MORE SPECIALISTS,
PARTNERING MORE POWERFULLY
THINKING MORE INNOVATIVELY,
DESIGNING MORE INTELLIGENTLY,
DELIVERING MORE RELIABLY.

ARMIDALE REGIONAL LANDFILL

Environmental Assessment - Volume 4 Technical Appendices I - R

Prepared for
Armidale Dumaresq Council
135 Rusden Street, Armidale NSW 2350

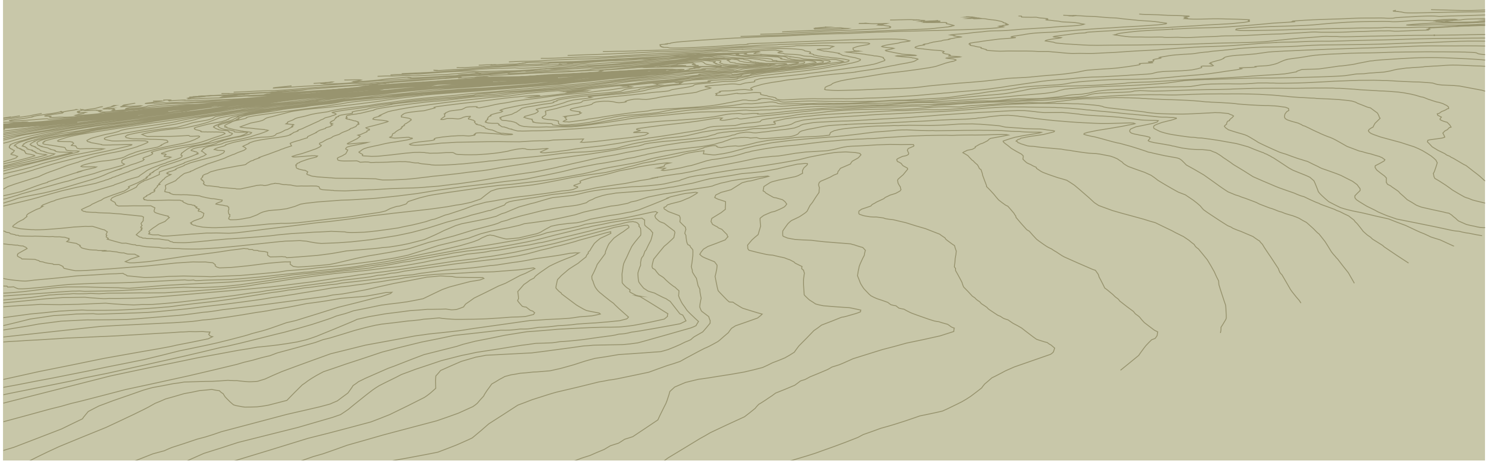
April 2010

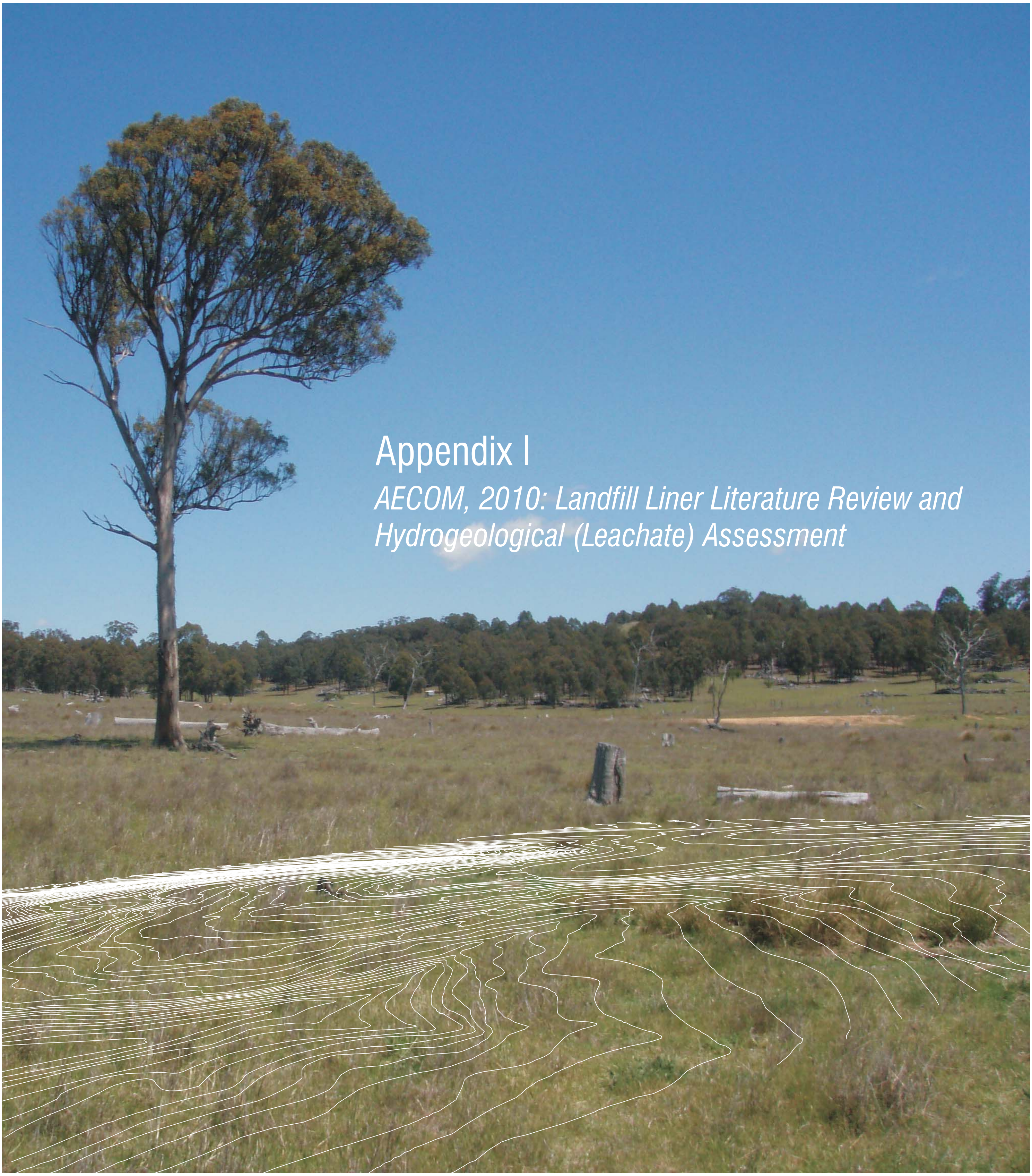
AECOM

MORE SPECIALISTS,
PARTNERING MORE POWERFULLY
THINKING MORE INNOVATIVELY,
DESIGNING MORE INTELLIGENTLY,
DELIVERING MORE RELIABLY.

ARMIDALE REGIONAL LANDFILL

Environmental Assessment



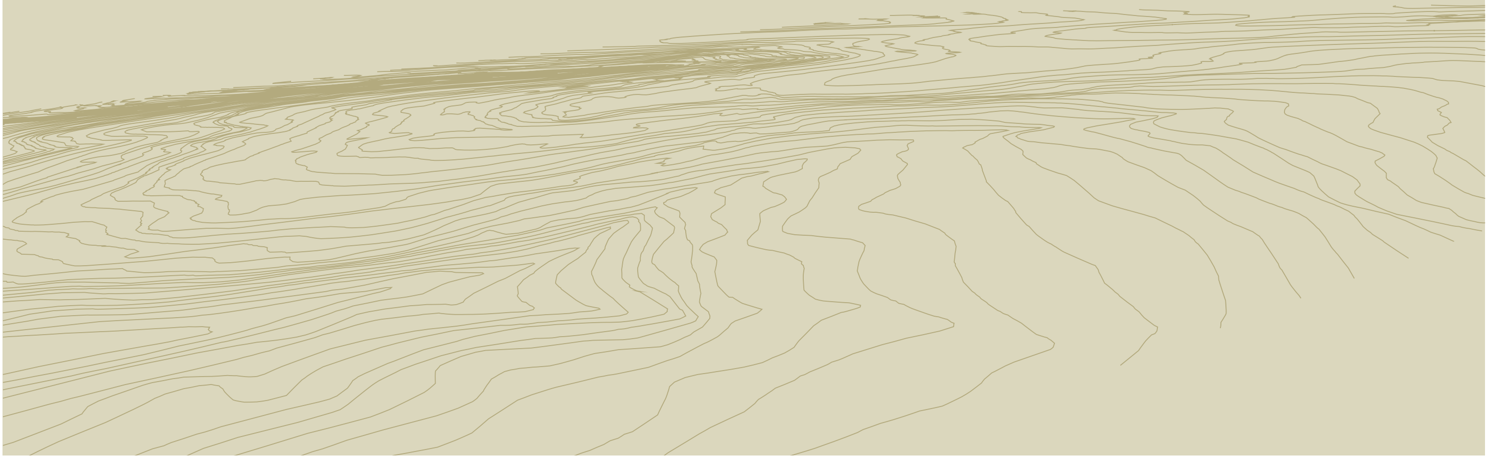


Appendix I

AECOM, 2010: Landfill Liner Literature Review and Hydrogeological (Leachate) Assessment

ARMIDALE REGIONAL LANDFILL

Environmental Assessment



Armidale Regional Landfill
Armidale Dumaresq Council
19 February 2010

Literature Review

Landfill Liners

Literature Review

Landfill Liners

Prepared for

Armidale Dumaresq Council

Prepared by

AECOM Australia Pty Ltd
Level 5, 828 Pacific Highway, Gordon NSW 2072
T +61 2 8484 8999 F +61 2 8484 8989 www.aecom.com
ABN 20 093 846 925

19 February 2010

60011672

Green Initiative

Printed on environmentally responsible paper. Made from 100% recycled post consumer waste.

Quality Information

Document	Literature Review
Ref	60011672 N:\20017605.00 ARMLANDFIL\Eng-Plan\Environment\EA Document\Post Adequacy Review EA 2009\revised reports\Appendix H Literature Review and Leachate Report\Literature Review Rev2
Date	19 February 2010
Prepared by	R. McKenzie Author Signature
Reviewed by	J. Pool Technical Peer Reviewer Signature Phillips (for JP)

Revision History

Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
1	13-01-10	Draft for Review	J.Pool	
2	19-02-10	Final	J. Pool Project Manager	Phillips (for JP)

Contents

1.0 Composite Landfill Liner Performance

Waste containment systems for landfills consist of liner systems below and around the sides of landfilled waste and final cover (capping) systems constructed over landfilled waste. In order to provide greater certainty in the containment of leachate within a landfill cell, a combination of liners and drainage layers performing complementary functions is usually employed. The purpose of constructing liner system is to eliminate or minimize, to the extent achievable, the migration of waste constituents out of a landfill. The goal of a final cover system is to cap and contain the wastes, minimize to the extent achievable the infiltration of water into the landfill and to control the emission of landfill gas.

The leachate barrier system to be installed at the proposed landfill will conform to the Benchmark Technique Number 1 of the *Environmental Guidelines: Solid Waste Landfills* (EPA, 1996). It is currently envisaged that this would consist of a 900 mm thick layer of recompacted clay with a permeability of less than 10^{-9} metres per second (m/s), as a minimum requirement. The leachate barrier system constructed for the landfill may also exceed these minimum permeability criteria, in order to create further surety of the ongoing integrity of the barrier.

If there is insufficient volume of appropriate clay material available from site excavation works to construct the required recompacted clay liner (to be determined during the detailed design phase), then an alternative composite clay / synthetic barrier system would need to be installed such as a landfill liner compromising a clay layer in combination with an artificial liner such as a Geosynthetic Clay Liner (GCL) or a High Density Polyethylene (HDPE) layer or an approved equivalent, would be used. Any such composite barrier system would also be subject to approval by DECCW and would need to meet or exceed the minimum Benchmark Technique requirements.

If required, it is anticipated that any such composite barrier design would consist of the following:

- A clay bedding layer with minimum thickness of 300 mm and permeability of less than 10^{-9}m/s;
- A 1.5 mm thick HDPE with a permeability of less than 10^{-11}m/s would overlay the clay bedding layer.

In conjunction with the barrier system the leachate level within the landfill is designed to be maintained not to exceed 300 mm above the base of the liner by a leachate collection system. The leachate barrier system would contain leachate over the period of time that the waste poses a potential environmental risk, that is, the time until Final Storage Quality is achieved. When final storage quality has been achieved, the waste is deemed to be acceptable in the surrounding environment, allowing the site to be safely closed (Hjelmar and Hansen, 2005). Therefore, 'leakage' at this time from landfill is considered to have negligible impact on the surrounding environment.

It is necessary to consider the potential, albeit limited, for defects to occur during the construction of a composite liner. It must be taken into account that components of the system may fail, with the leachate collection and conveyance system (LCCS) and geomembrane liner being the most vulnerable because they are subjected to severe chemical and biological conditions. Each component of the barrier system is not expected to function completely for the entire lifespan (which, for a large landfill, may be hundreds of years; Rowe et al., 2004). However, the system as a whole will provide the long-term environmental protection that is required.

A study of available literature on the efficiency of different landfill linings was undertaken to review typical liner life and performance and to establish the foreseeable life and performance for the proposed Armidale Regional Landfill, for which the findings are summarised in the sections below.

2.0 Leachate Generation and Quality Over Time

The proposed Armidale Regional Landfill would be used for disposal of General Solid Waste (Putrescible), which is typically classified as municipal solid waste (MSW). Published leachate chemistry data show that leachate from MSW landfills is a mineralized, biologically-active liquid containing trace concentrations of heavy metals and synthetic organic chemicals. During the active life of a MSW landfill which goes through various stages, waste decomposition takes place primarily in the acid stage. In this stage, the ratio of biochemical oxygen demand (BOD) to chemical oxygen demand (COD) is relatively high and pH is relatively low. As waste placement ceases, BOD to COD ratio decreases and pH increases. Trace chemicals are generally found to occur at significantly lower frequencies and concentrations in MSW leachate than in hazardous waste leachate (Bonaparte *et al,* 2002).

The concentrations of pollutants are mainly controlled by physico-chemical and biochemical processes, such as solubilisation, sorption, ion-exchange or biological degradation. Physico-chemical processes act as sinks for pollutants, resulting in a substantial decrease in pollutant mobility. The apparent effect of this phenomenon is to lower concentrations of pollutants in the leachate. Leachate quality in sanitary landfills is closely associated with biological degradation. Biological degradation will control the BOD and COD of the leachate as well as metal and sulphate concentrations. Any landfill containing biodegradable material will undergo separate degradation phases, although the necessary time might differ substantially from one case to another. As the waste passes through these phases, the leachate quality changes from a high pollution level to a rather low pollution level (Sven-Olof Ryding, 1992).

Bonaparte *et al* (2002) drew the following conclusions from various studies of landfill leachate generation rates in humid and arid regions:

- Open landfills (i.e., landfills without a final cover system) located in relatively humid regions have average leachate generation rates that are typically below 20,000 lphd.
- Average reported leachate generation rates for open landfills located in relatively humid regions can be up to 90% of precipitation that occurs at the landfill sites. This ratio is related to: (i) the type of waste and its initial moisture content; and (ii) waste placement and covering practices. The ratio is lower for MSW landfills than for hazardous waste or industrial solid waste landfills and for wastes with low hydraulic conductivity daily and intermediate covers than for uncovered wastes.
- Open landfill cells located in arid regions have average leachate generation rates that are much lower (i.e., less than 100 lphd) than cells in humid regions.
- Leachate generation rates decrease significantly after cell closure (i.e., after a final cover system is placed on the waste). From the published studies, Leachate Collection and Removal System (LCRS) flow rates decrease by approximately one to three orders of magnitude within one year after closure, and by up to two orders of magnitude after ten years of closure.

It is expected that a landfill operator can minimize leachate generation rates by using a small active disposal area and implementing effective measures to minimize infiltration of rainwater into the waste and to divert surface water away from the landfill. These measures are detailed in a Water and Leachate Management Plan which forms Appendix B of the Landfill Environmental Management Plan for the proposed Armidale Regional Landfill (refer to Appendix B of the EA) .

Based on these outcomes, we can conclude the following for the proposed Armidale Regional Landfill:

- Leachate quality and quantity would be dictated by the type of waste received, the design of the landfill and how the landfill is to be constructed and operated;
- Leachate chemistry and the naturally occurring processes within the landfill would act to degrade the pollutants over time; and
- While studies, such as the work by Hjelmar and Hansen (2005), discuss what constitutes final storage quality, there is acceptance that the naturally occurring degradation processes would eventually result in the leachate that has a low pollution level.

3.0 Performance and Degradation of Liners Using Geomembranes

A well-designed and installed intact geomembrane liner may be expected to experience some degradation or aging with time that will lead eventually to localised failure. The aging process of HDPE geomembranes is a simultaneous combination of physical aging and chemical aging. From an application perspective, chemical aging is the most important degradation mechanism and therefore requires particular attention (Rowe & Sangam, 2002). Degradation mechanisms include swelling, ultraviolet (UV) degradation, temperature, environmental stress cracking, degradation by extraction, biological degradation and oxidative degradation. These mechanisms are described as follows:

- Hsuan *et al* (1991), cited in Rowe and Sangam (2002), conducted a study of the performance of an HDPE geomembrane after 7year use for solid-waste leachate storage in a surface impoundment. The results indicated:
  - no substantial macroscopic change in the geomembrane sheets or seams after 7 year exposure;

  - no substantial changes in the internal structure of the material due to constant outdoor exposure; and
  - no affect on the engineering/hydraulic containment properties of the geomembranes.
- Eith and Koerner (1997), cited in Rowe and Sangam (2002), described a case in which an HDPE geomembrane was used as part of a double liner system for a landfill. During the eight years of service, the geomembrane had been exposed to various concentrations of leachate constituents. The physical, mechanical and endurance test results indicated no apparent degradation of the HDPE geomembrane properties since they were still within the range of data generated for the original material at the time of installation.
- Environmental stress cracking - An important consideration regarding the use of HDPE geomembranes is their susceptibility to stress cracking which, in turn, is a consequence of their highly crystalline structure (typically about 40–50%). Several investigators have reported field evidence of the vulnerability of HDPE geomembranes to stress cracking. With appropriate design, testing, specification, installation, seaming, and operational procedures, the potential for stress cracking failures can be significantly reduced.
- Koch et al. (1988) cited in Rowe and Sangam (2002), applied their pipe research expertise to the geomembrane area and concluded that the interaction with leachate is a primary issue in the service life of geomembranes. Although the stress fields in a HDPE pipe are different to those in a geomembrane liner, they conclude that considering all of the other factors (leachate interaction), the service life of HDPE geomembranes could be expected to be considerably greater than 100 years.
- Sangam (2001), cited in Rowe and Sangam (2002), examined the service lives of HDPE geomembranes under various exposure condition scenarios where geomembranes were used as bottom liners for MSW landfills. It was estimated that the primary geomembrane would last at least 200 years, when the landfill is well maintained and the temperature at the membrane is not higher than 151°C. For the conditions where the temperature is at 331°C, the service life is estimated to be about 70 years. For the typical groundwater temperature range of 7–101°C, it is estimated that the geomembrane used as a secondary liner will last at least 400 years, provided that it has a suitable antioxidant component, is not subjected to significant tensile stress and is covered by an adequate protection layer.
- The key findings of the work reported by Sangam (2001) and by Hsuan and Koerner (1995, 1998), cited in Rowe and Sangam (2002), are that the service lives of HDPE geomembranes are essentially controlled by the antioxidants in the liner material and the service temperature. However, there is a debate regarding the properties to be assessed with respect to the degree of polymer breakdown and the level used as the failure threshold. In landfill base liner applications, the real service life depends on the hydraulic and diffusive properties of the geomembranes and hence a geomembrane may lose strength while still performing satisfactorily as a barrier. Therefore, the ‘‘hydraulic and diffusive service life’’ of a geomembrane may exceed the service life as determined by the degradation of physical and mechanical properties, especially if tensile stresses are minimal.
- Bonaparte et al (2002) cite Bonaparte and Gross who concluded “the double-liner systems evaluated ... performed well. Leakage rates through the primary liners have been low or negligible in most cases”.

Based on these outcomes, the following can be concluded for the proposed Armidale Regional Landfill:

- HPDE is subject to a number of degradation mechanism;
- A typical HPDE liner should have an operational life of approximately 200 years if appropriately maintained; and
- HPDE liner elements need to be maintained during both construction and filling to maximise their operational life and performance.

4.0 Potential Leakage Rate Through Composite Liners

Leakage through a liner can be estimated by assuming a given number of defects occurring during liner construction/installation. While a good Construction Quality Control/Construction Quality Assurance (CQC/CQA) will minimise the number of defects, they cannot be completely eliminated.

Available field data suggests that given typical numbers of wrinkles and holes in a GCL, based on a per hectare surface area, for landfills with good CQC/CQA and where there is no damage to the liner during landfilling activities, post-closure leakages are very small and contaminant transport is likely to be controlled by diffusion through the liner system for contaminants that can readily diffuse through a geomembrane (Rowe (2007)).

Bonaparte *et al* (2002) drew the following conclusions regarding the hydraulic performance of composite liners:

- Leak Detection Systems (LDSs) underlying a geomembrane/recompacted clay liner composite liners almost always exhibit flow due to consolidation water. Measured LDS flow rates attributable to consolidation water are in the range of 0 to 1,000 litres/hectare/day (lphd), with most values being less than 200 lphd. LDS flow rates attributable to consolidation water are a function of the characteristics of the recompacted clay liner and the rate of waste placement in the overlying cell. Typically, the rate of flow decreases with time during the later portion of the active period of operation and the post-closure period. LDS flow rates in the range of 0 to 100 lphd have been reported within one to two years of the completion of active filling of a cell.
- Flow rates from the LDSs of cells with geomembrane/GCL composite primary liners are usually very low. LDS flow rates attributable to leakage through this type of primary liner typically varied from 0 to 50 lphd, with most values being less than about 2 lphd. The true hydraulic efficiency of geomembrane/GCL composite liners may often exceed 99.9%.
- Average LDS flow rates may increase by an order of magnitude, or more, due to liner system damage induced by heavy equipment operations in the cell. Engineering and operational measures should be used to prevent this type of occurrence.

In the event that defects are present in the HDPE membrane, AECOM has calculated a migration rate of leachate through the clay barrier layer at an estimated rate of 6.7 L/ha/day at discrete locations associated with the defects within the liner (AECOM, 2010). As these locations are considered to be discrete, discharges would, in effect, be a series of small point sources rather than the landfill being one large source area.

5.0 Recommendations for Improving Liner Performance

From the literature review, it can be concluded that many issues identified in the studies could be prevented or managed using robust design approaches, construction materials and procedures, and operation practices (Sangam and Rowe, 2001).

