (m)	Screen Depth (m) Below ground level	GW RL (m, AHD)
4	954.11	0.74	6.35	6.0-18.0	947.76
5	953.13	0.75	5.27	3.6-9.5	947.86
9	1014.03	0.95	46.7	53.5-59.5	967.33
10	993.78	0.67	37.0	41.0-47.0	956.78
11	977.58	0.72	28.0	30.0-36.0	949.58
12	969.79	0.62	21.3	34.0-40.0	948.49
13	961.70	0.60	13.3	16.0-22.0	948.40

Survey data from Hawkins Hook & Co site survey report May 2007 (Appendix F).

RL = reduced level

AHD = Australian Height Datum

Gauging of the standing groundwater levels allowed the groundwater flow direction to be interpolated, based on contours of hydraulic equipotential. Based on this data, the groundwater flow in the upper or southern section of the site is generally assumed to be toward the north-north east, whereas in the lower or northern section of the site flow is assumed to be more directly north-east.

Groundwater is assessed as likely to be leaving the site in a predominantly north easterly flow direction, towards the Gara River, close to the location of BH4. The direction of the groundwater flow on the site is represented on Drawing 1, Appendix A.

7.1.4 HYDRAULIC GRADIENTS

The gauging of the groundwater levels allowed the gradient of the groundwater in each section of the site. Table 4 presents the groundwater hydraulic gradient results.

Table 4 *Groundwater Hydraulic Gradient Results*

Site Section	GW RL (High)	GW RL (Low)	Distance	Gradient (m/m)
Upper	967.33 (BH9)	948.49 (BH12)	600m	3.14×10^{-2}
Lower	948.49 (BH12)	947.76 (BH4)	485m	1.51×10^{-3}

7.1.5 AQUIFER CHARACTERISATION

A trilinear plot of water chemistry of the samples is presented in Drawing 2, Appendix A to aid the assessment of groundwater geochemistry. Based on the results of the plot, a summary of the groundwater geochemistry on the site is presented in Table 5.

Table 5 *Groundwater Geochemistry*

Bore No.	Water Type	Classification
4	Bicarbonate	Ca + Mg, Na + K HCO_3, Cl + SO_4
5	Sulfate	Ca + Mg, Na + K Cl + SO_4, HCO_3
9	Chloride	Ca + Mg, Na + K Cl + SO_4, HCO_3
10	Calcium/Chloride	Ca + Mg, Na + K Cl + SO_4, HCO_3
11	Bicarbonate	Ca + Mg, Na + K Cl + SO_4, HCO_3
12	Bicarbonate	Ca + Mg, Na + K HCO_3, Cl + SO_4
13	Bicarbonate	Ca + Mg, Na + K HCO_3, Cl + SO_4

The above results indicate that the aquifer in the southern or upper section of the site, which is contained within the ridgeline, is predominantly a chloride water type.

In the lower or northern section of the site, the flatter topography means that the water is more likely to be influenced by influx of other water types from up gradient or south-west of the site. All groundwater sampled in this section of the site was predominantly a bicarbonate water type, except for the water in well BH5.

The water sampled in well BH5 only was a sulphate water type. BH5 is the well closest to the toe of the ridge at the northern extremity of the site. Based on field observations, this well had a significantly lower recovery rate than the other wells on the site following purging. The groundwater purged was also visually more turbid.

A review of the borelogs shows that well BH5 is screened in the argillite bedrock whereas well BH11, higher up the site to the south-west, is screened in sandstone. However, other wells screening the argillite had significantly higher recovery rates than BH5. A possible reason for the lower recovery observed in BH5 is the layer of mudstone, which was identified in BH5 immediately above the level of the argillite, but was not identified in the other bores.

The topography encountered suggests that groundwater is likely to flow predominantly from the north west toward this point on the site, given the close proximity of the ridge. This flow is in the opposite direction to the general groundwater flow direction for the majority of the subject site.

As a result, it is considered likely that the water sampled from BH5 is representative of, or is being impacted upon, by a separate aquifer to that of the majority of the site, flowing from the north back toward the low point of the site in the vicinity of BH4. Based on the limited number of wells in this section of the site, groundwater flow direction could not be accurately interpolated. However, the estimation of groundwater flow direction, based on the available data and the observed topography, is considered to give a valid representation of the flow direction in the northern section of the site.