From these studies, the following recommendations would be considered for the detailed design and construction of the proposed Armidale Regional Landfill

a) Needlepunched nonwoven geotextiles can provide adequate protection of geomembranes against puncture by adjacent granular soils.

b) Temperature-induced waves (wrinkles) in geomembranes do not disappear when the geomembrane is subjected to overburden stress (i.e., when the geomembrane is covered with soil), rather the wave height decreases somewhat, the width of the wave decreases even more (i.e., the height-to-width ratio (H/W) of the wave increases), and the void space beneath the wave becomes smaller. Residual stresses in HDPE geomembranes installed in the field may be on the order of about 1% to 22% of the geomembrane's short-term yield strength in the vicinity of geomembrane waves, with higher residual stresses associated with higher H/W values. Significant residual stresses can reduce the geomembrane service life. The relationship between geomembrane type, magnitude of residual stress and service life requires further investigation.

c) If geomembrane waves after backfilling are to be avoided, light-coloured (e.g., white) geomembranes can be used, geomembranes can be deployed and seamed without intentional slack, geomembranes can be covered with an overlying light coloured temporary geotextile until backfilling occurs, and backfilling can be performed only in the coolest part of the day or even at night.

d) Polypropylene (PP) geotextiles are slightly more susceptible to UV degradation than polyester (PET geotextiles, and lighter weight geotextiles degrade faster than heavier geotextiles.

e) Geotextiles that are partially degraded by UV light do not continue to degrade when covered with soil, i.e., the degradation process is not auto-catalytic. Nonetheless, good practice dictates that geotextiles be covered with overlying protective materials in a timely manner to minimize exposure. Also, geotextiles should be protected from exposure prior to installation (i.e., by keeping the geotextile rolls in the shade or in opaque bags).

f) Buried HDPE geomembranes have an estimated service life that is measured in terms of at least hundreds of years. The three stages of degradation and approximate associated times for each as obtained from the laboratory testing program are:
    - antioxidant depletion (≈ 200 years),
    - induction (≈ 20 years) (the induction time represents a time period required to initiate a measurable amount of oxidation-induced chain splitting of the polymer structure), and
    - half-life (50% degradation) of an engineering property (≈ 750 years).

6.0 Conclusions

In conclusion, a number of studies of the long-term performance of composite liner systems suggest that geosynthetic clay liners (GCLs) and geomembranes can play a fundamental, and beneficial, role in providing environmental protection. Like all engineering materials they must be used appropriately and in accordance with site specific design and in strict adherence to construction specifications including Construction Quality Assurance or Construction Quality Control (CQC/CQA) programmes, and appropriate protection of the geosynthetics after construction/installation. In particular, given the diversity of available GCLs and their different engineering characteristics, GCLs should be selected based on the required engineering properties.

The three main findings that can be applied to the proposed Armidale Regional Landfill are:

- Composite liner systems must be used appropriately and in accordance with site specific design and in strict adherence to construction specifications including Construction Quality Assurance or Construction Quality Control (CQC/CQA) programmes, and appropriate protection of the geosynthetics after construction. In particular, GCLs should be selected based on the required engineering properties.
- The available laboratory and field evidence, combined with modelling, indicates that primary LCCSs in Municipal Solid Waste (MSW) landfills have a finite service life, which could range from less than 70 years to more than a century depending on the design, waste characteristics and mode of operation.
- Examination of both laboratory and field data indicates that the projected service lives of HDPE geomembranes may range from 70 years to many centuries depending on the material and exposure conditions.

7.0 References

AECOM, 2010,Hydrogeological (Leachate) Assessment, Appendix I Armidale Regional Landfill EA

Bonaparte, R., David E. Daniel and Robert M. Koerner, December 2002, Assessment and Recommendations for Improving the Performance of Waste Containment Systems, EPA/600/R-02/099.

El-Zein, A. & R. Kerry Rowe, 2007, Simultaneous leakage and diffusion of organic pollutants through damaged geomembranes, Numerical Models in Geomechanics – NUMOG X – Pande & Pietruszczak (eds) © Taylor & Francis Group, London, ISBN 978-0-415-44027-1, PP 297 -301

Hjelmar, O. & J.B. Hansen, 2005,Sustainable Landfill: The Role of Final Storage Quality, Proceeding Sardinia 2005

Rowe, R.K., January-April 2007, Advances and remaining challenges for Geosynthetics in Geoenvironmental Engineering Applications, Soils and Rocks, São Paulo, 30(1): PP3-30.

Rowe, R.K. & Henri P. Sangam, 2002, Durability of HDPE Geomembranes, Geotextiles and Geomembranes, Review article, PP 77–95

Rowe, R.K. & Henri P. Sangam, and Craig B, 2003, Evaluation of an HDPE Geomembrane after 14 years as a leachate lagoon liner, Geotech. J. 40: PP 536–550

Rowe, R. K., 2005, Long-term performance of contaminant barrier systems, Ge´otechnique 55, No. 9, PP 631–678

Rowe, R.K., Andrew Pollard, Andrew Chong, Eric Chisholm, Rebecca Toda, & Caroline Tomson, 2007, Sustainable landfills – A Technique for extracting heat to prolong service-life of Geomembrane liners, OttawaGeo 2007, PP 1310-1315

Ryding, Sven-Olof, 1992, Environmental management Handbook; Lewis Publishers, Amsterdam : Boca Raton, Fla

Sangam, H.P., 2001, Performance of HDPE geomembrane liners in landfill applications, The University of Western Ontario, Ontario, Canada, 400p.

Sangam, H.P. & R. Kerry Rowe, 2001, Migration of dilute aqueous organic pollutants through HDPE Geomembranes, Geotextiles and Geomembranes 19: PP 329–357

"This page has been left blank intentionally"

Worldwide Locations

Australia	+61-2-8484-8999
Azerbaijan	+994 12 4975881
Belgium	+32-3-540-95-86
Bolivia	+591-3-354-8564
Brazil	+55-21-3526-8160
China	+86-20-8130-3737
England	+44 1928-726006
France	+33(0)1 48 42 59 53
Germany	+49-631-341-13-62
Ireland	+353 1631 9356
Italy	+39-02-3180 77 1
Japan	+813-3541 5926
Malaysia	+603-7725-0380
Netherlands	+31 10 2120 744
Philippines	+632 910 6226
Scotland	+44 (0) 1224-624624
Singapore	+65 6295 5752
Thailand	+662 642 6161
Turkey	+90-312-428-3667
United States	+1 978-589-3200
Venezuela	+58-212-762-63 39

Australian Locations

Adelaide
Brisbane
Canberra
Darwin
Melbourne
Newcastle
Perth
Sydney
Singleton

www.aecom.com

Armidale Regional Landfill
Armidale Dumaresq Council
12 February 2010

Hydrogeological (Leachate) Assessment

Hydrogeological (Leachate) Assessment

Prepared for

Armidale Dumaresq Council

Prepared by

AECOM Australia Pty Ltd
Level 8, 17 York Street, Sydney NSW 2000
T +61 2 8023 9333 F +61 2 8023 9399 www.aecom.com
ABN 20 093 846 925

12 February 2010

20017605

Green Initiative

Printed on environmentally responsible paper. Made from 100% recycled post consumer waste.

Quality Information

Document	Armidale Landfill Hydrogeological Impact Assessment
Ref	20017605 N:\20017605.00 ARMLANDFIL\Eng-Plan\Environment\EA Document\Post Adequacy Review EA 2009\revised reports\Appendix H Literature Review and Leachate Report\Leachate Report - Final
Date	12 February 2010
Prepared by	Jason Clay Author Signature Jason Clay
Reviewed by	Elizabeth Perry Technical Peer Reviewer Signature

Revision History

Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
0	14/01/2010	Draft	J. Clay	Jason Clay
1	31/01/2010	Revised Draft	J. Clay	Jason Clay
2	12/02/2010	Final	J. Clay	Jason Clay

"This page has been left blank intentionally"

Contents

List of Tables

Body Report

Tables Section

List of Figures

Figures Section

1.0 Introduction and Approach

In relation to the proposed Armidale Dumaresq Landfill the Department of Planning requires that:

> *"Risk of Migration of Leachate*
>
> *The quantified impact of leachate seepage on the national park should be included based on the potential risk and timeframe of seepage, and the amount and concentration of leachate that would reach the national park".*

In order to make an assessment of potential 'impact' AECOM has built a conceptual model that describes our understanding of the proposed landfill, existing site investigation data and standardised published assumptions about landfill design and leakage rates. In order to provide a quantitative assessment of the potential impact of the landfill this hydrogeological assessment requires conservative assumptions to be made based on our understanding of the design of the landfill and local geological and hydrogeological conditions. The nature of this process means that assumptions are made to be conservative i.e. to over predict impact in order to develop a worse case understanding of impact. However, this assessment assumes that the landfill may leak from day one of operation and that leaked leachate migrates in an unimpeded fashion toward the national park. In reality natural conditions are more complex than this simplified assessment allows and if the landfill is constructed as designed then there should be no demonstrable impact to the Gara River or Oxley Wild Rivers National Park.

1.1 Conceptual Model

The Armidale Dumaresq Council proposed landfill is located approximately 12 km east of Armidale in the New England region NSW. The site is located approximately 1000 m west of the Gara River, which flows into the Oxley Wild Rivers National Park.

The landfill is proposed to comprise a series of cells constructed in a staged approach, beginning with Cell 1 to the south of the site. The facility is also planned to include a sedimentation basin, leachate storage pond and a dry basin.

It is understood that the landfill cells are proposed to have the following design surface area of the cap:

- Cell 1 33 403 m^2
- Cell 2 24 237 m^2
- Cell 3 24 017 m^2
- Cell 4 25 163 m^2
- Cell 5 35 889 m^2
- Total 142 700 m^2
- Total 14.2 ha

Site investigation data relating to the physical/hydrogeological nature of the area proposed for the landfill that was used to develop the conceptual model is taken from:

> *Hydrogeological Assessment, Proposed Armidale Landfill, RCA Australia RCA ref 5929-004/2, August 2007. (RCA 2007)*

This reported the geology of the site from the Dorrigo – Coffs Harbour 1:250000 Geological Series Sheet SH 56-10 and 11 as comprising:

- Greywacke, slate, siliceous argillite, pebbly mudstone containing bands of Conglomerate, greybilly, sandstone and claystone in the northern part of the site.

Gauging of the standing groundwater levels within monitoring wells established on the site found the depth to groundwater to be highly variable ranging from 5 to almost 50 m below ground level at relative elevations above Australian Height Datum (m AHD) of 948 m to 967 m. RCA (2007) estimated groundwater flow direction to be generally toward the north-north east, towards the Gara River.

The Gara River is located within the Macleay River Catchment Area. The Department of Natural Resources rates the water source and cumulative stress as high within the river, with summer extraction demand regularly exceeding available flows in November (RCA 2007).

Geochemical testing of groundwater quality conducted by RCA (2007) found it to be '…*predominantly a chloride water type*.' Groundwater flow was presumed to have a longer residence time because of lower permeability of the rock, with slower groundwater velocity allowing longer contact with soluble minerals.

The relatively high concentration of both chloride and sulphate ions detected in groundwater on the site was considered by RCA (2007) 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.

AECOM has adopted a simplified approach, using screening level equations that cannot account for heterogeneity and made the following assumptions about the hydrogeology of the environment in the landfill area in order the estimate possible impacts from leachate on the National Park.

Table 1: Assumptions Relating to the Environment

Assumption	Units	Value	Notes
Distance from Site to Gara River.	m	1000	Approximate distance from the facility to the River.
Hydraulic Conductivity	m/s	3.8E-06	Conductivity reported during Site investigation works. Value for BH11 (RCA 2007).
Vadose Zone thickness	m	21.3	Depth to groundwater in BH 12 in RCA (2007).
Sat zone thickness	m	25	Assumed
Hydraulic Gradient to River Gara	m/m	1.51E-03	Reported hydraulic gradient 1.51×10^{-3} between BH12 and BH04 which is likely to be representative of conditions below proposed landfill.
Effective porosity - Sandstone Bedrock		0.21	Specific Yield value for Sandstone, estimation of effective porosity. Zheng and Bennett 2002. *Applied Contaminant Transport Modeling 2nd ed.*Wiley.

“This page has been left blank intentionally”

2.0 Landfill Leakage

The landfill is designed to minimise the potential for leachate leakage by utilising the multi-barrier design and a leachate collection system. The multi-barrier system comprises a layer of 2 mm HDPE liner overlying 900 mm of compacted clay liner (CCL) with a design permeability of 10^{-9} m/s. In conjunction with the barrier system the leachate level within the landfill is designed to be maintained not to exceed 300 mm above the base of the liner by a leachate collection system. Therefore, 'leakage' from the base of the landfill is considered to be negligible in practice. However, it is necessary to assess the potential impact of leakage on the basis that there is potential, albeit limited, for defects in construction of the HDPE liner. Leakages from the liner would then enter the environment, migrate downwards through the vadose zone, until the saturated zone is reached and then migrate laterally toward the Gara River. The potential impact is assessed as follows:

Leakage through the liner can be estimated using Giroud (1994)[1]

$$Q = 0.21 * iavg * a^{0.1} * h^{0.9} * k^{0.74} \quad \text{Equation 1}$$

Where:

Q = Volume of leakage though a liner (m^3/s)

iavg = Unitless factor based on h/D

a = Area of defect (m^2)

h = Hydraulic head on the liner (m)

k = Permeability of the liner (m/s)

D = Thickness of the liner (m)

Table 2: Calculations to Estimate the Landfill Leakage

Assumption	Value	Notes
Defects in the HDPE Liner.	1/4000 m^2	Typical for liner performance evaluation one defect per acre (4000 m^2) (Giroud et al., 1994)
Area of defect	1E-05 m^2	Diameter of 3.5 mm (Giroud et al., 1994)
Head on liner	0.3 m	Design maximum depth of leachate on liner.
Clay Permeability	1E-09 m/s	Design maximum permeability specification.
Clay thickness	0.9 m	Design minimum thickness of clay barrier.
iavg	5	Per Giroud (1994)
Leakage	3.09E-08 m^3/s	As per Equation 1
Leakage	6.7 L / ha / day	(unit conversion)
Leakage from landfill	95 L/day	6.7 * Landfill area (14.2 ha).

---

[1] Giroud, J.P., Badu-Tweneboah, K., and Soderman, K.L., 1994, "Evaluation of Landfill Liners", Proceedings of the FifthInternational Conference on Geotextiles, Geomembranes and Related Products, Singapore, September 1994, Vol. 3, pp.981-986.

The worse case value for leakage has been be estimated using the assumptions in Table 2 above. In order to model a worse case scenario this assessment makes no assumptions about the length of time required for defects in the liner to appear. Instead the model considers that leakage can occur once operation commences and the time taken for infiltration through the clay is driven by 300mm of leachate being present above the liner.

The time taken for leachate to traverse the clay barrier layer can be estimated using Darcy's Law:

$$v = \frac{q}{\eta} \quad \text{Equation 2}$$

Where:

v = Average linear/vertical velocity (m/s)

q = Darcy flux m/s

n = Porosity

Where:

$$q = k * \frac{dh}{dx} \quad \text{Equation 3}$$

Where:

k = Hydraulic conductivity

dh/dx = Hydraulic gradient assumed to be unitary for vertical flow.

Table 3: Estimation of Leachate Travel Time Across the Liner System

Assumption	Value	Notes
Hydraulic conductivity	1E-09 m/s	Design maximum permeability of the clay layer
Hydraulic gradient	1	Unitary value for a vertical flow path
Darcy flux	1E-09 m/s per m^2	As per equation 3
Porosity	0.6	Domenico and Schwartz (1990)[2]
Groundwater velocity	1.7E-09 m/s	As per equation 3
Time (Seconds)	5.4E08	
Time (Years)	17.12	

---

[2] Domenico, P. A. & Schwartz, F. W., (1990). Physical and Chemical Hydrogeology, John Wiley and Sons, Toronto.

3.0 Leachate Migration through the Vadose Zone

In the event that defects are present in the HDPE membrane, leachate has been assumed to migrate through the clay barrier layer at discrete locations associated with the defects at an estimated rate of 6.7 L/ha/day. As these locations are considered to be discrete, discharges will, in effect, be a series of small point sources rather than the landfill being one large source area.

Leachate will then enter the vadose zone and move down under the influence of gravity to groundwater. Typical subsurface geology found at the site comprises (RCA, 2007):

> *TOPSOIL:*
>
> *Sandy gravely silt, dry, brown to depths between 0.15 and 0.2m, overlying*
>
> *RESIDUAL CLAY:*
>
> *Sandy silty clay/Sandy gravelly clay, variable colour including orange, yellow and grey, dry, typically stiff or better, overlying*
>
> *ROCK:*
>
> *Rock observed at the site includes greywacke, argillite and mudstone. Depth to rock is typically in the range 0.75-1.5 m, with the depth to groundwater of 21.3 m.*

This type of strata is more complex than can be described by simple Darcy's Law equations and the use of Darcy's Flux is likely to considerably under estimate the length of time required for leachate to traverse the unsaturated zone. However, an estimation likely to represent a worse case scenario for vadose zone travel time has been made and this is described in Table 4 below. This calculation also does not account for interaction between the leachate and soil, which would tend to attenuate (reduce) contaminant concentrations.

Table 4: Estimation of Leachate Travel Time through the Vadose Zone

Assumption	Value	Notes
Hydraulic conductivity	3.8E-06 m/s	Saturated value for horizontal flow (RCA ,2007)), assumed conservatively to apply vertically for vadose zone
Hydraulic gradient	1	Unitary value for a vertical flow path
Darcy flux	3.8E-06 m/s	As per equation 3
Porosity	0.21	Domenico and Schwartz (1990)
Groundwater velocity	1.8E-05 m/s	As per equation 2
Flow path	21.3 m	
Time (Seconds)	1.2E06	
Time (Days)	13.62	

“This page has been left blank intentionally”

4.0 Mixing in the Saturated Zone

Once leachate has traversed across the vadose zone it will cross the capillary zone and eventually enter the saturated zone. There will then be a degree of mixing and dilution with within the saturated zone. It is possible to estimate the mixing depth of leachate in the saturated zone (Equation 4)[3] and the resultant potential dilution factor (Equation 5)[3].

$$d = (0.0112L^2)^{0.5} + d_a\{1 - \exp[(-LI)/Kid_a)]\}$$ Equation 4

$$dilutionfactor = 1 + \frac{Kid}{IL}$$ Equation 5

Where

d = Mixing zone depth (m)

d_a = Aquifer thickness (m)

L = Source length parallel to groundwater flow (m)

I = Infiltration rate (m/yr)

K = Aquifer hydraulic conductivity (m/yr)

i = Hydraulic gradient (unitless)

Table 5: Estimation of Aquifer Mixing Zone Depth and Dilution Factor

Assumption	Value	Notes
Aquifer thickness	25 m	Assumed value.
Source length parallel to groundwater flow	10 m	Assumed value as a result of discrete point source discharges
Infiltration rate	2.4E-04 m/yr	6.7 L/ha/day *365 days/yr / 1000 L/m^3 /10000 m^2/ha
Hydraulic conductivity	1.2E02 m/yr	3.8E-06 m/s Conductivity reported during Site investigation works. Value for BH11, RCA (2007).
Hydraulic gradient	1.51E-03	Hydraulic gradient reported between BH12 and BH04.
Mixing zone depth	1.07 m	As per equation 4
Dilution factor	78.6	As per equation 5

4.1 Migration through the Saturated Zone

Once leachate has been mixed into the saturated zone it will migrate with the groundwater flow down gradient and attenuate and disperse as it does so. There are no site-specific data for leachate constituent concentrations as the landfill is a proposed facility, therefore, representative concentrations were selected from leachate concentration data from the Long Swamp Landfill. This landfill is understood to be representative of the proposed Armidale landfill. These were used to estimate saturated zone solute concentrations that could be used as inputs to a groundwater model to calculate lateral groundwater solute transport over a distance of 1 000 m, approximately the distance from the site to the Gara River.

---

[3] US EPA 1996 *Soil Screening Guidance: Users Guide 2nd ed,* reference 9355.4-23

"This page has been left blank intentionally"

5.0 Methodology

A three dimensional analytical solute transport model (Domenico, P. 1987)[4] was then used to simulate transport with groundwater of representative source zone solute concentrations.

Bioscreen Version 1.4 is a software package produced by the USEPA that implements the Domenico analytical model to simulate advective transport and three-dimensional dispersion of source zone solute concentrations in groundwater (USEPA 1996 *BIOSCREEN Natural Attenuation Decision Support System User's Manual Version 1.3*, reference EPA/600/R-96/087).

Solute degradation and adsorption (retardation) in the natural environment were not included in the simulations. AECOM's adopted approach is considered appropriate for landfill leachate species that are unlikely to significantly degrade in the environment such as ammonia and chloride and is conservative for other species.

Solute transport was simulated over a 1000 metre distance for time periods ranging from 100 years to 10,000 years.

Table 6: Dilution Factor Mixing Zone Leachate Migration Model

Parameter	Symbol	Units	Value	Notes
Dilution Factor	DAF	-	78.6	Calculated in Table 4 above using equations 4 and 5

---

[4] Domenico, P. 1987 *An analytical model for multidimensional transport of a decaying contaminant species, Journal of Hydrology 91, pp 49*-58

“This page has been left blank intentionally”

6.0 Bioscreen Input Parameters

Input parameters used in the model are summarised in the table below, hydrogeological parameters were taken from RCA (2007) where applicable.

Table 7: Bioscreen Input Parameters

Parameter	Symbol	Units	Value	Notes
Hydraulic Conductivity	K	cm/sec	3.8E-04	See Table 1
Hydraulic Gradient	i	-	1.51E-03	See Table 1
Porosity	n	-	0.21	See Table 1
Longitudinal Dispersivity	alpha x	ft	37.4	Calculated by Bioscreen.
Transverse Dispersivity	alpha y	ft	3.7	Calculated in Bioscreen (10% of alpha x)
Vertical Dispersivity	alpha z	ft	0.0	Conservative assumption
Retardation Factor	R	-	1.0	Assumes no retardation.
Modelled Area Length	-	ft	3000	Distance from source to receptor
Modelled Area Width	-	ft	1000	
Source Zone Width	-	ft	32	10 m See table 5
Source Thickness in Saturated Zone	-	ft	3.6	Mixing zone thickness of 1.09 metres (approx 3.57 feet) calculated for mixing zone model of leachate migration to groundwater.
Soluble Mass	-	kg	Infinite	
Time Period 1	-	yrs	100	
Time Period 2	-	yrs	500	
Time Period 3	-	yrs	1000	
Time Period 4	-	yrs	10,000	
Note: values given in imperial measures as a US EPA model was used that has these as inputs.				

"This page has been left blank intentionally"

7.0 Results

The results of the assessment of leachate migration through the saturated zone are shown in Table 8 and Figures 1 to 4 below.

Leachate migration was modelled as a two-part process, comprising dilution of leachate as it moves vertically downwards to groundwater, followed by lateral transport of diluted leachate dissolved in groundwater. Modelling was based on representative leachate concentrations sourced from the Long Swamp Landfill.

Initial vertical leachate migration and concentration dilution model results are presented in column four of Table 8.

Subsequent lateral transport of dissolved leachate in groundwater model results are presented in columns five to eight of Table 8.

Conservatively assuming that no degradation and no retardation of solutes occurs, Figures 1 through 4 indicate that the first arrival of solutes at a distance of 300 metres (conservatively assumed to be the site boundary) is approximately 300 years and at 1,000 metres (i.e. the Gara River) would be between 700 and 800 years after generation of dissolved source zone concentrations.

This worse case assessment estimates that concentrations of solutes derived from leachate considered typical for the local area are predicted to be approximately 0.1% of the assumed original leachate concentration at the Gara River after a period of 10,000 years. The concentration of ammoniacal nitrogen was estimated to reduce from 132 mg/L to 0.13 mg/L and arsenic from 0.048 mg/L to 0.000051 mg/L after 10 000 years of continuous leakage. Furthermore, this model does not account for degradation or retardation of solutes and in reality these factors are likely to reduce the concentrations of solutes at the Gara River still further.

"This page has been left blank intentionally"

8.0 Conclusions

An assessment has been made of the potential impact of the proposed Armidale landfill on the groundwater at the national park by undertaking simplistic quantified hydrogeological modelling. Estimates have been made of possible leakage from the landfill and the timescales over which leakage and subsequent transport of leachate in groundwater to the Gara River may take place. These estimates are largely based on assumed and uniform conditions and are considered likely to represent conservative estimates.

Potential leakage from the landfill was estimated as approximately 100 L/day.

The time taken for leachate to escape from potential defects in the liner and traverse the clay layer was calculated as approximately 17 years.

Travel time from there to the saturated zone was calculated as 13 days. Upon mixing with the underlying groundwater, leachate is calculated to be significantly diluted (80 times) over a depth of approximately 1 m in the groundwater.

Leachate contaminants would then take approximately 1000 years to reach the Gara River. After 10 000 years of consistent operation in this fashion leachate-related parameters are calculated to reach a concentration at the Gara River of approximately 0.1% of its input concentration.

Leachate concentration data from the Long Swamp Landfill were used as input concentrations to assess attenuation down gradient. The estimated down gradient concentrations were then compared to ANZECC (2000) 95% Trigger values for freshwater at 95% level of protection of species, it can be seen that results compare favourably with the exception of chloride, which is already acknowledged by RCA (2007) to be an issue in groundwater locally.

Therefore, in summary, this assessment of the hydrogeological impact of the Arimdale landfill on the national park indicates that impact will be negligible to indistinguishable from the existing groundwater quality.

Notwithstanding the simplifying assumptions made in the assessment, a groundwater model is a simplified approximation of a heterogeneous and highly complex physical system. As such, whilst models may be used to assess and predict aquifer behaviour and responses to a range of stresses, a degree of uncertainty is inherent in all models.

The report has been prepared by AECOM, and has been requested by our Client, Armidale Dumaresq Council. It is not to provide seepage migration time frames but to quantify impact of leachate seepage using a risk assessment model.

"This page has been left blank intentionally"

Tables

"This page has been left blank intentionally"

Table T1: Dilution Factor Mixing Zone Calculation and Solute Transport Simulation Results

Compound	**Units**	**Initial Concentration (mg/L) - Long Swamp Road Landfill Data December 2009 (Cody Hart Environmental, Ref: 09.243.5)**	**Leachate Dilution to Groundwater (DAF=78.6)**	**100 year Model 1 km (3000 feet). Final Concentration C_{final} / $C_{initial}$= 0%**	**500 year Model 1 km (3000 feet). Final Concentration C_{final} / $C_{initial}$= 0%**	**1000 year Model 1 km (3000 feet). Final Concentration C_{final} / $C_{initial}$ = 3%**	**10, 000 year Model 1 km (3000 feet). Final Concentration C_{final} / $C_{initial}$= 8.5%**	**ANZECC (2000) 95% Freshwater**
Chloride	mg/L	556	7.1	0	0	0.21	0.60	0.003
Arsenic	mg/L	0.048	0.0006	0	0	0.000018	0.000051	0.013
Ammonia-Nitrogen	mg/L	132	1.58	0	0	0.04	0.13	0.9
Nitrate-Nitrogen	mg/L	18.5	0.24	0	0	0.0071	0.020	0.7
Zinc	mg/L	4.5	0.054	0	0	0.00135	0.0045	0.008

“This page has been left blank intentionally”

Figures

“This page has been left blank intentionally”

Figure F1: Solute Transport – 100 Year Scenario

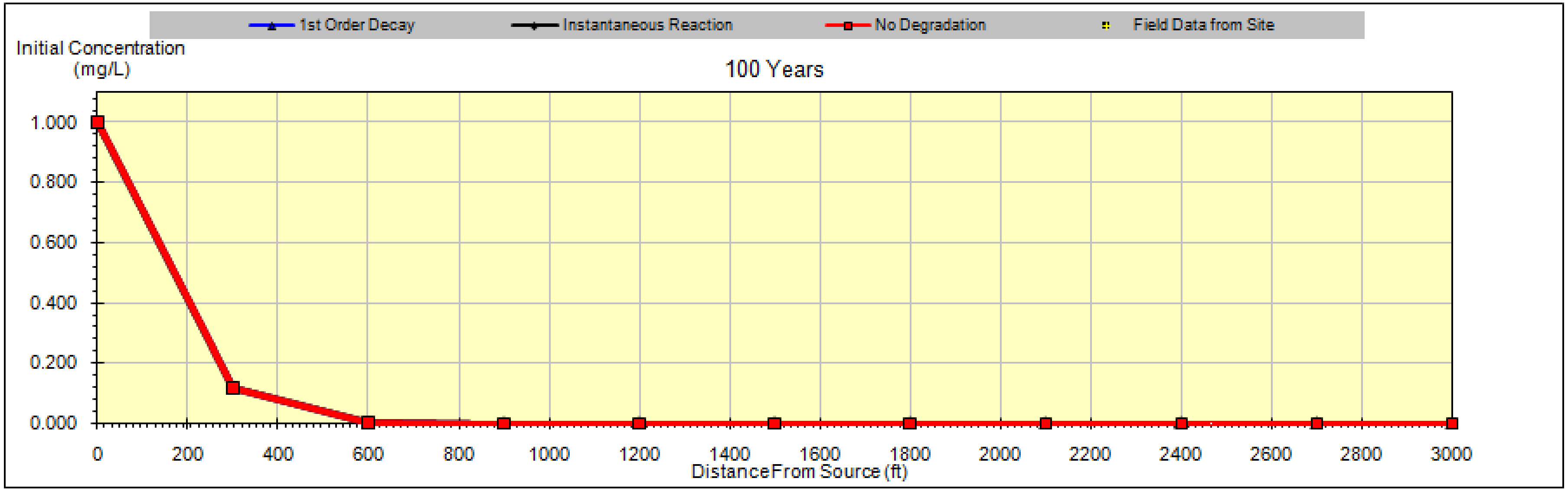


Figure F2: Solute Transport – 500 Year Scenario

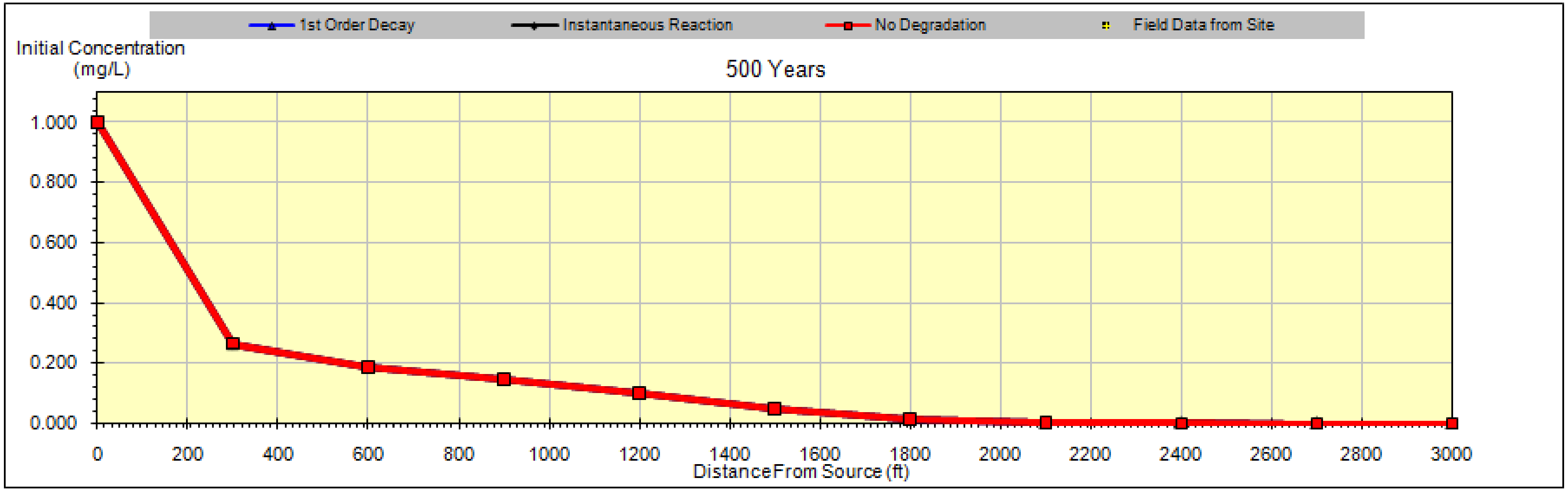


Figure F3: Solute Transport – 1,000 Year Scenario

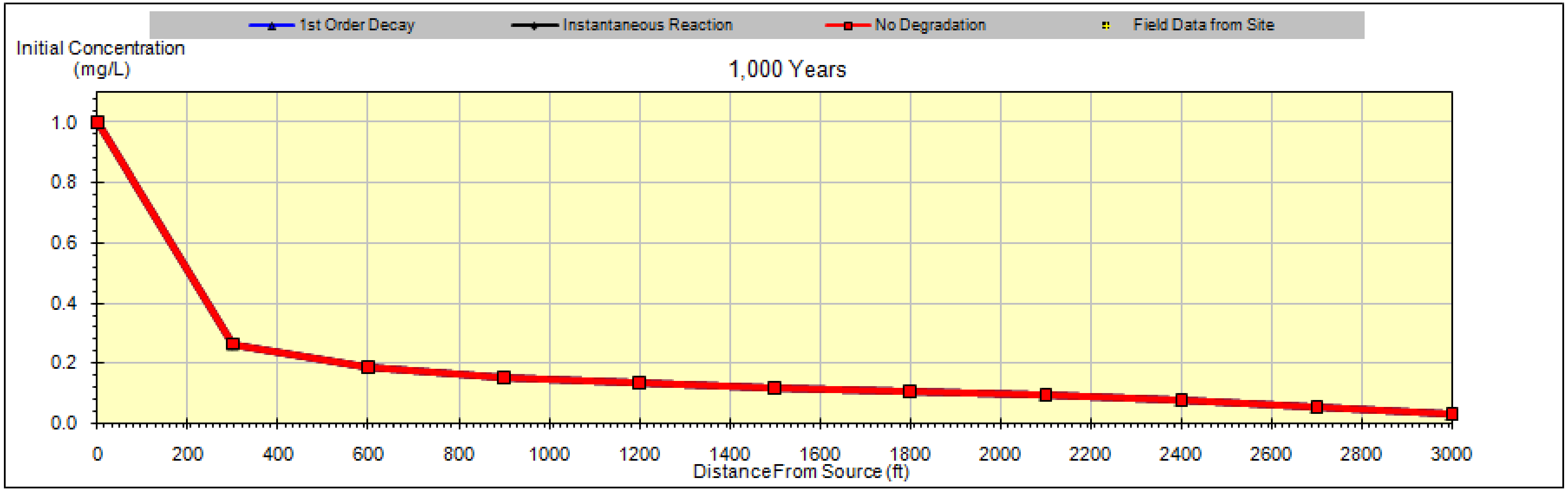
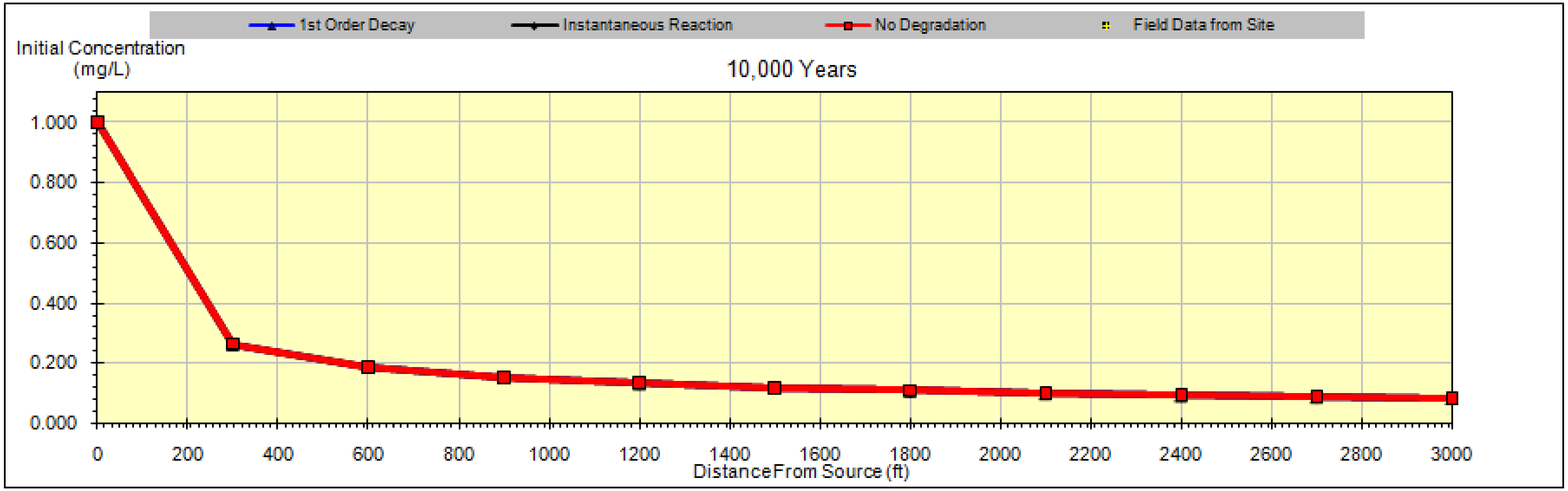


Figure F4: Solute Transport – 10,000 Year Scenario



Worldwide Locations

Australia	+61-2-8484-8999
Azerbaijan	+994 12 4975881
Belgium	+32-3-540-95-86
Bolivia	+591-3-354-8564
Brazil	+55-21-3526-8160
China	+86-20-8130-3737
England	+44 1928-726006
France	+33(0)1 48 42 59 53
Germany	+49-631-341-13-62
Ireland	+353 1631 9356
Italy	+39-02-3180 77 1
Japan	+813-3541 5926
Malaysia	+603-7725-0380
Netherlands	+31 10 2120 744
Philippines	+632 910 6226
Scotland	+44 (0) 1224-624624
Singapore	+65 6295 5752
Thailand	+662 642 6161
Turkey	+90-312-428-3667
United States	+1 978-589-3200
Venezuela	+58-212-762-63 39

Australian Locations

Adelaide
Brisbane
Canberra
Darwin
Melbourne
Newcastle
Perth
Sydney
Singleton

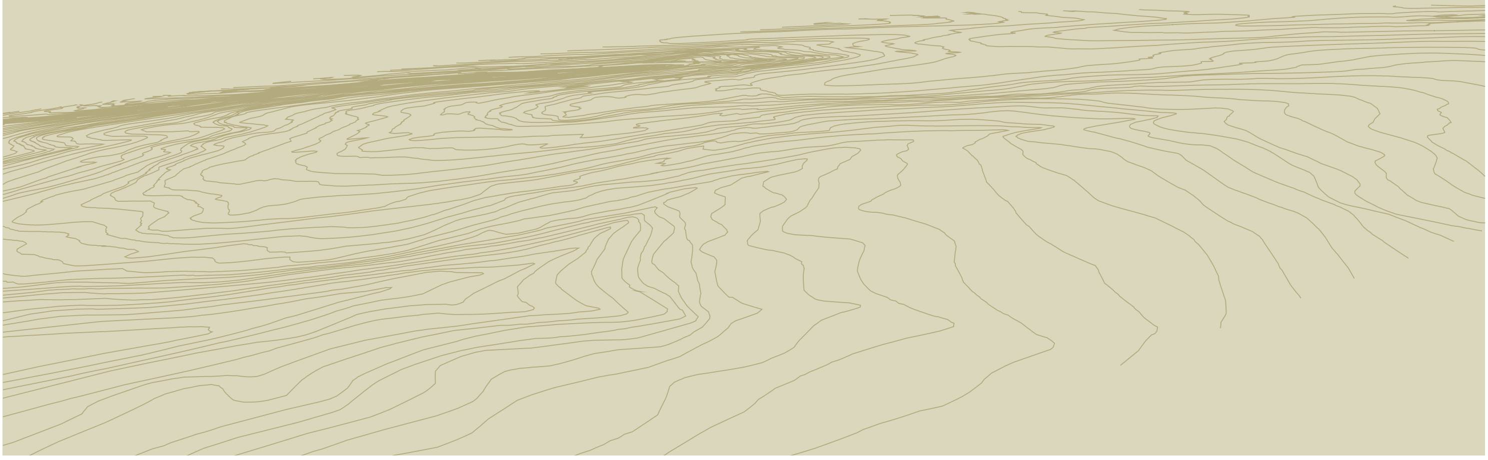
www.aecom.com

Appendix J

NSW Department of Public Works and Services, 2002: Landfill Siting Study, Aerial Photographic Survey

ARMIDALE REGIONAL LANDFILL

Environmental Assessment



Armidale Dumaresq Council

Landfill Siting Study

Aerial Photographic Survey

NSW Department of Public Works and Services

JUNE 2002

TABLE OF CONTENTS

1. INTRODUCTION

1.1 OBJECTIVE

The Department of Public Works and Services (DPWS), Lismore were engaged, in June 2002 by Armidale Dumaresq Council, to undertake a brief review of aerial photographs, to determine if suitable landfill sites, other than those previously identified by Council, might exist.

1.2 BACKGROUND

Consultants Brian J. Mackney & Associates Pty. Ltd. (BJM), ERM Mitchell McCotter (ERM), and the Department of Public Works and Services (DPWS) previously reported on a total of nine landfill sites.

BJM was engaged in 1996 jointly by Armidale, Dumaresq and Uralla Councils to assist Councils in landfill siting investigations. This engagement was to *establish baseline information about the region and to determine what are likely to be the key landfill site selection criteria.* This was to narrow the focus of investigation to areas of maximum potential.

BJM was then engaged to carry out assessments of sites which had been identified by Council. These studies were presented in the following reports:

- Preliminary Regional Landfill Siting Study (PRLSS) - BJM July 1996
- Landfill Siting Study - Metz Site Assessment - BJM December 1996
- Preliminary Site Assessment Sites 2, 3 & 4 - BJM November 1997
- Preliminary Site Assessment Sites 5, 6 & 7 - BJM July 1998

ERM was then engaged by Boral to carry out further studies on Site 1, the Metz quarry owned by Boral, as follows:

- Preliminary Desktop Investigation – Metz Quarry - ERM January 1999
- Preliminary Geotechnical & Hydrogeological Investigation - ERM April 2000
- Draft Concept Design Proposed Landfill Site Metz Quarry - ERM March 2001

The ERM studies relate only to Site 1 and deal specifically with the geology and hydrogeology of the site, and the concept for landfill layers, sealing, drainage and collection of leachate.

DPWS were subsequently engaged to carry out a Peer Review and Risk Assessment of the work previously done by BJM and ERM. In addition they examined two new sites (Sites 8 & 9) using the same methodology previously employed by BJM.

- Landfill Facility Peer Review – DPWS, June 2001.
- Siting Study Site 8 Assessment – DPWS, June 2001
- Siting Study Site 9 Assessment – DPWS, April 2002

Geotechnical Consultants Australian Soil and Concrete Testing P/L, under the direction of DPWS, were engaged by Council to report on more detailed geotechnical investigations of Site 9.

Following these investigations and reports, Site 9 has been recommended by DPWS as the preferred site for a landfill.

2. AERIAL PHOTOGRAPHIC SURVEY

In a further effort to identify other possible landfill sites, Council engaged DPWS to conduct a review of aerial photographs of target areas nominated in the PRLSS (BJM July 1996).

These efforts have been focussed on areas to the north and east of Armidale, acknowledging the expressed interest of Guyra Council in using the proposed regional landfill and the need to maintain acceptable proximity of the facility to that Council's area.

2.1 METHODOLOGY

Figure 1 shows the aerial extent of photographs included in the review. The survey included all Csx and Ccgs geological formations located within an area bounded to the west by the Dumaresq Dam, to the north by Black Mountain, east to Hillgrove and Four Mile Creek and south to Bald Knobs Hill and Hillgrove. These formations were previously identified in the PRLSS as offering the most suitable geology in the region for the siting of a landfill.

A total of 119 aerial photographs, at a scale of 1:25000, were obtained from Land and Property Information NSW. The photographs were taken from an aerial photographic survey dated 10th May, 2001. Details of photographs are as follows:

Area	Film No.	Run No.	Print Numbers
Armidale	4556	1	131 – 146 (inclusive)
Armidale	4556	2	215 – 229 (inclusive)
Guyra	4554	9	141 – 154 (inclusive)
Guyra	4556	10	28 – 43 (inclusive)
Guyra	4556	11	56 – 73 (inclusive)
Guyra	4556	12	78 – 97 (inclusive)
Guyra	4556	13	104 – 123 (inclusive)

Figure 1 - Aerial Photographic Runs

The photographs were viewed as stereo-pairs using a SOKKIA MS27 Mirror Stereoscope. The MS27 is specifically designed for detailed interpretation of aerial photographs, allowing direct or magnified (x 3) viewing. The field of view (18 x 23 cm) allows adequate viewing of 23 x 23 cm format stereo photographs. The standard binoculars (x 3) of the MS27 have a 70mm field of view.

Direct viewing was used, in the first instance, to broadly identify potentially suitable sites. The binoculars were then used for more detailed examination of each site.