7.1.6 AQUIFER GEOCHEMISTRY

Flowpaths through the argillite bedrock are expected to be restricted to some fractures and bedding-plane separations. Unweathered rock can contain readily soluble minerals if they are part of the rock composition. The water flowing through the rock has a longer residence time because of lower permeabilities and the slower flow rate allows longer contact with soluble minerals. The permeability is shown to be several orders of magnitude less than that for the sandstone and the residence time is likely to be in the order of years. Groundwater in passing through the sedimentary argillite bedrock would therefore be expected to have higher dissolved solids than water discharging from the sandstone or highly weathered argillite layers.

In addition to the analyses of the ion concentrations used to characterise the groundwater types encountered on the site, several other chemical groundwater quality parameters were assessed in accordance with the list provided in the required scope of works.

A brief discussion of each of these parameters and their potential effects on the groundwater quality on the site follows:

7.1.6.1 AMMONIA

Ammonia is a basic industrial chemical, a soil nutrient and a common product of human and animal wastes. Other natural sources of ammonia are lightning, volcanic activity and decomposition of plant material. Ammonia is very soluble in water, the solubility being around 100 000mgL (Ref [4]). Although the ammonia concentration in BH5 was slightly greater (<109%) than the NHNRC and NRMMC 2004 drinking water guidelines, the overall concentration of ammonia across the aquifers encountered could be considered as low, given the high potential for solubility.

7.1.6.2 CHLORIDE AND SULPHATE

Chloride is a monovalent anion and one of the major ions used to characterise groundwater quality. Sulphate is a divalent anion which is also used to characterise groundwater quality. The relatively high concentration of both ions detected in groundwater on the site is considered likely to be as a result of the long residence time of the groundwater within the predominantly argillite bedrock and the solubility of the chemical constituents of the rock.

7.1.6.3 CHLOROFORM

Chloroform is a chlorinated alkane. Chlorinated alkanes such as chloroform are formed as a by-product of the chlorination of water and waste water. Chloroform has limited use as a fumigant for foods and seeds. Chloroform has a negligible rate of hydrolysis, slow biodegradation and negligible photodegradation. The main route of loss of chlorinated alkanes from water is by evaporation (Ref [4]). Chloroform was detected in very low concentrations in two (2) wells, BH9 and BH11. The wells are on opposite sides of the site and do not have the same geochemical characterisation. Therefore, an apparent source of the chloroform detected was not noted. Given the large volumes purged prior to sampling of the wells, it is not considered likely that the chloroform detected is from a source introduced by the sampling methods. Despite a potential source of the chloroform being unknown, the chloroform detected is not currently considered to be significant given the low concentrations.

7.1.6.4 Phenols

Phenols are a common by-product of refining or treatment of fossil fuels. They are commonly used as a raw material in the manufacture of organic products including phenolic resins, salicyclic acid, pentachlorophenol, bisphenol-A (for polycarbonates and epoxy resins), aniline, alkyl phenols and cyclohexanol (for nylon and other fibres). They are also used as a household and industrial disinfectant (Ref [4]). Phenols have been detected in BH5 in both monitoring events undertaken to date. The concentrations detected in BH5 do not exceed the site guidelines and are falling. No likely source of phenols was observed in the vicinity of BH5. Contamination of the well due to drilling is not considered to be a likely source as the phenols were detected over several months and the bore has been subjected to repeated rigorous development.

7.1.6.5 Total Organic Carbon

Unless water is re-aerated efficiently such as by turbulent flow, it rapidly becomes depleted in oxygen and will not therefore support higher life forms. In addition to the micro-organism-mediated oxidation of organic matter, oxygen in water may also be consumed by the bio-oxidation of nitrogenous material and by the chemical or biological oxidation of chemical reducing agents. The degree of oxygen consumption by micro-organism-mediated oxidation of organic carbon in water is called the biochemical oxygen demand (BOD). An alternative method of measuring water quality with regards to oxygen concentrations is the total organic carbon (TOC) method. The TOC of a given water is generally measured by oxidising the carbon present in the water and detecting the CO_2 produced (Ref [7]). The available carbon reacts with oxygen molecules producing CO_2 as a product. Therefore the amount of CO_2 produced is a direct measure of the organic available for oxidation. TOC concentrations in water can be affected by the type of vegetation supported, the climate and by domestic waste water releases. The TOC concentrations detected in all wells is considered relatively low except for BH5. The TOC concentration in BH5 has risen markedly (740%) since measured in October, 2006. No apparent reason for this rise was observed.