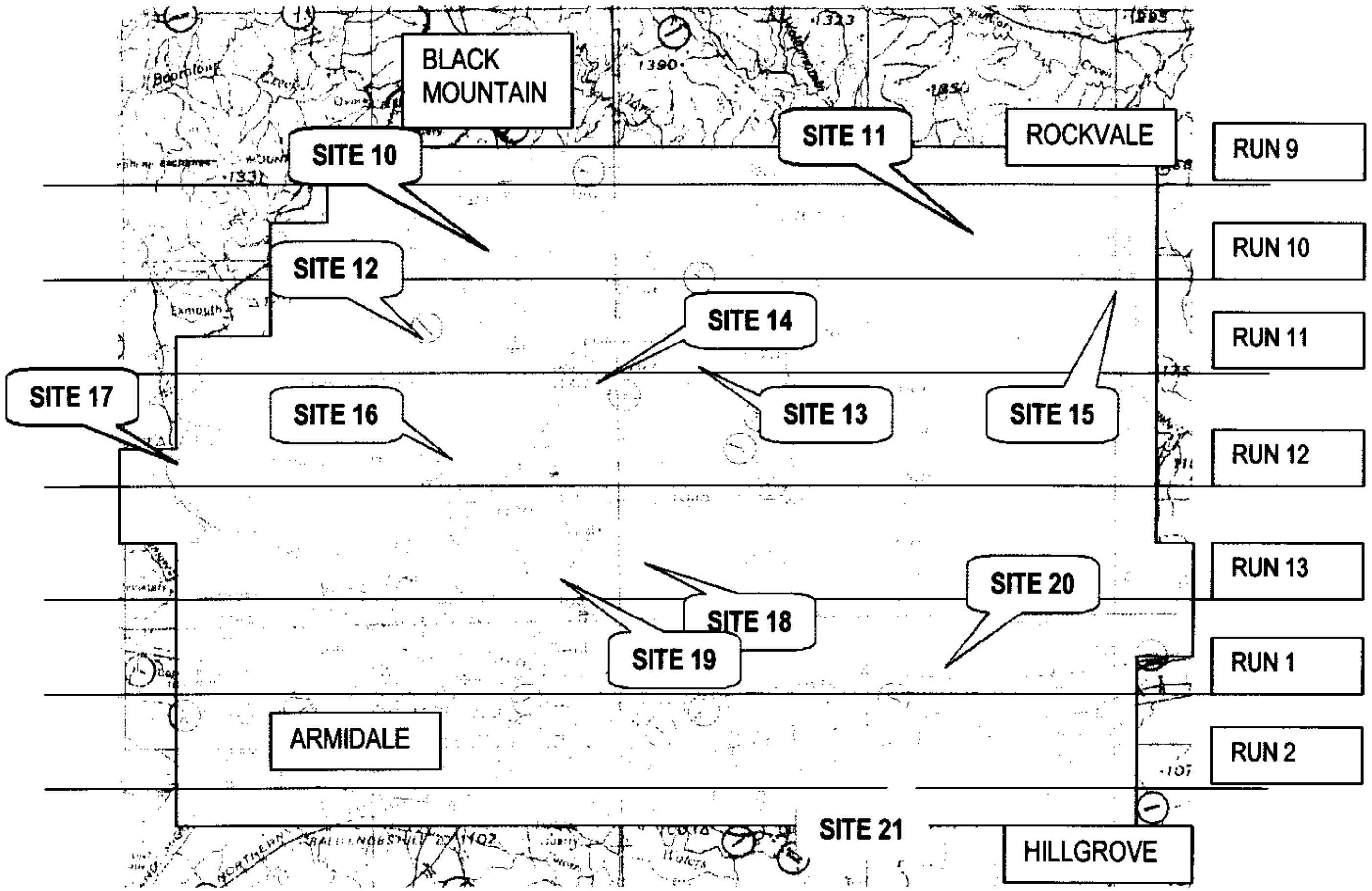


Figure 2 - Photographic Runs & Site Locations

□ -- *Photo Coverage*

2.1.1 Site Identification Criteria

Target sites for the aerial survey were identified with reference to the selection criteria adopted in the earlier PRLSS. These were interpreted for application to the aerial photographic survey. The primary identification criteria used in the photographic survey were as follows:

Criteria	Comment
Suitable geology	Assessed by reference to the PRLSS
Distant from waterways	Separation distance subjectively assessed, taking into account practical management of surface & groundwater.
Low ground relief	Sites with slopes > 5% discarded.
Good surface water control	Sites at head of catchment targeted
Minimal external catchments	Avoid through flow of run-off
Good erosion protection	Control of surface run-off & slopes
Compatibility with adjoining development	Adequate buffer distance > 1 km approx.
Low agricultural value	Defined by soils, geology, terrain.
Visually protected	Subjective assessment, subject to inspection
Minimal impact on local roadways	Limit distances to main road.
Adequate road access	Elevated, flood free, alignment.
Proximity to centres serviced	Locate nearest centroid of service area
Topography and terrain	Undulating with adequate protection
Elevated	Flood free
Capacity for 50 years minimum	Preferably 100 year capacity
Opportunity for expansion	Desireable
Orientation	North easterly preferred. Protected.

Table 1 - Site Identification Criteria

2.2 OUTCOMES.

The review identified an additional twelve (12) possible sites. These are discussed in the context of the primary identification criteria listed in Table 1. Subjective assessments for the twelve sites are provided in Table 2 below.

Site	Run	Photo No.	Comment
10	10	40	Isolated location. Poor road access. Exposed visual aspect. Limited capacity.
11	10	32	Remote location. Poor road access. Distant from centres serviced. Substantial on site roads required. Elevation excessive. Surface water controls difficult.
12	11	59	Visually and physically exposed site. Costly highway intersection. Soils appear erodible, possible dispersive. External surface water catchment. Nearby dwellings. Not favoured.
13	11	63	Three potential sites of variable potential. Good capacity and potential for expansion. Nearby dwellings possible constraint. Visually exposed? External catchments would require careful attention. Orientation variable but manageable. ,Geology & soil type possibly basalt with associated groundwater issues.
14	11	65	Exposed southwest orientation. Large capacity. Remote. Access poor. Lengthy internal access road required. Soils unknown. Possibly basalt. Not recommended.
15	11	73	Remote location. Limited capacity. Rocky outcrops suggest site is unlikely to have adequate construction materials, particularly clays.
16	12	86	Unsuitable terrain. Surrounding soils appear susceptible to erosion. Difficult to manage external catchments. Nearby dwellings within line of site. Not favoured.
17	12	98	Visually exposed. Access and location OK, although dust may be an issue on access road. Indirect access from Guyra. Not favoured.
18	13	118	Lengthy access roads. Mix of small sites would cause difficulties in managing stormwater and leachate. Remote from dwellings. Landform suggests basalt, with inherent groundwater issues. Doesn't appeal.
19	13	114	Visually exposed and adjacent (~ 2km) closely developed area. West orientation not desirable. Proximity and access to Armidale good. Not recommended.
20	1	133	Two sites considered. First site visually exposed to main road. Second site has external catchment which may be difficult to manage. Not favoured.
21	2	226	Two possible sites. Relatively steep terrain. Geology appears a mix of igneous extrusions, with potential groundwater issues. Access good. Not ideal topography.

Table 2 - Subjective Assessment of Sites

3. CONCLUSIONS

This report concludes that none of the possible sites identified by this preliminary aerial photographic review are likely to offer a superior alternative to the previously recommended Site 9 when compared using site identification criteria listed in Table 1 of this report. In these circumstances, none of the sites are recommended for further investigation while Site 9 remains a viable option.

Given the level of detail available on the aerial photographs, it is unlikely that other sites exist other than those identified by this investigation.

The report supports the earlier conclusions of the DPWS "Siting Study - Site 9 Assessment" and recommends that Council proceed with the ongoing Environmental Impact Assessment of Site 9 and other investigations into alternative processes now in progress.

4. APPENDICES

APPENDIX A – AERIAL PHOTOGRAPHS OF POTENTIAL SITES

Site 10 - Run 10, South of Black Mountain

Site 11 – Run 10, Southwest of Rockdale

Site 12 – Run 11, North of Tillbuster

Site 13 – Run 11, Northeast of Tillbuster

Site 14 – Run 11, Northeast of Tillbuster

Site 15 – Run 11, Southeast of Rockdale

Site 16 – Run 12, East of Tillbuster

Site 17 – Run 12, Dumaresq Dam

Site 18 – Run 13, Northeast of Armidale

Site 19 – Run 13, Northeast of Armidale

Site 20 – Run 1, Grafton Road east of Armidale

Site 21 – Run 2, South of Grafton Road at Hilgrove

Site 10 - Run 10, South of Black Mountain

Site 11 – Run 10, Southwest of Rockdale

Site 12 – Run 11, North of Tillbuster

Site 13 – Run 11, Northeast of Tillbuster

Site 14 – Run 11, Northeast of Tillbuster

Site 15 – Run 11, Southeast of Rockdale

Site 16 – Run 12, East of Tillbuster

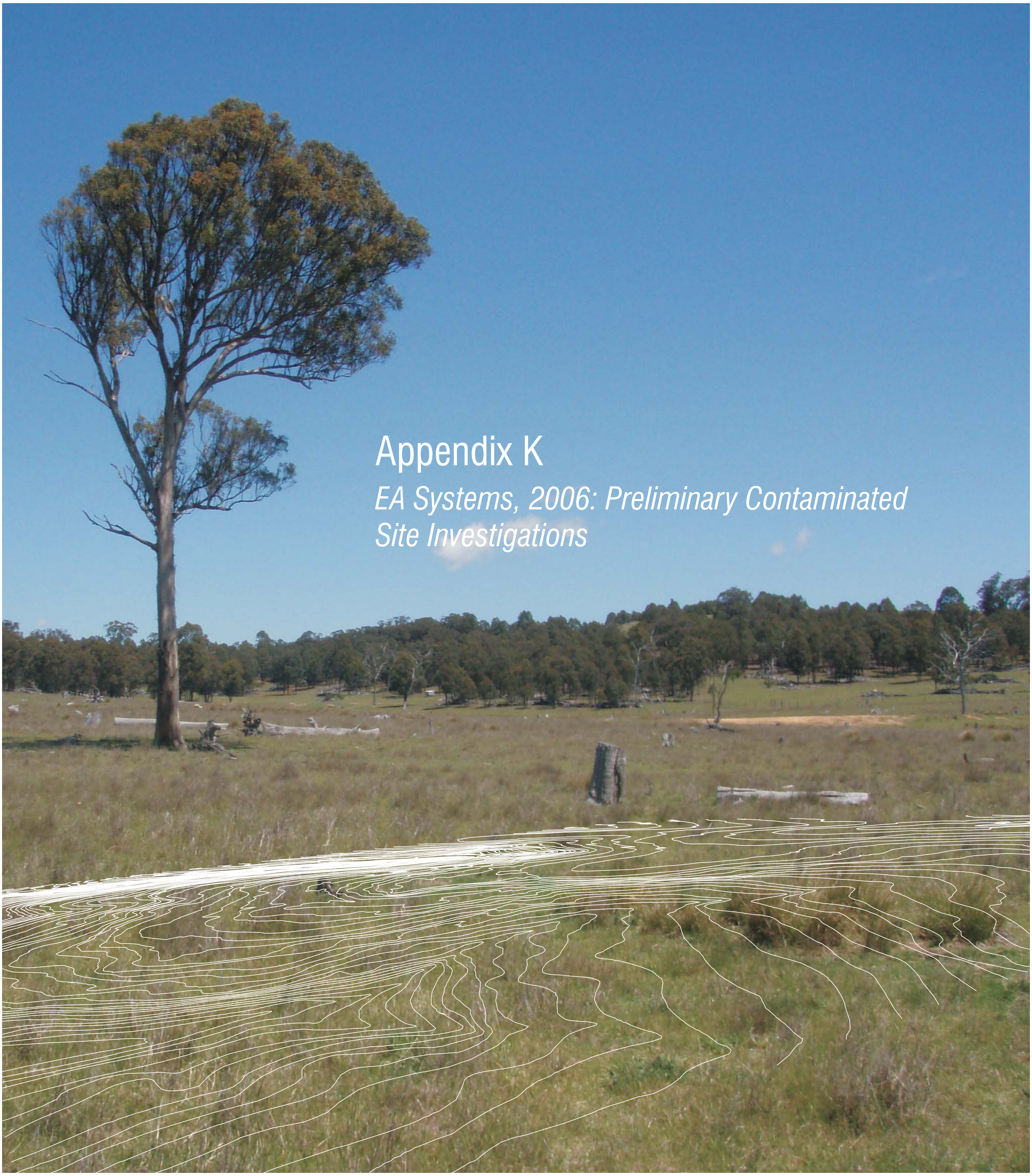
Site 17 – Run 12, Dumaresq Dam

Site 18 – Run 13, Northeast of Armidale

Site 19 – Run 13, Northeast of Armidale

Site 20 – Run 1, Grafton Road east of Armidale

Site 21 – Run 2, South of Grafton Road at Hilgrove

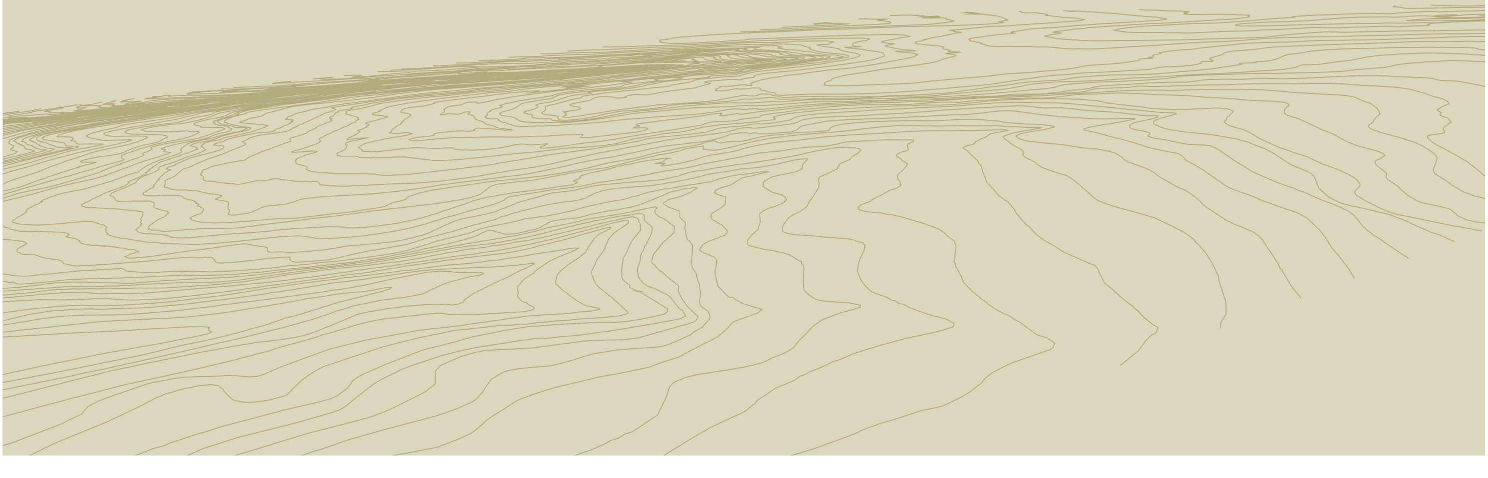


Appendix K

EA Systems, 2006: Preliminary Contaminated Site Investigations

ARMIDALE REGIONAL LANDFILL

Environmental Assessment



Preliminary Contaminated Site Investigation

Lot 1 DP 253346 and 2 DP 253346 and (County of Sandon, Parish of Gara) located on Gara Road, Armidale, NSW

Report Number 20971.13871

Prepared for *by*

MAUNSELL | AECOM

EASYSTEMS
ENVIRONMENTAL & AGRICULTURAL
SCIENCE & ENGINEERING

Maunsell Australia
PO Box Q410
QVB Post Office
Telephone: 02 8295 3600
Facsimile: 02 9262 5060

PO Box 1251
ARMIDALE NSW 2350
Telephone: (02) 6771 4864
Facsimile: (02) 6771 4867
ABN: 67 081 536 281

Document Status Record

Report Type:	Preliminary Contaminated Site Investigation
Project Title:	Lot 1 DP 253346 and Lot 2 DP 253346 (County of Sandon, Parish of Gara) located on Gara Road, Armidale, NSW
Client:	Maunsell Australia
Job.Document Number:	20971.13871
File Name:	20971.13871 Final PCSI Report.Doc

Issue No.	Date of Issue	Author	Checked	Approved
2	27 Nov 2006	Sarah-Jane Hackett, Fred Esmundo	Sue Wilson	Martin Dillon
Signatures		--------------------------------	--------------------------------	M. Dillon

Notes:

Issue 2 – Final Report

Distribution:

Recipient	No. Copies
Maunsell Australia	1
E.A. Systems	1

This document provides information to address the intent of Project Number 20971 as agreed to by Maunsell Australia.

Executive Summary

This report presents the findings of a Preliminary Contaminated Site Investigation (PCSI) undertaken by E.A. Systems Pty Limited (EAS) of Lot 1 DP 253346 and Lot 2 DP 253346 (County of Sandon, Parish of Gara) located on Gara Road, Armidale, NSW.

The scope of work included the following:

- A site history review and site visit to identify potential areas of environmental concern (AECs) and chemicals of concern (CoCs); and
- Assessment of site contamination based on the site history review and site visit.

The information obtained from the site history review and site inspection can be summarised as follows:

- The registered owners of Lot 1 DP 253346 "*Edington*" are Kenneth Paul Waters and Deirdre Antoinette Waters.
- The registered owners of Lot 2 DP 253346 "*Sherraloy*" are Derry Wallace Crisp and Gail Margaret Crisp.
- The subject lots have been used for grazing.
- A small quarry is in operation in Lot 2 DP 253346, this quarry is used for extracting gravel.
- Sheep yards are located in Lot 1 DP 253346. Two empty 200 litre (44 gallon) drums were located near the yards.
- There was no permanent infrastructure present in or near the sheep yards that would have allowed for sheep dipping or fixed hose jetting.

Based on the site history review and site inspection, it is considered that:

- There is no evidence of oil spills or stains from the use of heavy vehicles in the quarry area.
- No dangerous goods or explosives were used in the quarry.
- No chemicals of concern have been used for gravel extraction.
- There is no evidence of either contaminated or clean earth fill material (acquired from another site) present on the site.
- There is no evidence of old rubbish tips on the site.
- The onsite sewage system connected in 1991 for the residence on Lot 2 DP 253346 is outside the proposed landfill site boundary (approximately 300 m down slope on the other side of a ridge) and is therefore unlikely to be a source of potential contamination for the site.
- There may be areas in and around the sheep yards that have been exposed to chemicals associated with routine sheep drenching, jetting and vaccination. However as there is no permanent infrastructure present that would have allowed dipping or fixed hose jetting, therefore any contamination would be low and limited to localised surface stains.
- The overall potential for the site to be contaminated is low.

Table of Contents

List of Tables

List of Figures

List of Plates

List of Appendices

1. Introduction

1.1 General

This report presents the findings of a Preliminary Contaminated Site Investigation (PCSI) undertaken by E.A. Systems Pty Limited (EAS) of Lot 1 DP 253346 and Lot 2 DP 253346 (County of Sandon, Parish of Gara) located on 597 Gara Road, Argyle, New South Wales. The coordinates for the approximate centre of the site are 383467 East and 6619175 North (GDA1994 MGA zone 56). A site location plan is provided in Figure 1. Figure 2 shows the site plan.

The site is proposed to be redeveloped to form the new Armidale Dumaresq landfill site and a PCSI is required for a development application.

1.2 Objectives and Scope of Work

The objective of the Preliminary Contaminated Site Investigation was to identify potentially contaminating activities that are currently being performed at the site and that may have been performed in the past on the site.

The scope of work included the following:

- A site history review and site visit to identify potential areas of environmental concern (AECs) and chemicals of concern (CoCs); and
- Assessment of site contamination based on the site history review and site visit.

2. Local Context of Site

2.1 Site Location

The site is located approximately 12 km east of the Armidale CBD along the Waterfall Way highway (also known as the Grafton Road) within the Armidale Dumaresq Council Municipality. The site is composed of sections of two lots known as *Sherraloy* Lot 2 in DP 253346 and *Edington* Lot 1 in DP 253346. The areas of *Sherraloy* and *Edington* that form the landfill site are approximately 36 and 28 hectares respectively (not including area of land required for road access). The site is bound by the Grafton Road to the north east, and rural properties to the south, east and west.

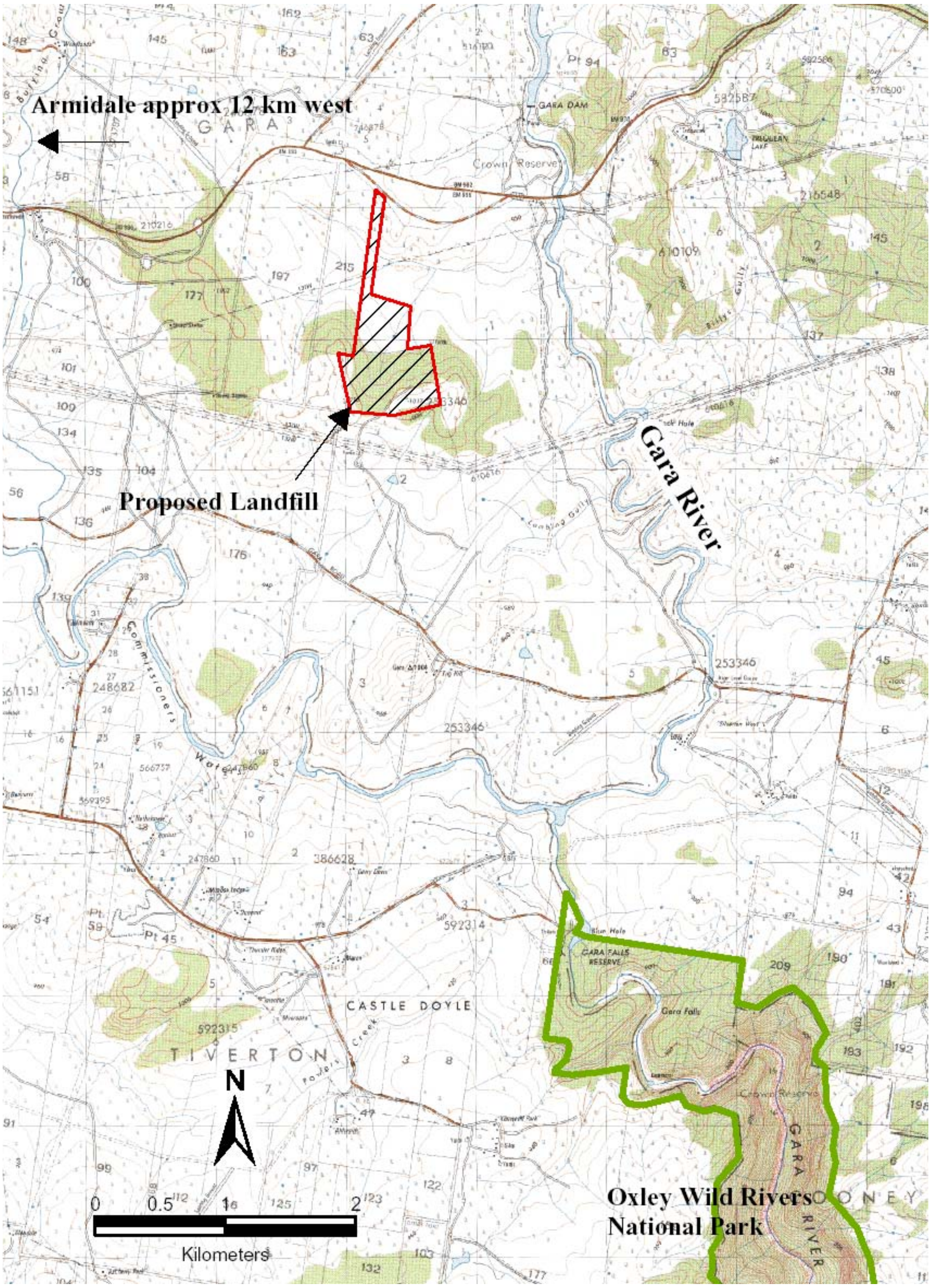


Figure 1. Site location for proposed new landfill (County of Sandon, Parish of Gara)

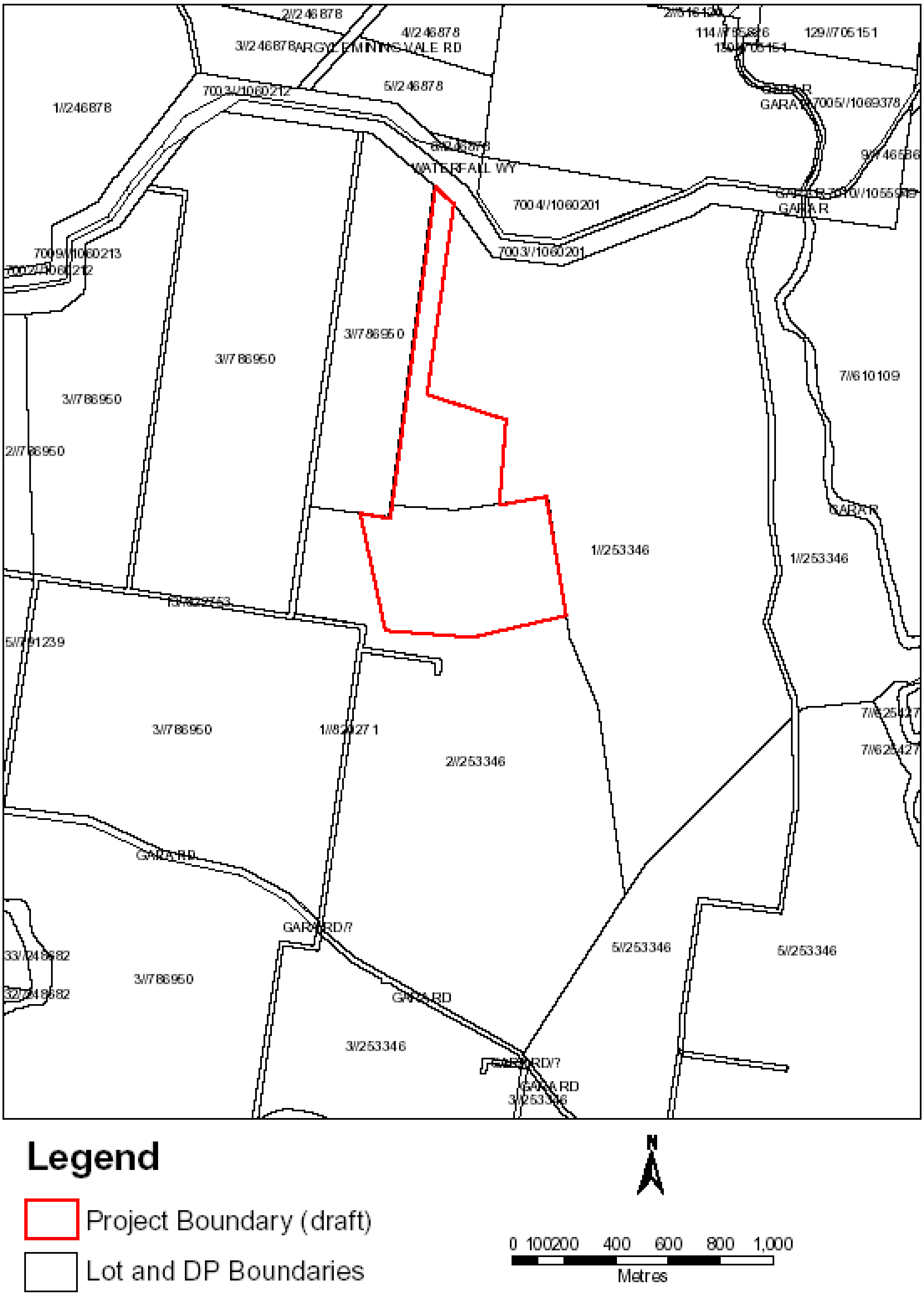


Figure 2. Site plan for Lot 1 and 2 in DP 253346 (County of Sandon, Parish of Gara), including proposed landfill area.

2.2 Surrounding Land Use

The surrounding land use is rural and is primarily applied to livestock (sheep and cattle) production. There is an olive grove located on the neighbouring property *Strathaven* 500 metres west of the proposed landfill site. The olive grove is estimated to be 7 ha in area. This grove is on the upper slopes of the catchment for the gully that runs from west to east across *Edington*. The land immediately north of *Edington* on either side of the Waterfall Way highway is part of the Gara Travelling Stock Reserve (TSR).

2.3 Geology, Soils and Hydrogeology

2.3.1 Local Geology

An on-ground geological survey of the site (Ashley, 2006) indicated that the underlaying substrate rocks within the landfill site are part of the Sandon Beds, and comprise siltstone, mudstone-argillite and chert. On the southern side of the landfill site are Tertiary age sedimentary rocks. There is a small Tertiary basalt mass approximately 0.5 km south of the landfill boundary. Sandon Beds greywacke comprise the dominant rock type surrounding the site.

2.3.2 Local Soils

A soil survey of the area undertaken by the Department of Natural Resources (King, in prep), indicates that the proposed landfill site occurs predominantly within two soil landscape groups; *Argyle* and *Middle Earth*. A small section of site, located along the drainage gullies, is classified as *Commissioners Waters*.

The description of the soil landscapes is presented below:

Argyle
Landscape—rolling low hills and occasional hills on greywacke/chert and related sediments. Local relief 30 - 80 m, slopes mostly 10 - 30%, elevation 910 – 1170 m . Minor rock outcrop (<10%) Partially cleared Eucalyptus caliginosa (New England stringybark) open woodland (King, in prep).

Soils—very shallow to shallow (<50 cm), well drained Basic Lithic Leptic Rudosols (Lithosols) and other shallow soils on crests, ridges and upper slopes. Shallow to moderately deep (40- 80 cm) moderately well drained Haplic Eutrophic Yellow Kandosols/ Tenosols (Yellow Earths) on midslopes and occasionally extending onto crests. Shallow to moderately deep (<80 cm) moderately well drained Yellow/Red and Grey Chromosols (Yellow and Red Podzolic Soils) on mid slopes, footslopes and drainage lines. Mottled-Subnatric Eutrophic Brown and Yellow Sodosols (Soloths) occur along some drainage depressions (King, in prep).

Commissioners Waters
Landscape—Narrow streams, swamps and occasional small floodplains/terraces on Quaternary alluvium. Includes Commissioners Waters and the Gara River. Local relief 0-10 m, slopes 0 – 3%, elevation 900 –1070 m. Extensively cleared open woodland (King, in prep).

Soils—Variable soils according somewhat to the source rocks from which they are derived. Shallow to moderately deep (40 – 100 cm), well drained Alluvial Sands and Alluvial Loams (Yellow/ Brown and Grey Earths) occur in areas derived from coarse grained parent materials. Moderately deep to deep (>80 cm), moderately well drained Mottled Eutrophic Grey Chromosols/ Grey Sodosols (Gleyed Podzolic Soils/ Grey Brown Podzolic Soils/ Lateritic Podzolic Soils) are fairly common. Some Haplic Eutrophic Brown Dermosols/ Kandosols (Prarie Soils) are encountered along parts of Burying Ground Creek (King, in prep).

Middle Earth
Landscape—undulating plains, rises and footslopes on Sandon Beds. Local relief 0-30 m, slopes 0-10%, elevation 910 - 1120 m. Extensively cleared open woodland to partially cleared (King, in prep).

Soils—moderately deep to deep (>70 cm), moderately well drained Bleached-Mottled Haplic Eutrophic Yellow Kurosols and Chromosols (Yellow Podzolic Soils) are widespread. Deep (>100 cm), poorly drained Yellow Chromosols and Mottled-Mesonatric and Mottled-Subnatric Eutrophic Yellow Sodosols (Soloths) and Bleached-Manganic and Bleached-Ferric Eutrophic Yellow Chromosols (Lateritic Podzolic Soils/ Grey Brown Podzolic Soils) occupy drainage depressions and poorly drained areas. Occasional shallow (<40 cm), well drained Bleached Eutrophic Yellow Kandosols (Yellow Earths) on slopes with bedrock close to the surface (King, in prep).

2.3.3 Local Hydrogeology

The closest registered bore (GW 305317) is located approximately 80 m from the subject site.The geographic coordinates for this bore are $30^0$33’16”latitude and $151^0$46’49” longitude and date of establishment was July 2004. The bore summary obtained from the Natural Resource Management Groundwater Database indicates that for registered bore GW 305317 the aquifer is located in basalt rock with the top of the aquifer at 29.90 m below ground surface (BGS) and the aquifer floor is at 38.72 m BGS. The standing water level for this bore was 31.4 m with a yield of 0.76 litres per second.

Four groundwater bores installed onsite by E.A. Systems Pty Limited on 13th October 2005 have shown no groundwater present from 0 – 5m BGS, and a fifth bore installed on 17th November 2005 has shown no groundwater present from 0 – 10m BGS up to the time of writing (28th April 2006). This suggests that during this period there have been no flows of groundwater within 5 metres of the surface under the proposed operational area, and no evidence of groundwater within 10metres of the surface between the two farm dams within the proposed operational area of the landfill.

The Gara River flows from north to south along the eastern boundary of *Edington*. The river frontage extends approximately 2500 m along the property boundary. The minimum distance between the Gara River and the potential site footprint for the landfill is 1,060 m.

Two intermittent drainage lines flow onto *Edington* from the western neighbouring property *Strathaven*. These drainage lines flow onto the site from westerly and south westerly directions for approximately 200 m before they merge to form a single intermittent gully that flows east a further 1300 m across *Edington* until it joins the Gara River at the north-western corner of the site.

Seven small farm dams are scattered across *Sherraloy*, and two small farm dams are present on *Edington*. The preliminary footprint area for the landfill and associated buffers contains two of these dams.

The Gara catchment is a major catchment in the local area. The Gara River runs into the Macleay River that eventually reaches the ocean at Trial Bay near South West Rocks in Northern NSW. The mid and lower reaches of the Gara and Macleay rivers are characterised by deep and extensive gorge systems that form part of the Oxley Wild Rivers National Park and the Central Eastern Rainforest Reserves World Heritage Area. The Gara River descends into a gorge approximately 4.3 km south-south-east of the landfill site in Oxley Wild rivers National Park. The distance along the riverbed between the closest point to the landfill site and the Oxley Wild Rivers National Park is 8.8km. Burying Ground Creek flows into the Gara River from the east at a point 800 m upstream of the Oxley Wild Rivers National Park.

3. Site History Review

The site history review included the following:

- A site visit by an E.A. Systems Environmental Scientist;
- Interviews with people familiar with the history and operations of the site;
- A review of Council records on the site;
- A review of aerial photography dated 13th May 2001

3.1 Site Inspection

The following observations were noted during the site inspection conducted on 8 September 2005:

- The primary land use of the subject lots has been livestock grazing (Plates 1 and 2).
- A small quarry was in operation in Lot 2 DP 253346, this quarry has been used for extracting gravel (Plates 3 to 5).
- Sheep yards were located in Lot 1 DP 253346 (Plate 6).
- Two empty 200 litre (44 gallon) drums and discarded empty vaccination packs were observed on the ground beside the sheep yards (Plate 7). The tops of the drums were intact, indicating that the drums had not been used for mixing of chemicals.
- There was no evidence of earth fill material (acquired from another site) present on the site.

Plate 1. Small Paddocks have sparse ground cover and are used for livestock grazing

Plate 2. One of the two dams located on Lot 1 in DP 253346

Plate 3. Small quarry located in the north eastern corner of Lot 2 in DP 253346

Plate 4. The boundary of the small quarry located in the north eastern corner of Lot 2 in DP 253346

Plate 5. Small quarry in the background of Lot 2 in DP 253346

Plate 6. Sheep yards located in the centre corner of Lot 1 in DP 253346. The yards include pens and a race that are likely to have been used for drenching, jetting and vaccinating sheep

Plate 7. Empty vaccination packs (foreground) and empty 44 gallon drums (background) beside the sheep yards located Lot 1 in DP 253346

3.2 Interviews

Mr Derry Crisp, who acquired *Sherraloy* in 1986, was interviewed by telephone on 10th April 2006 to gain information about the historical land uses on the property. Mr Crisp confirmed that there were no old stock dips or rubbish tips present on the property, there had been no storage of dangerous goods or explosives on the property, and there had been no storage of pesticides or herbicides. Furthermore, Mr Crisp's property is an accredited "CattleCare" property. An accredited CattleCare property must be managed to prevent unacceptable residues accumulating in cattle (DPI&F, 2006). This accreditation required an assessment of the risk of soil on the property being contaminated with persistent chemicals.

Mr Ken Waters, who acquired *Edington* in 1974, was interviewed by telephone on 5th May 2006. Mr Waters confirmed that there had been no storage of dangerous goods or explosives on the property, there were no old stock dips or rubbish tip sites and there had been no storage of pesticides or herbicides on *Edington*. Mr Waters confirmed that the empty 44 gallon drums located near the sheep yards had not been used for mixing of chemicals, they had been used as tables to hold gear for lamb marking.

3.3 Titles Search

A list of past and present registered owners and lessors was obtained from the New South Wales Department of Lands. Registered owners of Lot 1 in DP 253346 are summarised in Table 1 while registered owners of Lot 2 in DP 253346 are summarised in Table 2.

Table 1. Registered Owners – Lot 1 in DP 253346

Year of Acquisition	Registered Owner
1974	Kenneth Paul Waters and Deirdre Antoinette Waters

Table 2. Registered Owners – Lot 2 in DP 253346

Year of Acquisition	Registered Owner
1986	Derry Wallace Crisp and Gail Margaret Crisp

Results of the title search are provided in Appendix A**.**

3.4 Council Records

Armidale Dumaresq Council records regarding Lot 1 and 2 in DP 253346 (County of Sandon, Parish of Gara) located on 597 Gara Road, Argyle, New South Wales were available for review. A summary of the findings of these records is outlined below;

Lot 1 in DP 820271 and Lot 2 in DP 253346

- 30th August 1983 – A building application was submitted to the Armidale Council for the development of a single dwelling house in Lot 2 DP 253346.
- 3rd August 1990 – A building application to the Shire of Dumaresq for a house extension.
- 11 June 1999 – Application for approval to operate an onsite sewage management system
- 22 August 2002 – S149 certificate

3.5 Environmental Protection Agency Records

A review of the EPA Environmental Management Register (EMR) provided the following information:

- Lot 1 and 2 in DP 253346 is not in the EMR;

3.6 New South Wales Environment Protection Authority Records

A search of the New South Wales EPA records was conducted on the 30 January 2006. No contaminated land record has been issued for the subject site.

3.7 Aerial Photograph Review

An aerial photograph dated May 2001 was reviewed to determine whether there was an indication of previous landuse activities. A scanned copy of the aerial photo is attached in Appendix B and is described in Table 3.

Table 3. Summary of historical aerial photograph review for Lot 1 and 2 in DP 253346 (County of Sandon, Parish of Gara)

Year	Observation
2001	Land sparse with minimal vegetation cover. Vegetation cover on upper slopes and toward the Waterfall Way (Grafton Road). Two dams evident in the aerial photograph. The sheep yards and the quarry are visible in the photograph.

4. Potential Areas of Environmental Concern and Chemicals of Concern

Based on the site history, potential areas of environmental concern and associated chemicals of concern were identified. These are summarised in Table 4.

Table 4. Summary of Potential Areas of Environmental Concern and Chemicals of Concern on Lot 1 and 2 DP 253346 (County of Sandon, Parish of Gara)

Potential Areas of Environmental Concern	Description of Potentially Contaminating Activity	Chemicals of Concern	Likelihood of Contamination (Based on Site History Review)^{A}	Comments
Waste Oil	Waste oil from the maintenance of heavy vehicles may have been disposed of on-site.	TPH PAHs Lead Phenol Additives	Low	The maintenance of heavy vehicles would have resulted in the generation of waste oil. The site history review cannot rule out with certainty that waste oil was disposed off-site. This may be limited to the quarry site.
Sheep Yards	Spraying Drenches	DDT, Arsenic and lead based pesticides OCs OPs	Low	Usually low level and diffuse. Contamination, if present, is likely to be limited to the near subsurface.
Sewage Management	Potential bacterial contamination	Bacterial contamination	Low	Residence is located outside the area of interest approximately 300 m on the other side of a ridge from the proposed landfill site boundary.
Entire Site	Contaminated fill material may have been imported to the site.	Metals PAHs TPH OCPs Asbestos PCBs	Low	Site observations suggest that significant fill material is unlikely to be present at the site.
	Pesticides may have been applied within the property boundaries for weed or pest management.	OCPs OPPs Metals TPs SPs	Low	Contamination, if present, may be limited to the near subsurface.

LEGEND:

A	Qualitative assessment of the probability of occurrence of contamination	**TPH**	Total Petroleum Hydrocarbon
BTEX	Benzene, Toluene, Ethyl Benzenes and Total Xylenes	**MTBE**	Methyl Tertiary Butyl Ether
PAHs	Polynuclear Aromatic Hydrocarbons	**OCPs**	Organochlorine Pesticides
PCBs	Polychlorinated Biphenyls	**OPPs**	Organophosphorus Pesticides
TPs	Triazine Pesticides	**SPs**	Synthetic Pyrethroids

5. Conclusions

Based on the site history review and site inspection, it is considered that:

- There is no evidence of oil spills or stains from the use of heavy vehicles in the quarry area.
- No dangerous goods or explosives were used in the quarry.
- No chemicals of concern have been used for gravel extraction.
- There is no evidence of either contaminated or clean earth fill material (acquired from another site) present on the site.
- There is no evidence of old rubbish tips on the site.
- The onsite sewage system connected in 1991 for the residence on Lot 2 DP 253346 is outside the proposed landfill site boundary (approximately 300 m down slope on the other side of a ridge) and is therefore unlikely to be a source of potential contamination for the site.
- There may be areas in and around the sheep yards that have been exposed to chemicals associated with routine sheep drenching, jetting and vaccination. However there is no permanent infrastructure present that would have allowed dipping or fixed hose jetting, therefore any contamination would be low and limited to localised surface stains.
- The overall potential for the site to be contaminated is low.

6. Project Limitations

The report will not provide a complete assessment of the environmental status of the site, and it is limited to the scope defined herein. Should further information become available regarding the conditions at the site, including previously unknown likely sources of contamination, E.A. Systems Pty Limited reserves the right to review the report in the context of the additional information.

7. References

Ashley, P. (2006) *Geological report on proposed Armidale Dumaresq Council landfill site with emphasis on investigation of a possible geological fault. Report prepared for E.A. Systems Pty Limited*. E.A. Systems Pty Limited, Armidale.

Department of Mineral Resources (1972) *Dorrigo-Coffs Harbour 1:250,000 Geological Series Sheet SH 56–10&11,* Department of Mineral Resources .