7.1.7 Impact of Surrounding Site Uses

It is considered that potential exists for activities on the surrounding sites to impact on the groundwater quality of the existing site. Further desktop and field investigations into the background groundwater conditions of the adjacent sites would be required to accurately assess the extent of any impact. Detailed desktop and field investigation of the background groundwater conditions surrounding the subject have not been included in this report as they are outside the proposed scope of the assessment.

7.1.8 POTENTIAL GEOTECHNICAL CONSTRAINTS

RCA report 5929-002/1; Geotechnical and Hydrogeological Investigation, Proposed Armidale Landfill, January, 2007 (Ref [1]) reported that one potential geotechnical constraint at the site related to the possible presence of a fault on the site with associated deeper weathered profile and fracturing. The drilling conditions encountered are considered likely to be due to either a subsurface void or a fault in the rock structure. The fault encountered could be part of the Mihi Fault which passes close to the southern extremity of the site. Two (2) bores were abandoned in the vicinity of BH9 due to loss of confining pressure as discussed in Section 2. The effect to groundwater of the presence of the fault/subsurface void cannot be established based on the amount of investigation undertaken to date. If further assessment of the fault/subsurface void is required, it is recommended that additional geotechnical and hydrogeological investigation be undertaken in the vicinity of the feature.

8 RECOMMENDATIONS

8.1 GROUNDWATER MONITORING PROGRAMME

Recommendations with regard to the groundwater monitoring programme were made in detail in the RCA report 5929-002/1 (Ref [1]). In summary, the report recommends that groundwater monitoring/sampling be undertaken quarterly once the landfill is operational and, where possible, this sampling should be undertaken following significant rainfall events.

It is recommended that all wells be assessed again prior to the proposed operations commencing, as the current data is not sufficient for accurate trend analyses to be undertaken. It is considered to be particularly important to include BH5 in any such monitoring events, as the aquifer in this well is exhibiting indicators of detrimental impacts from external sources.

Further desktop and field investigations of conditions on adjacent properties to the site is also recommended prior to commencing the proposed site operations as it is considered vital to establishing a defined baseline data set for the area.

It is recommended that during subsequent monitoring rounds, additional repeated permeability testing be undertaken in wells BH5 and BH11 to verify the preliminary results.

This report provides data which is supplementary to, and should be read in conjunction with, the RCA report Geotechnical and Hydrogeological Investigation, Proposed Armidale Landfill, January, 2007 (Ref [1]).

9 LIMITATIONS

This report has been prepared for Maunsell Australia Pty Ltd on behalf of Armidale-Dumaresq Council in accordance with the agreement with RCA Australia (RCA). The services performed by RCA have been conducted in a manner consistent with that generally exercised by members of its profession and consulting practice.

This report has been prepared for the sole use of Maunsell Australia Pty Ltd on behalf of Armidale-Dumaresq Council for the specific purpose and the specific proposed development described in the report. The report may not contain sufficient information for purposes or developments other than that described in the report or for parties other than Maunsell Australia Pty Ltd and Armidale-Dumaresq Council. This report shall only be presented in full and may not be used to support objectives other than those stated in the report without permission.

The information in this report is considered accurate at the date of issue with regard to the current conditions of the site. The conclusions drawn in the report are based on interpolation between boreholes or test pits. Conditions can vary between test locations that cannot be explicitly defined or inferred by investigation.

Yours faithfully
RCA AUSTRALIA

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REFERENCES

[1] RCA Australia, Report 5929-002/1 - *Geotechnical and Hydrogeological Investigation, Proposed Armidale Landfill*, January 2007.

[2] NSW DEC, Contaminated Sites - *Guidelines for the Assessment and Management of Groundwater Contamination*, March 2007.

[3] Australian Government - National Health and Medical Research Council/National Resource Management Ministerial Council: National Water Quality Management Strategy – *Australian Drinking Water Guidelines* 6, 2004.

[4] ANZECC, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, October 2000.

[5] NEPC, *National Environment Protection (Assessment of Site Contamination) Measure*, 1999.

[6] Department of Natural Resources, Macro Water Planning Process - *Macleay River Catchment Area – Unregulated Water Sources*, March 2006.

[7] Freeze, RA, Cherry, JA, *Groundwater*, Prentice Hall Publishing, 1979.