King D. P. (in prep) *Soil Landscapes of the Armidale 1:100 000 Sheet*, Department of Natural Resources, Sydney
DPI&F (accessed May 2006) *CATTLECARE - a quality assurance program for beef producers*, Department of Primary Industries and Fisheries, <http://www2.dpi.qld.gov.au/beef/3476.html>

8. Appendices

Appendix A. Title Search and Registered Plans

Land and Property Information **LAND AND PROPERTY SEARCHES**

```
LAND AND PROPERTY INFORMATION NEW SOUTH WALES - TITLE SEARCH
------------------------------------------------------------


FOLIO: 1/253346
------

            SEARCH DATE       TIME            EDITION NO    DATE
            -----------       ----            ----------    ----
            7/7/2005          4:27 PM              2
6/10/1999


LAND
----
LOT 1 IN DEPOSITED PLAN 253346
   AT ARMIDALE
   LOCAL GOVERNMENT AREA: ARMIDALE DUMARESQ
   PARISH OF GARA   COUNTY OF SANDON
   TITLE DIAGRAM: DP253346

FIRST SCHEDULE
--------------
KENNETH PAUL WATERS
DEIRDRE ANTOINETTE WATERS
    AS TENANTS IN COMMON IN EQUAL SHARES                       (T
Q666085)

SECOND SCHEDULE (7 NOTIFICATIONS)
---------------
1.  LAND EXCLUDES MINERALS AND IS SUBJECT TO RESERVATIONS AND
    CONDITIONS IN FAVOUR OF THE CROWN - SEE CROWN GRANT(S)
2.  L54189     EASEMENT FOR TRANSMISSION LINE AFFECTING THE
               PART(S) SHOWN SO BURDENED IN THE TITLE DIAGRAM
        O914674   EASEMENT VESTED IN NEW SOUTH WALES ELECTRICITY
                  TRANSMISSION AUTHORITY
3.  LAND EXCLUDES THE ROAD SHOWN IN DP253346
4.  Q666086    MORTGAGE TO WESTPAC BANKING CORPORATION (FORMERLY
               BANK OF NEW SOUTH WALES)
5.  S517224    EASEMENT FOR TRANSMISSION LINE AFFECTING THE LAND
               SHOWN SO BURDENED IN DP610616
        O892591   EASEMENT VESTED IN THE NEW SOUTH WALES
                  ELECTRICITY TRANSMISSION AUTHORITY
6.  3443111    LEASE TO TELSTRA CORPORATION LIMITED OF THE "WORKS
               AREA" SHOWN HATCHED IN PLAN WITH 3443111 EXPIRES
               30.6.2016
7.  6247078    MORTGAGE TO RABOBANK AUSTRALIA LIMITED

NOTATIONS
---------
UNREGISTERED DEALINGS: NIL
```

Land and Property Information **LAND AND PROPERTY SEARCHES**

```
LAND AND PROPERTY INFORMATION NEW SOUTH WALES - TITLE SEARCH
-----------------------------------------------------------

FOLIO: 2/253346
------

            SEARCH DATE         TIME            EDITION NO    DATE
            -----------         ----            ----------    ----
            7/7/2005            4:20 PM             2
24/5/1999


LAND
----
LOT 2 IN DEPOSITED PLAN 253346
   AT ARMIDALE
   LOCAL GOVERNMENT AREA: ARMIDALE DUMARESQ
   PARISH OF GARA   COUNTY OF SANDON
   TITLE DIAGRAM: DP253346

FIRST SCHEDULE
--------------
DERRY WALLACE CRISP
GAIL MARGARET CRISP
    AS JOINT TENANTS                                          (T
W692772)

SECOND SCHEDULE (5 NOTIFICATIONS)
---------------
1.  LAND EXCLUDES MINERALS AND IS SUBJECT TO RESERVATIONS AND
    CONDITIONS IN FAVOUR OF THE CROWN - SEE CROWN GRANT(S)
2.  L54189     EASEMENT FOR TRANSMISSION LINE AFFECTING THE
               PART(S) SHOWN SO BURDENED IN THE TITLE DIAGRAM
        O914674    EASEMENT VESTED IN NEW SOUTH WALES ELECTRICITY
                   TRANSMISSION AUTHORITY
3.  LAND EXCLUDES THE ROAD SHOWN IN DP253346
4.  S258823    EASEMENT FOR TRANSMISSION LINE AFFECTING THE LAND
               SHOWN SO BURDENED IN DP610616
        O892591    EASEMENT VESTED IN THE NEW SOUTH WALES
                   ELECTRICITY TRANSMISSION AUTHORITY
5.  5845435    MORTGAGE TO NATIONAL AUSTRALIA BANK LIMITED

NOTATIONS
---------
UNREGISTERED DEALINGS: NIL

        ***  END OF SEARCH  ***
```

D P 253346 1/3

PLAN FORM 2

Signatures and seals only.

...ING CO. PTY. LIMITED Common Seal

Director

Secretary

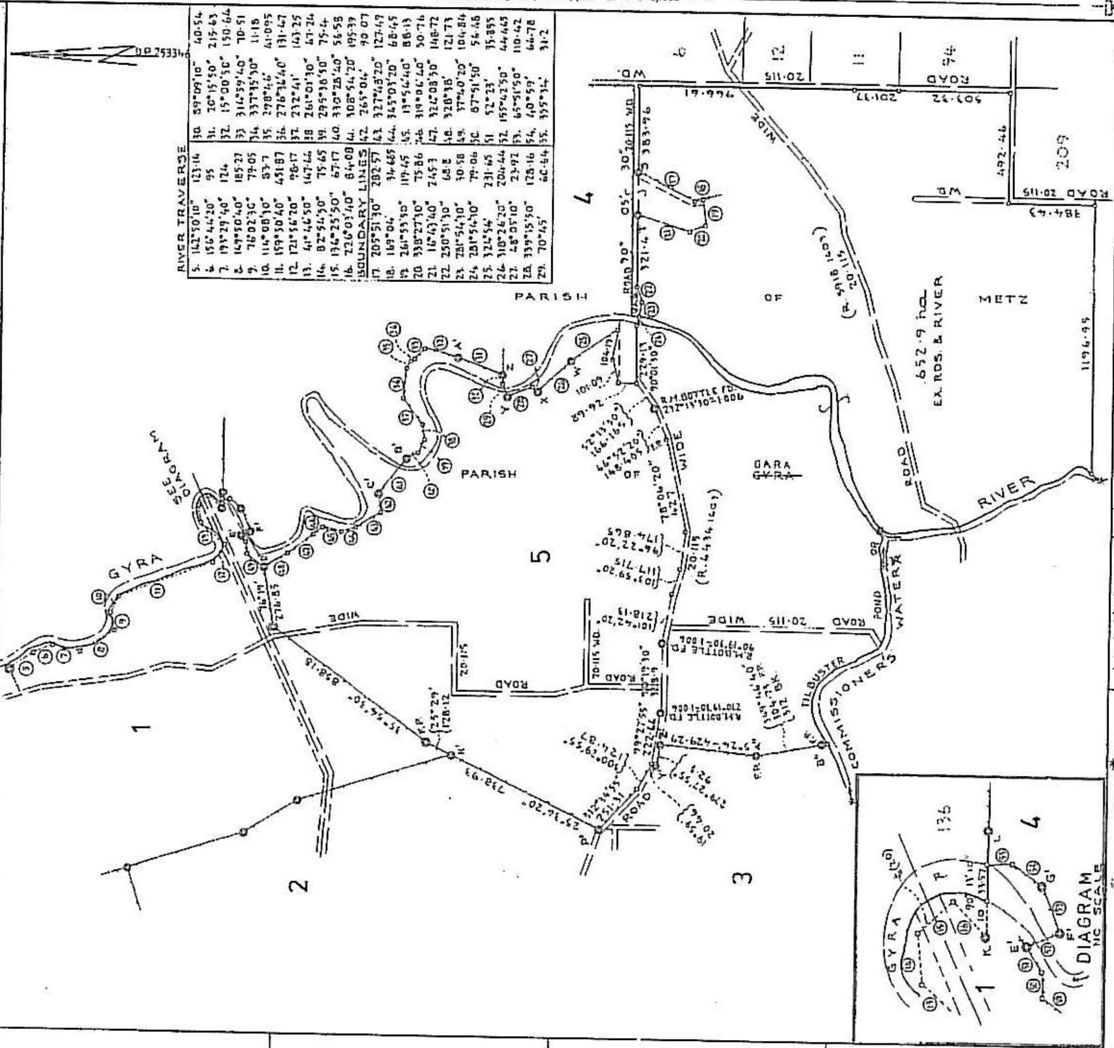
THE NATIONAL BANK OF AUSTRALASIA LIMITED as Mortgagee hereby consents to within Plan.

SIGNED ... LIMITED

WILLIAM JOHNSTONE FREW

WILLIAM JOHNSTONE FREW ... LENDING MANAGER

← Plan Drawing only to appear in this space



RIVER TRAVERSE					
5.	142°50'10"	123·14	30.	59°09'10"	40·54
6.	156°44'20"	95	31.	20°15'50"	215·63
7.	193°29'40"	124	32.	15°00'50"	150·64
8.	149°50'40"	185·27	33.	314°39'40"	70·51
9.	76°02'30"	79·05	34.	337°35'30"	11·18
10.	114°08'10"	83·7	35.	298°46'	41·095
11.	159°50'40"	451·87	36.	276°34'40"	131·47
12.	121°56'20"	98·17	37.	232°41'	143·25
13.	41°44'50"	147·44	38.	261°01'30"	47·24
14.	82°54'50"	75·65	39.	295°38'50"	75·4
15.	134°25'50"	67·17	40.	330°28'40"	56·58
16.	226°03'40"	84·08	41.	308°54'20"	195·39
BOUNDARY LINES			42.	265°04'	90·07
17.	205°51'30"	282·57	43.	327°48'20"	127·49
18.	169°04'	34·485	44.	345°03'20"	68·45
19.	261°55'50"	119·45	45.	13°54'40"	88·13
20.	338°27'30"	75·86	46.	319°06'40"	50·76
21.	16°43'40"	745·3	47.	324°08'50"	148·72
22.	250°51'30"	68·8	48.	328°38'	121·73
23.	281°54'10"	30·58	49.	37°40'20"	104·84
24.	281°54'10"	79·06	50.	87°51'50"	54·48
25.	324°54'	231·65	51.	52°23'	35·895
26.	318°26'20"	204·44	52.	155°42'50"	44·445
27.	48°05'10"	23·92	53.	65°51'50"	110·42
28.	339°15'50"	128·16	54.	40°59'	64·78
29.	70°45'	60·64	55.	355°34'	31·2

DP 253346 OFFICE USE ONLY

D P 253346

Registered: RP 24-1-1977

C.A.: N° 11/76 of 12-11-1976

Title System: TORRENS

Purpose: SUBDIVISION

Ref. Map: PARISH

Last Plan:

PLAN OF SUBDIVISION OF
THE LANDS IN C'S OF T.
VOL: 1459 FOL: 172,
VOL: 7336 FOL: 156 AND
VOL: 9450 FOL: 102.

Reduction Ratio 1: 12500
Lengths are in metres.

Mun./Shire ~~City~~: DUMARESQ

Locality: ARMIDALE

Parish: GARA ~~GYRA~~ & METZ

County: SANDON

This is sheet 1 of my plan in 3 sheets.
(Delete if inapplicable).

I, John Stanley Hawkins of P.O. Box 456, Armidale, 2350 a surveyor registered under the Surveyors Act, 1929, as amended, hereby certify that the survey represented in this plan Lot 5 compiled as to part is accurate and has been made *(1) by me ~~(2) under my immediate supervision~~ in accordance with the Survey Practice Regulations, 1933, and was completed on † 8.10.76.

Signature

Surveyor registered under Surveyors Act, 1929, as amended.
Datum Line of Azimuth X" Y"
*Strike out either (1) or (2). †Insert date of survey.

Panel for use only for statements of intention to dedicate public roads or to create public reserves, drainage reserves, easements or restrictions as to user.

*Pursuant to Section 88B of the Conveyancing Act, 1919-1964, it is intended to create a Right of Carriageway 20 Wide

INSTRUMENT FILED AS Q 1646

A Y 0 0 5 A A

D P 253346 1/3

Council Clerk's Certificate

I hereby certify that –

(a) the requirements of the Local Government Act, 1919 (other than the requirements for the registration of plans), and

~~*(b) the requirements of section 32B of the Metropolitan Water, Sewerage and Drainage Act, 1924, as amended. (Hunter District Water, Sewerage and Drainage Act, 1938, as amended)~~

have been complied with by the applicant in relation to the proposed Subdivision.
(Insert "new road", "subdivision" or "consolidated lot") set out herein

Subdivision No. 11/76

Date 12/11/76

(Signature) Deputy Council Clerk

*This part of certificate to be deleted where the application is only for a consolidated lot or the opening of a new road or where the land to be subdivided is wholly outside the area of operations of the Metropolitan Water Sewerage and Drainage Board and the Hunter District Water Board.
†Delete if inapplicable.

M P.D.

Table of mm

WARNING: CREASING OR FOLDING WILL LEAD TO REJECTION

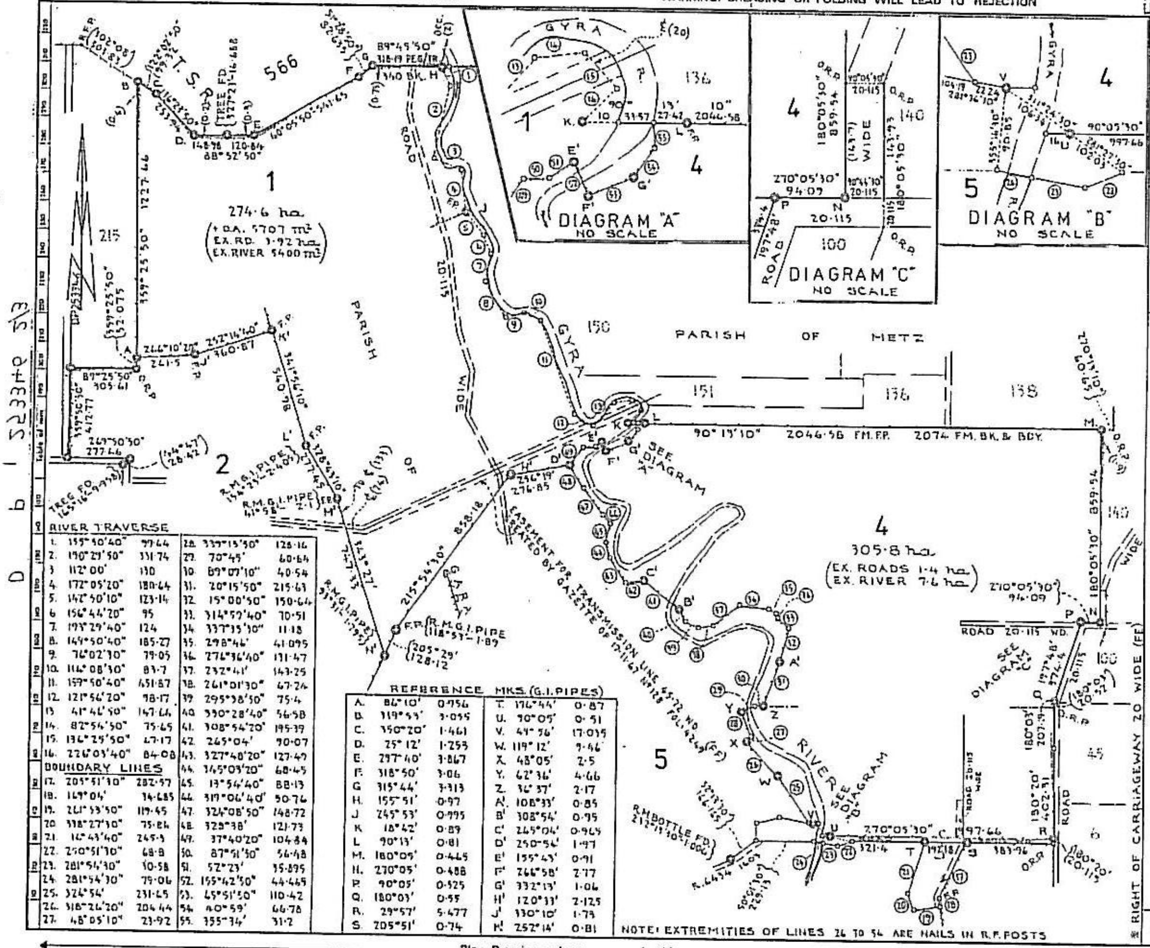
A.W. Simpson

SURVEYOR'S REFERENCE: GARA

I, Bruce Richard Davies, Registrar General for New South Wales, certify that this negative is a photograph made as a permanent record of a document in my custody this 26th day of January, 1977

PLAN FORM 3 To be used in conjunction with Plan Form 2

WARNING: CREASING OR FOLDING WILL LEAD TO REJECTION



RIVER TRAVERSE

1.	155°50'40"	97·44	28.	339°15'50"	126·16
2.	190°29'50"	331·74	29.	70°49'	60·64
3	112°00'	130	30.	89°07'10"	40·54
4.	172°05'20"	180·64	31.	20°15'50"	215·63
5.	142°50'10"	123·14	32.	15°00'50"	150·64
6	156°44'20"	95	33.	314°57'40"	70·51
7.	193°29'40"	124	34.	337°35'30"	11·18
8.	149°50'40"	185·27	35.	298°46'	41·095
9.	76°02'30"	79·05	36.	276°36'40"	131·47
10.	114°08'30"	83·7	37.	232°41'	143·25
11.	159°50'40"	451·87	38.	261°01'30"	67·24
12.	121°56'20"	98·17	39.	295°38'50"	75·4
13	41°46'50"	147·66	40.	330°28'40"	56·58
14.	82°54'50"	75·65	41.	308°54'20"	195·39
15.	136°29'50"	67·17	42.	245°04'	90·07
16.	226°03'40"	84·08	43.	327°48'20"	127·49

BOUNDARY LINES

17.	205°51'10"	282·57	44.	345°03'20"	68·45
18.	149°04'	34·685	45.	19°54'40"	88·13
19.	261°33'50"	119·45	46.	319°06'40"	50·76
20.	338°27'30"	75·84	47.	324°08'50"	148·72
21.	16°43'40"	245·5	48.	329°38'	121·73
22.	250°51'30"	68·8	49.	37°40'20"	104·84
23.	281°54'30"	10·58	50.	87°51'30"	56·48
24.	281°54'30"	79·06	51.	52°23'	35·895
25.	324°54'	231·65	52.	155°42'50"	44·449
26.	318°26'20"	204·44	53.	45°51'50"	110·42
27.	48°05'10"	23·92	54.	40°59'	66·78
			55.	355°34'	31·2

REFERENCE MKS. (G.I. PIPES)

A.	86°10'	0·756	T.	176°44'	0·87
B.	319°53'	3·055	U.	90°05'	0·51
C.	350°20'	1·461	V.	49°56'	17·035
D.	25°12'	1·253	W.	119°12'	9·46
E.	297°40'	3·867	X.	48°05'	2·5
F.	318°50'	3·06	Y.	62°36'	4·66
G	315°44'	3·313	Z.	36°37'	2·17
H.	155°51'	0·97	A'.	108°33'	0·85
J	245°53'	0·995	B'	308°54'	0·95
K	18°42'	0·89	C'	245°04'	0·965
L	90°13'	0·81	D'	250°54'	1·97
M.	180°09'	0·445	E'	155°43'	0·91
N.	270°05'	0·488	F'	266°58'	2·77
P.	90°05'	0·525	G'	332°13'	1·06
Q.	180°03'	0·55	H'	120°33'	2·125
R.	29°57'	5·477	J'	330°10'	1·79
S.	205°51'	0·74	K'	252°14'	0·81

NOTE: EXTREMITIES OF LINES 26 TO 54 ARE NAILS IN R.F. POSTS

Plan Drawing only to appear in this space

DP253346R OFFICE USE ONLY

D. P. 253346

Registered: 24·1·1977

This is sheet 2 of my plan in 3 sheets dated 8·10·1974

Surveyor registered under Surveyors Act 1929.

This is sheet 2 of the plan of 3 Sheets covered by my Certificate No. 11/76 of 12/11/76.

Ulrow
Deputy Council Clerk.

Signatures and seals duly.

Common Seal

F.C. Collins
Director

Secretary

Reduction Ratio 1: 12500

Lengths are in metres

SURVEYOR'S REFERENCE. GARA

D P 253346 2/3

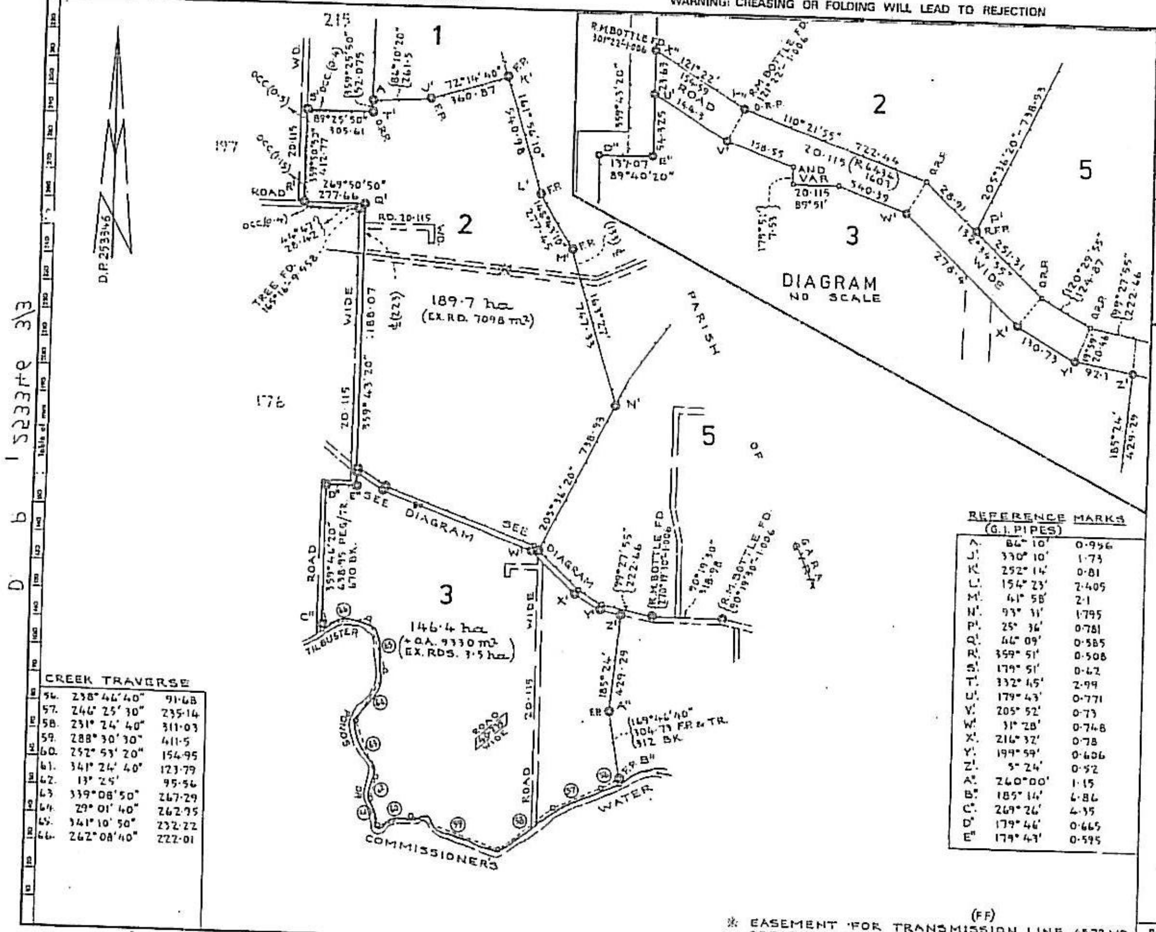
I, Bruce Richard Davies, Registrar General for New South Wales, certify that this negative is a photograph made as a permanent record of a document in my custody this 24th day of January, 1977

PLAN FORM 3 To be used in conjunction with Plan Form 2

WARNING: CREASING OR FOLDING WILL LEAD TO REJECTION

• OFFICE USE ONLY

D P 253346 3/3



(FF)
※ EASEMENT FOR TRANSMISSION LINE 45·72 WD. CREATED BY GAZETTE OF 17·11·47 Nº128 FOL. 4249

CREEK TRAVERSE

56.	238° 46' 40"	91·68
57.	246° 25' 30"	235·14
58.	231° 24' 40"	311·03
59.	288° 30' 30"	411·5
60.	252° 53' 20"	154·95
61.	341° 24' 40"	123·79
62.	13° 25'	95·56
63	339° 08' 50"	267·29
64.	29° 01' 40"	262·75
65.	341° 10' 50"	232·22
66.	262° 08' 40"	222·01

REFERENCE MARKS
(G.I. PIPES)

A.	84° 10'	0·956
J'.	330° 10'	1·73
K'.	252° 14'	0·81
L'.	154° 23'	2·405
M'.	41° 58'	2·1
N'.	93° 31'	1·795
P'.	25° 36'	0·781
Q'.	46° 09'	0·585
R'.	359° 51'	0·508
S'.	179° 51'	0·62
T'.	332° 45'	2·99
U'.	179° 43'	0·771
V'.	205° 52'	0·73
W'.	31° 28'	0·748
X'.	216° 32'	0·78
Y'.	199° 59'	0·606
Z'.	5° 24'	0·52
A".	240° 00'	1·15
B".	185° 14'	6·86
C".	269° 26'	4·35
D".	179° 46'	0·665
E"	179° 43'	0·595

D. P. 253346

Registered: RP 24·1·1977

This is sheet 3 of my plan in 3 sheets
dated 8·10·1976

Surveyor registered under Surveyors Act 1929.

This is sheet 3 of the plan of 3
Sheets covered by my Certificate No. 11/76
of 12/11/76

Deputy Council Clerk

Signatures and seals only.

Common Seal

R.O. Leothers
Director

Secretary

THE NATIONAL BANK OF AUSTRALASIA LIMITED
as Mortgagee hereby consent to within Plan

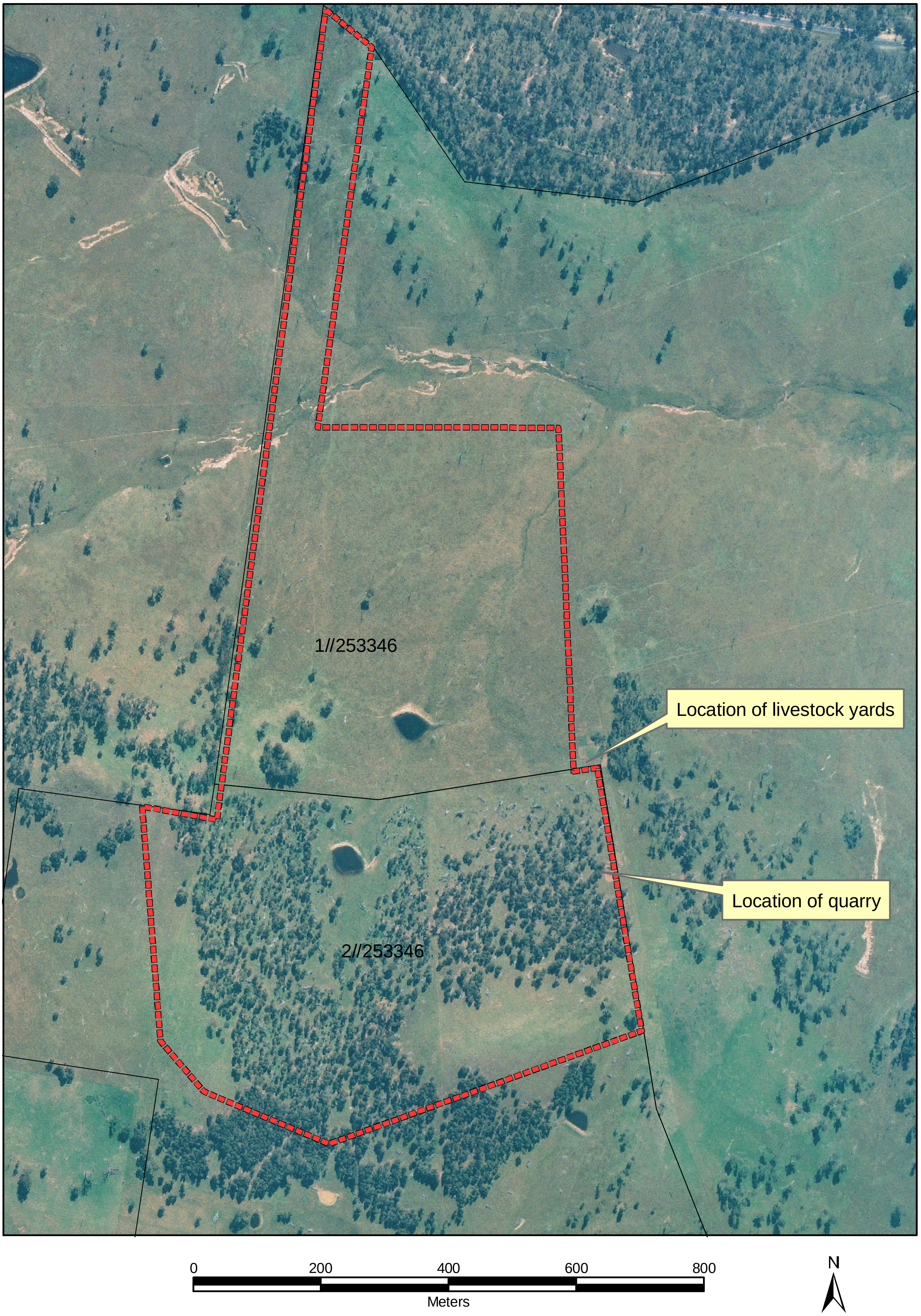
Reduction Ratio 1: 12500
Lengths are in metres

Plan Drawing only to appear in this space

SURVEYOR'S REFERENCE GARA

I, Bruce Richard Davies, Registrar General for New South Wales, certify that this negative is a photograph made as a permanent record of a document in my custody this 24th day of January, 1977

Appendix B. Aerial Photograph

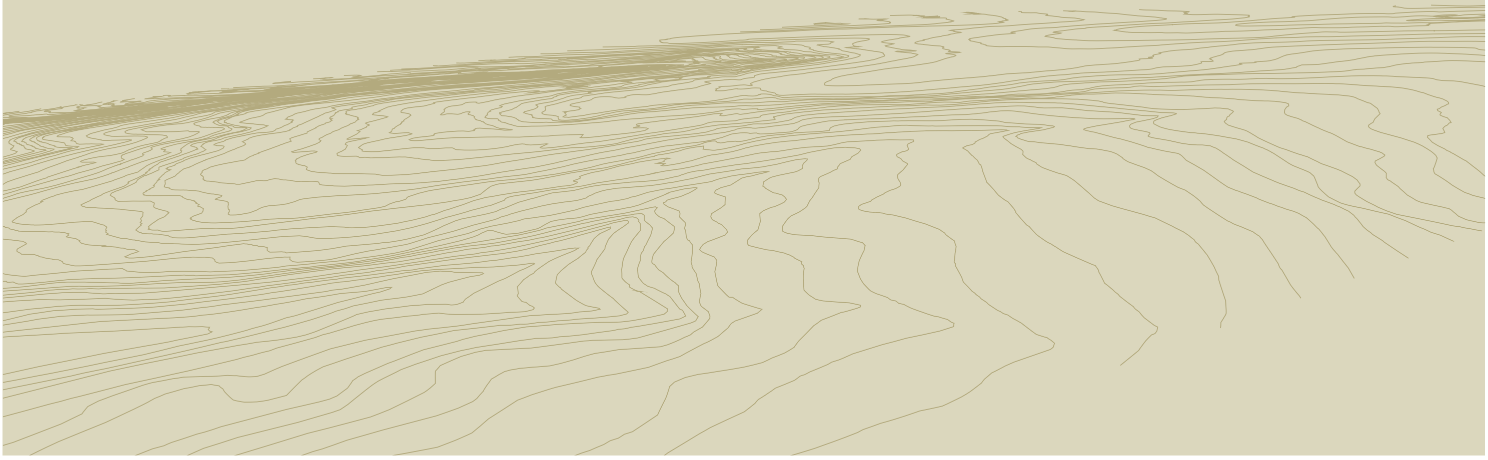

1//253346
2//253346
Location of livestock yards
Location of quarry
0
200
400
600
800
Meters
N

Appendix L

EA Systems, 2006: Salinity Assessment

ARMIDALE REGIONAL LANDFILL

Environmental Assessment



~ Commercial-in-Confidence ~

Salinity Assessment

FINAL REPORT

Armidale Dumaresq Council Landfill Facility Salinity Assessment

Report Number 20969. 13866

Prepared for *by*

Armidale Dumaresq Council

ENVIRONMENTAL & AGRICULTURAL SCIENCE & ENGINEERING

PO Box 75A
ARMIDALE NSW 2350
Telephone: (02) 6770 3600
Facsimile: (02) 6772 9275

PO Box 1251
ARMIDALE NSW 2350
Telephone: (02) 6771 4864
Facsimile: (02) 6771 4867
ABN: 67 081 536 281

Document Status Record

Report Type: Salinity Assessment

Project Title: Armidale Dumaresq Council Landfill Facility Salinity Assessment

Client: Armidale Dumaresq Council

Job.Document Number: 20969.13866

File Name: 20969.13866 Final Salinity Report.doc

Issue No.	Date of Issue	Author	Checked	Approved
1	27 November 2005	Amy Harburg	Martin Dillon	Simon Lott
Signatures		-	M. Dillon	A. C. Lott.

Notes:	Recipient	No. Copies
Issue 1 – Preliminary Draft Report 7 Nov 2005	Maunsell Australia	1
Issue 2 –Draft Report 19 Dec 2005	Maunsell Australia	1
Issue 3 –Final Report 27 Nov 2006	Maunsell Australia	1

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

Table of Contents

List of Tables

List of Figures

List of Appendices

1. Introduction

E.A. Systems Pty Limited has been commissioned by Maunsell Australia to complete a Hydrogeotechnical Investigation for a proposed landfill site for Armidale. This investigation is a component of the Environmental Assessment prepared on behalf of Armidale Dumaresq Council. As part of the hydrogeotechnical investigation a salinity assessment was conducted at the site to identify any soil salinity issues or saline groundwater that may impact upon the site.

This Salinity Investigation was prepared to:

- Describe and identify the soil landscape of the site;
- Identify any limitations of the soils in regard to the proposed development; and
- Identify the potential salinity related impacts that the landfill may have on localised soil and groundwater conditions.

The salinity investigation consisted of two components. A desktop study was conducted to identify the soil landscapes of the site and a site assessment of the physical and chemical attributes was also undertaken

A soils investigation was completed across the site. This investigation aimed to ground-truth the Electro-Magnetic conductivity (EM) survey results. This provides a more accurate indication of soil conditions across the site and assesses the potential for salinity at the site. Nine test pits were excavated with a backhoe to a depth of approximately 1.5 metres below ground surface. The pits were excavated to allow the collection of bulk samples and to gain a greater understanding of the soil profile. Fifteen representative (15) soil samples were taken from the site for analysis by Lanfax Laboratories, Armidale. Lanfax is an Australian Soil and Plant Analysis Council (ASPAC) proficiency tested laboratory.

1.1 Location of Study Site

The regional context of the site is presented Figure 1.The study site is located approximately 12 km east of the Armidale CBD along the Waterfall way (also known as the Grafton Road) on portions of the two properties *Sherraloy* and *Edington*. The footprint of the proposed landfill will occupy a site approximately 1 kilometre south of the Waterfall way. The estimated total area for the site including buffers and access routes is approximately 100 hectares. The approximate centre of the study site is located at E 30^{o} 33’ 30” and N 151^{o}47’ 30”(AGD 1966 AMG Zone 56) on the Hillgrove (92361N 1:25,000 Topographic Map. The local context of the site is presented in Figure 2.

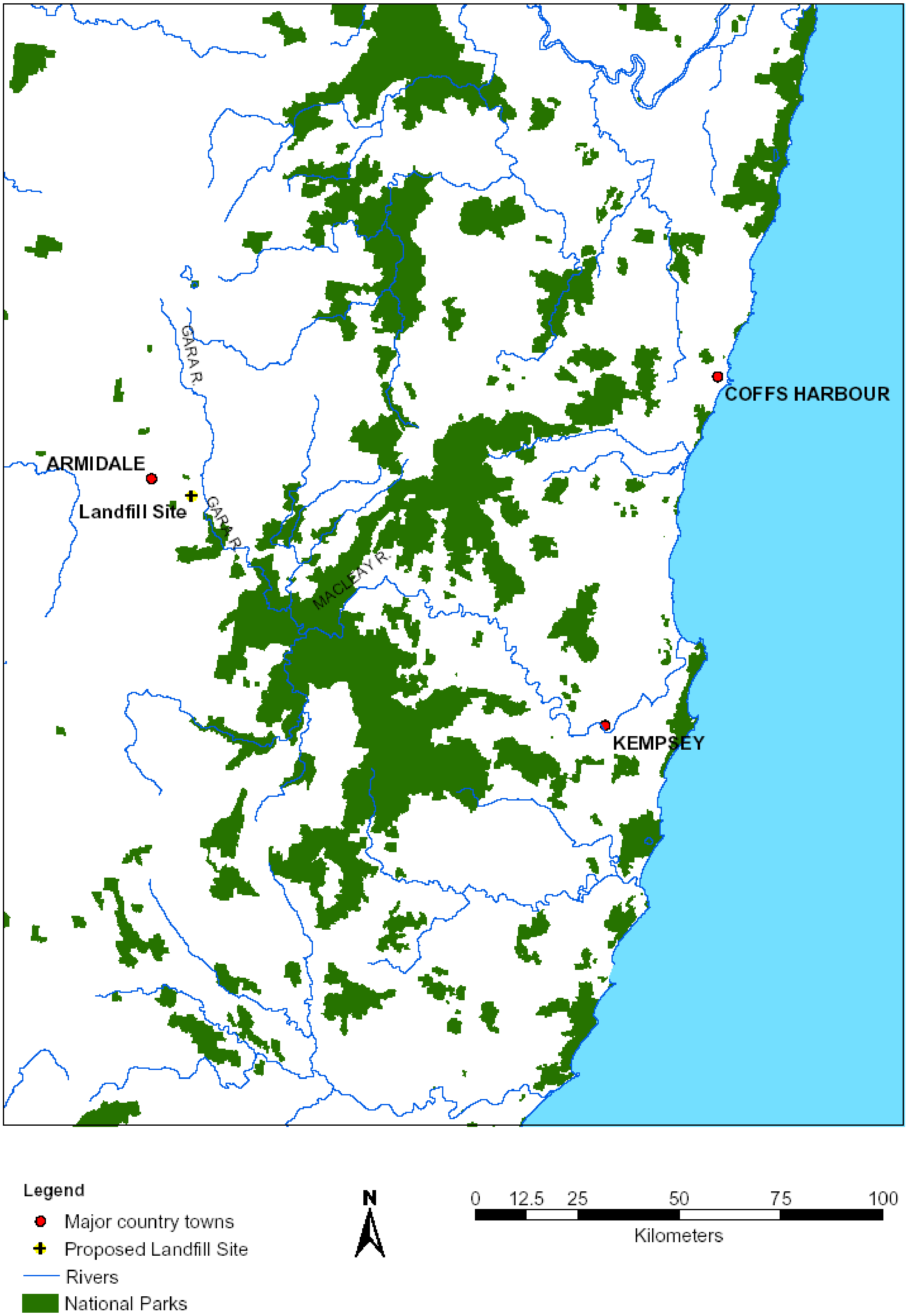


Figure 1. Regional Context of the Study Site.

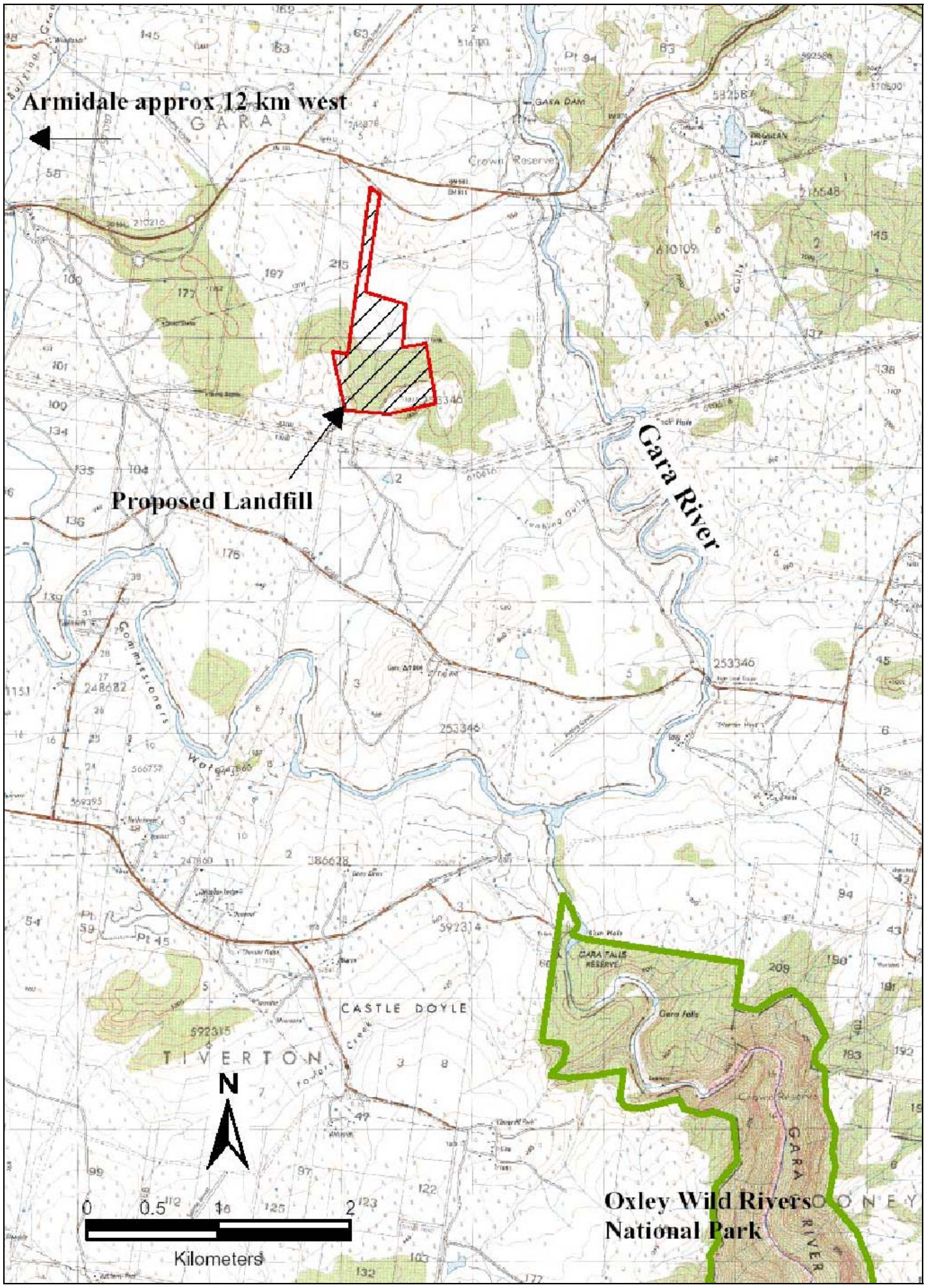


Figure 2. Local Context of the Study Site

2. Armidale Soil Landscape

The most recent and comprehensive soil survey of the area was prepared by the Department of Natural Resources and is currently in draft copy by King, D.P. (in prep), *Soil Landscapes of the Armidale 1:100 000 Sheet* Report, Department of Natural Resources, Sydney.

The proposed landfill site occurs predominantly within two soil landscape groups; Argyle and Middle Earth. A small section of site, located along the drainage gullies, is classified as Commissioners Waters. The distribution of soil landscape classes on and around the study site is presented in Figure 3. King (in prep, 2005) provides the following description of the Argyle, Middle Earth and Commissioners Waters soil landscapes.

2.1 "Argyle" Soils

The Argyle soil landscape group has a landscape of rolling low hills and occasional hills on greywacke/chert and related sediments. Local relief typically ranges from 30 - 80 m, slopes mostly 10 - 30%, and elevation between 910 – 1170 m . Minor rock outcrops if present generally occupy less than 10% of the surface. Typical vegetation on this type of soil in the region is partially cleared *Eucalyptus caliginosa* (New England stringybark) open woodland.

Soil in the Argyle landscape are typified by very shallow to shallow (<50 cm), well drained Basic Lithic Leptic Rudosols (Lithosols) and other shallow soils on crests, ridges and upper slopes. Shallow to moderately deep (40- 80 cm) moderately well drained Haplic Eutrophic Yellow Kandosols/Tenosols (Yellow Earths) occur on midslopes and occasionally extend onto crests. Shallow to moderately deep (<80 cm) moderately well drained Yellow/Red and Grey Chromosols (Yellow and Red Podzolic Soils) occur on mid slopes, footslopes and drainage lines. Mottled-Subnatric Eutrophic Brown and Yellow Sodosols (Soloths) occur along some drainage depressions.

The geology of the area includes the Permian to Late Carboniferous Coffs Harbour Association (the Girrakool Beds) and some Devonian-Carboniferous Sandon Association metasediments. Lithology is mostly lithofeldspathic wacke (greywacke), with slate, shale, mudstone, siltstone, chert and rare mafic and felsic volcanics (Gilligan *et al*. 1992). In the vicinity of the "Argyle" landscape group, greywacke is the most commonly occurring rock type. Other common rock types in the area include chert and sandstone. The greywacke/chert and related rocks are seldom heavily weathered forming resistant outcrops which rise above the surrounding less resistant countryside. Some metamorphosed rocks e.g. slates, phyllites, and schists may also be present. The geology is often locally referred to as trap or traprock country.

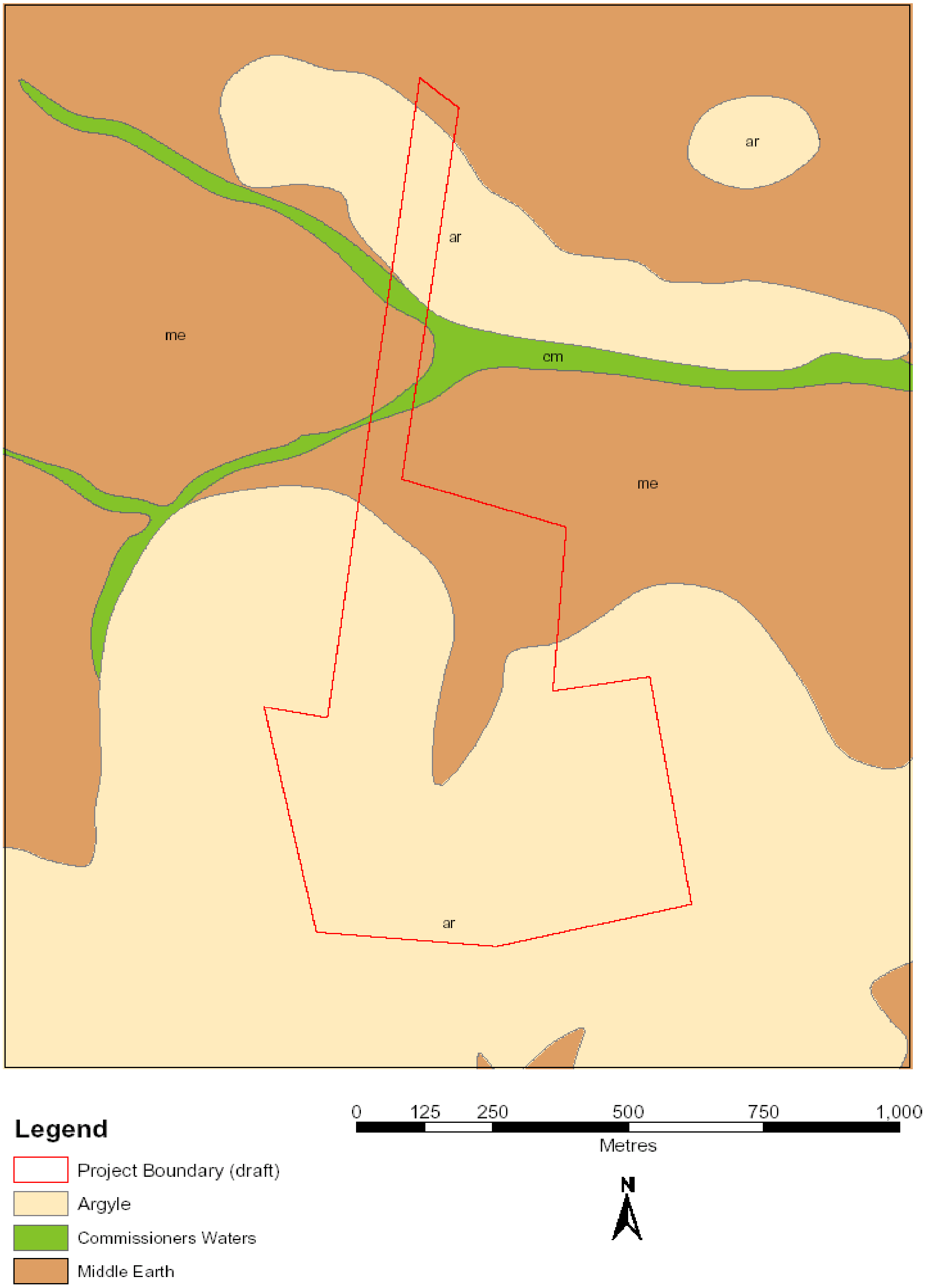


Figure 3. The distribution of soil landscape classes around the study (King, in prep, 2005)

2.2 “Middle Earth” Soils

The Middle Earth landscape occupies undulating plains, rises and footslopes on Sandon Beds. Local relief ranges from 0-30 m, slopes range from 0-10%, and elevation falls between 910 - 1120 m. Typical vegetation cover is partially to extensively cleared open woodland.

The soils across the Middle Earth landscape group can be identified as moderately deep to deep (>70 cm), moderately well drained Bleached-Mottled Haplic Eutrophic Yellow Kurosols and Chromosols (Yellow Podzolic Soils). Deep (>100 cm), poorly drained Yellow Chromosols and Mottled-Mesonatric and Mottled-Subnatric Eutrophic Yellow Sodosols (Soloths) and Bleached-Manganic and Bleached-Ferric Eutrophic Yellow Chromosols (Lateritic Podzolic Soils/Grey Brown Podzolic Soils) occupy drainage depressions and poorly drained areas. There are occasional shallow (<40 cm), well drained Bleached Eutrophic Yellow Kandosols (Yellow Earths) on slopes with bedrock close to the surface.

Geology and Regolith of the Middle earth landscape group is identified as Sandon Beds. Greywacke is the main rock type with chert, slate, and ferricrete. Some Girrakool Beds (Coffs Harbour Association) with a similar lithology underlie parts of this landscape. Traise (1973) noted the soil colour at any give site reflected the bedrock from which the soil was developed with rusty brown coloured soils associated with chert and a dusty yellow colour associated with the greywacke lithologies.

2.3 “Commissioners Waters” Soils

The Commissioners Waters landscape group is described as narrow streams, swamps and occasional small floodplains/terraces on Quaternary alluvium. This soil landscape is present along local waterways including Commissioners Waters and the Gara River. Local relief typically ranges from 0-10 m, slopes 0 – 3%, and elevation 900 –1070 m. Typical vegetation cover is extensively cleared open woodland.

Commisioners Waters soils are variable according somewhat to the source rocks from which they are derived. Shallow to moderately deep (40 – 100 cm) well drained Alluvial Sands and Alluvial Loams (Yellow/ Brown and Grey Earths) occur in areas derived from coarse grained parent materials. Moderately deep to deep (>80 cm), moderately well drained Mottled Eutrophic Grey Chromosols/Grey Sodosols (Gleyed Podzolic Soils/Grey Brown Podzolic Soils/ Lateritic Podzolic Soils) are also fairly common.

The geology and Regolith of Commissioners Waters include quaternary alluvium derived primarily from metasediments (the Sandon Beds). Some areas also have some granite source rock – the Gara adamellite and Hillgrove adamellite and more rarely basalt source rock (giving rise to slightly darker coloured soils).

3. Field observations

The investigation site can be broadly broken down into three geomorphological areas; the ‘flats’ running out to the creek line (See Plate 1 below), the wooded mid-slope(See Plate 2 below) area and the rocky crests of the hills. These areas, and the locations of the excavated test pits on the study site are presented in Figure 4. With the exception of the hill crests where the profile was generally shallower and contained more rock, the soils were relatively uniform across the site. The general soil profile also reflected those described by King, P, D (in prep) in the soil landscape group classifications.

Plate 1. The ‘flats running down to the creek line (photo taken from across the main drainage line looking south up towards the proposed landfill.

Plate 2. Typical area of the wooded midslope area.

Figure 4. Site geomorphology and the locations of the test pits.

Generally, the soils in the lower section of the site showed;

Layer 1, A1 topsoil horizon of approximately 150 mm thick. This soil can be described as very dark brown to greyish brown (10YR 3/1 or 3/2) with a clay loam texture. The soil in this horizon contains some sand and gravel. An abrupt boundary to...

Layer 2, highly bleached A2 horizon, extended from approximately 150 mm to 300 mm. Greyish yellow brown (10YR 5/2) to bleached light grey (10YR 8/2D) hardsetting sandy clay. The highly bleached nature of the A2 horizon indicates that this is a layer of high permeability and transient flow. The transient flow is generated by the less permeable clay layer underlying the A2 horizon. An abrupt boundary to…

Layer 3, B1 horizon, extending form a depth of approximately 300mm to 550mm.Yellowish Red (5YR 5/8) to strong brown (7.5YR 5/8) heavy clay. This clay is generally sticky with an absence of rock or gravel.

Layer 4, B2 horizon, extending from a depth of approximately 550 mm to a depth of around 850mm. Yellowish brown (10YR 6/6) heavy clay. This stiff clay has a number of gravel seams through it, which may provide a conduit for the movement of groundwater. These gravels are generally small and angular.

Layer 5, B3 horizon. Depth >900mm. Below these clays are sub-soils of decomposed and mineralised, sedimentary sandstone rock. The backhoe investigation encountered difficulties digging through this layer, which provides and indication of the soil strength. The light drilling operation ground this material into fine clay.

Plate 3 shows the soil profile of pit 1, which is typical for the lower areas of the site.

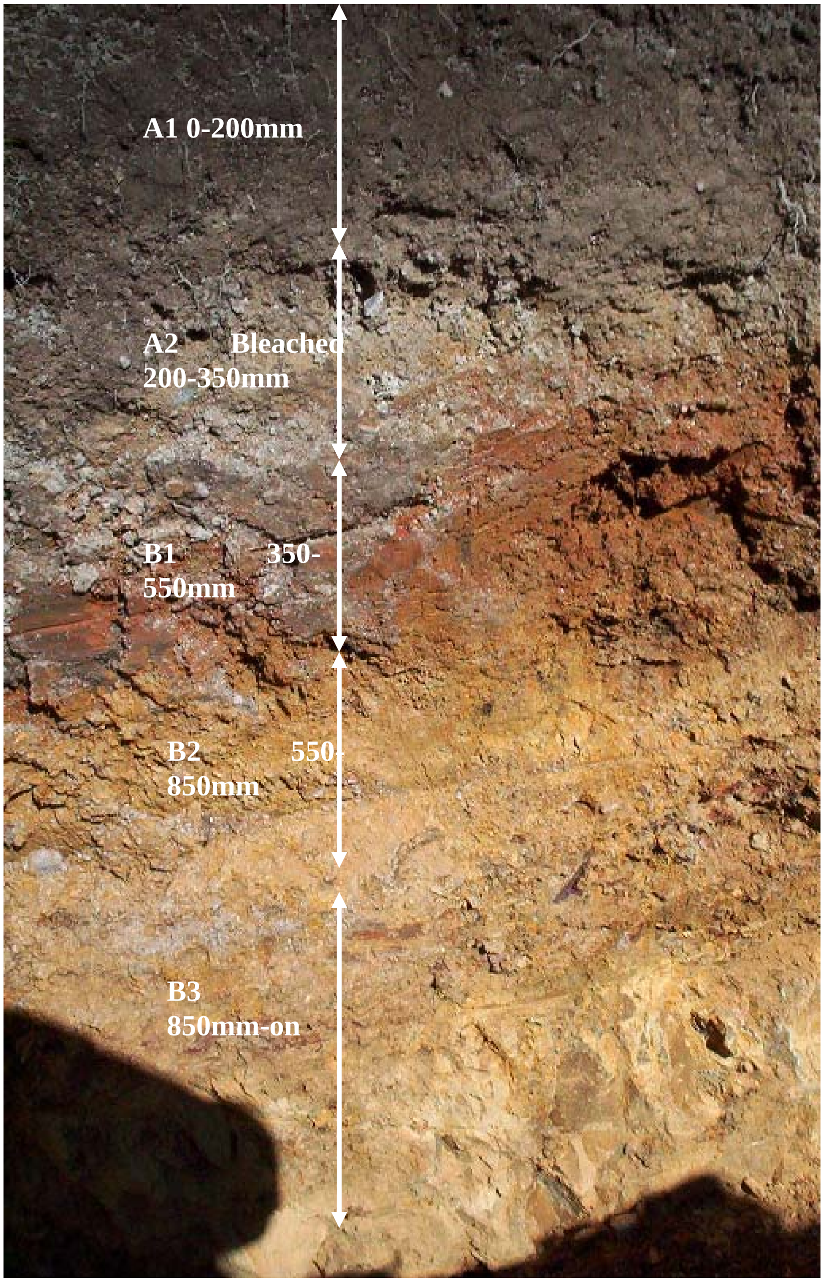


Plate 3. Soil profile at Pit 1. This profile is typical of the soils lower at the site.

Further up the slope to soil can generally be described as;

Layer 1, A1 topsoil horizon of approximately 150 mm thick. This soil can be described as very dark brown to greyish brown (10YR 3/1 or 3/2) with a clay loam texture. The soil in this horizon contains some sand and gravel. An abrupt boundary to...

Layer 2, A2 horizon, extended from approximately 150 mm to 300 mm. A small horizon of Brown (10YR 5/3) to brownish yellow (10YR 6/8) heavy clay. This layer has some sand and small gravel throughout.

Layer 3, B1 horizon, extending form a depth of approximately 300mm to 1100mm. Brown (10YR 5/3) to brownish yellow (10YR 6/8) heavy clay with orange and grey mottles.

Layer 4, B2 horizon, extending form a depth of approximately 1100 mm to 1450mm. Olive Yellow (2.5YR 6/8) heavy clay, very smooth and no rocks.

Plate 4 below shows the soil profile of pit 6, which is typical for the upper areas of the site.

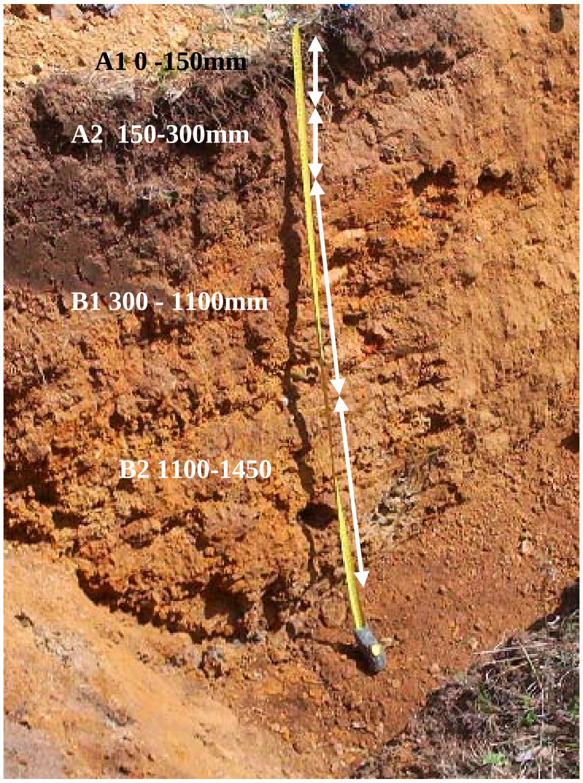


Plate 4. Soil Profile in pit 6. This profile is typical of soils further up the slope.

4. Laboratory results

Fifteen samples from four profiles were sent to Lanfax Laboratories, Armidale for analysis. Lanfax is an Australian Soil and Plant Analysis Council (ASPAC) proficiency tested laboratory.

Soils were analysed for:

- pH (1:5 soil/0.01M $CaCl_2$),
- Electrical Conductivity (1:5 soil/water suspension),
- Sodium (Na),
- Potassium (K),
- Calcium (Ca),
- Magnesium (Mg),
- Cation Exchange Capacity (CEC), and
- Slaking and Dispersion. (Emerson Aggregate Test)

Calculations were made for:

- Exchangeable Sodium Percentage (ESP), and
- Calcium/Magnesium Ratio.

The major salinity related analytes are electrical conductivity (ECe), sodium (Na), potassium (K), and exchangeable sodium percentage (ESP). Chemical analysis showed the soils to have mean ECe of 0.4 dS/m (range 0.1 - 1.1dS/m), mean Na levels of 255.2 mg/kg (range 12.0 - 931.5 mg/kg), and a mean ESP of 8.2% (range 1.3 - 24.1%) (Table1).

Table 1. Summary Table of Laboratory Analysis. n = number of samples

					Sampling Depth (mm)			
		Overall			**A1 0-200**	**A2 200-320**	**B 320-700**	**B2 700-1200**
		min	***mean***	***max***	***mean***	***mean***	***mean***	***mean***
	n	*15*	*15*	*15*	*4*	*4*	*4*	*2*
pH (CaCl)	*scale*	3.8	5.0	6.5	4.5	4.7	5.0	6.02
ECe	*dS/m*	0.1	0.4	1.1	0.30	0.02	0.05	0.65
Na	*mg/kg*	12.0	255.2	931.5	17.6	55.5	357.8	685.9
K	*mg/kg*	9.2	44.7	96.6	41.8	19.8	59.6	62.9
Ca	*mg/kg*	28.3	668.0	2422.0	406.0	296.8	769.7	1671.7
Mg	*mg/kg*	75.4	601.0	1365.0	97.8	212.2	974.9	1296.5
ESP	*%*	1.3	8.2	24.1	2.0	6.4	10.7	14.3
CEC	*mg/kg*	2.4	11.4	26.6	4.0	5.0	17.8	22.8
Ca / Mg	*ratio*	0.0	1.3	3.2	2.6	1.2	0.5	0.8

4.1 Soil pH

In general the soils at the site range from strongly acidic to slightly acidic with pHca range from 3.8 - 6.5. These pH levels are considered to be in the range common for most mineral soil (Peverill *et al*, 1999). A pH range of 4.5 to 6.5 is considered optimal for the growth of most plants species. The majority of the samples analysed fell within this optimal range. If the soils at the site continue to acidify over time possible amelioration strategies may include applying lime to the soil.

4.2 Emerson Aggregate Test

The Emerson aggregate test is a measure of soil structural stability in water (Patterson 1999). The degree of soil aggregate stability increases from Class 1 through to Class 8. Aggregates in Emerson Classes 1 and 2 are generally regarded as being unstable while those in classes 4 to 8 are considered to be stable. Results of the EAT on soils from the proposed landfill site are presented in table 2 below.

Table 2. Summary table of laboratory results – Emerson Class

Sample Number	Depth (mm)	Emerson Class	Description
Pit 1	0-200	8	No swelling
Pit 1	200-350	3	Dispersion
Pit 1	350-550	6	Complete flocculation
Pit 1	550-850	2	Some dispersion
Pit 1	850-1200	1	Complete dispersion
Pit 6	0-300	7	Swelling
Pit 6	300-1100	6	Complete flocculation
Pit 6	1100-1400	6	Complete flocculation
Pit 7	0-100	8	No swelling
Pit 7	100-300	3	Dispersion
Pit 7	300-800	2	Some dispersion
Pit 8	0-150	7	Swelling
Pit 8	150-320	6	Complete flocculation
Pit 8	320-700	6	Complete flocculation
Pit 8	700-1200	6	Complete flocculation

Soils from the A1 surface horizon from the site are classified as being in Emerson classes 7 and 8. This showed that soil aggregates either remained unchanged when immersed in water (Class 8) or the aggregates remained intact but showed some visible swelling (Class 7). This is mainly a function of the presents of organic matter in the soil. Many of the soils are in class 6 and displayed complete flocculation when dropped into water. Flocculation occurs when there are long-range attractive forces between clay particles, even if the clay particles are moved far apart in water, the particles come together again. This flocculating nature is noted in soils generally from the B1 or lower horizons. Soils pits 6 and 8 have a flocculating nature in all horizons except the A1 surface horizon. The soil from the A2 horizon in pit 1 has a dispersive nature, this soil can be unstable when wet. Some soils are classified as Class 1 or 2 these samples were reported, by the laboratory, as being mostly weathered and decaying sandstone rock fragments.

4.3 Soil Salinity

Soil salinity is a measure of the presence of water soluble salts, mainly sodium, calcium and magnesium in the soil solution. Soil salinity can have major impacts on plant productivity and survival. Other effects of soil salinity can include a breakdown of soil structure and erosion. Soil samples taken from the site have a mean ECe of 0.4 dS/m (range 0.1 - 1.1dS/m). These low ECe results indicate that there are no salinity issues in the soil from the site and all sample are below the salinity threshold of ECe <4ds/m. Table 3 shows the ECe Values of Soil Salinity Classes.

Table 3. ECe Values of Soil Salinity Classes (Richards 1954)

Class	ECe (dS/m)	Comments
Non-saline	<2	Salinity effects mostly negligible
Slightly saline	2-4	Yields of very sensitive crops may be affected
Moderately	4-8	Yields of many crops affected
Very	8-16	Only tolerant crops will yield satisfactorily
Extremely	>16	Only a few very tolerant crops will yield satisfactorily

4.4 Soil Sodicity

Sodic soils contain high levels of sodium which take up a significant portion of the total exchangeable cations. Sodic soils readily lose their structure upon becoming wet causing structural collapse and closing off soil and water pores. This leads to restricted air and water movement through the soil and reduces hydraulic conductivity. As conditions dry out these soils form a hard crust effectively sealing the layer and reducing water infiltration.

Exchangeable sodium levels vary with depth and position across the site. On average soils are non-sodic in the surface A1 horizon and subsurface A2 horizon, and becoming sodic (ESP>6%) deeper through the profile. Specifically the soils in Pit 1 start becoming sodic (ESP 9.9%) in the B 1 350-550mm horizon. Sodicity increases (ESP 17.9%) in the B 2 550-850mm horizon and become very sodic (ESP 21.4%) at depth in the B 3 >850mm horizon. Pit 7 displays a similar pattern with sodicity increasing with depth, the B 2 400-800mm horizon had an ESP 24.1%. None of the soils in pit 6 were above the sodicity threshold ESP>6%. Pit 8 displayed a slightly high ESP result of 7.2% in the B3 700-1200mm horizon. The high sodicity levels in the sub soils may cause a breakdown in soil structure during wet conditions, this may inturn cause sealing in these layers and a reduction in future water infiltration.

5. Conclusions

Soils at the proposed landfill site vary from the lower to the upper slope and reflect the landscape and soils descriptions made by King (in prep, 2005). Soil pH levels fall within a range that is common for most mineral soils and will not restrict plant growth. All soils at the proposed landfill site are considered to be non-saline and at the present there is no salinity issue at the site. On average the surface and sub-surface soils are non sodic. However, most soils are considered sodic at depth in the B2 and B3 horizons. These soils may become unstable when initially wet though will form a surface crust and seal very well upon drying. This crust will reduce the likelihood of moisture infiltration in future rainfall events. Once these soils form a seal on the surface potential water infiltration is reduced. While sodicity in the soils at the proposed landfill site is evident it should pose no restrictions to the development of the Armidale landfill. Clay material located in the B1 300-550mm horizon is suitable for a lining/capping material. Soils from this horizon were generally only slightly sodic. This would indicate that after compaction they would form a lining with low permeability suitable for the proposed landfill.

It is recommended that standard erosion control measures are employed during the construction and operation stages of the development to avoid the possibility of erosion or dispersion of any sodic soils that may be exposed during excavations. In the event that clearing of portions of the woodland regrowth occupying the mid-slopes is required, bunding should be employed to minimise surface water run-on onto the cleared areas to prevent potential problems with salinity. Precautions should also be taken to ensure the base of the landfill is completely sealed so that the site does not contribute to potential groundwater recharge zones.

6. References

Gilligan, L.B., Brownlow, J.W., Cameron, R.G., and Henley, H.F., 1992, *Dorrigo - Coffs Harbour 1:250 000 Metallogenic Map SH/56-10, SH/56-11: Metallogenic Study and Mineral Deposit Data Sheets*. 509 pp. NSW Geological Survey, Sydney.

King, D.P. (in prep), *Soil Landscapes of the Armidale 1:100 000 Sheet* Report, Department of Natural Resources, Sydney.

Patterson, A.R. (1999). Effects of effluent chemistry on soil properties. Paper PEM009 in: *Proceedings of 1999 production and Environmental Monitoring Workshop*. University of New England Armidale. March 1999.

Peverill, K.I., Sparrow, L.A. and Reuter, D.J. (1999). Soil Analysis: an interpretation manual. CSIRO Australia.

Traise, G.A. 1973, *Palaeozoic Sediments in the Armidale to Gara River District*. BSc (Hons) thesis, University of New England, Armidale.

7. Appendices

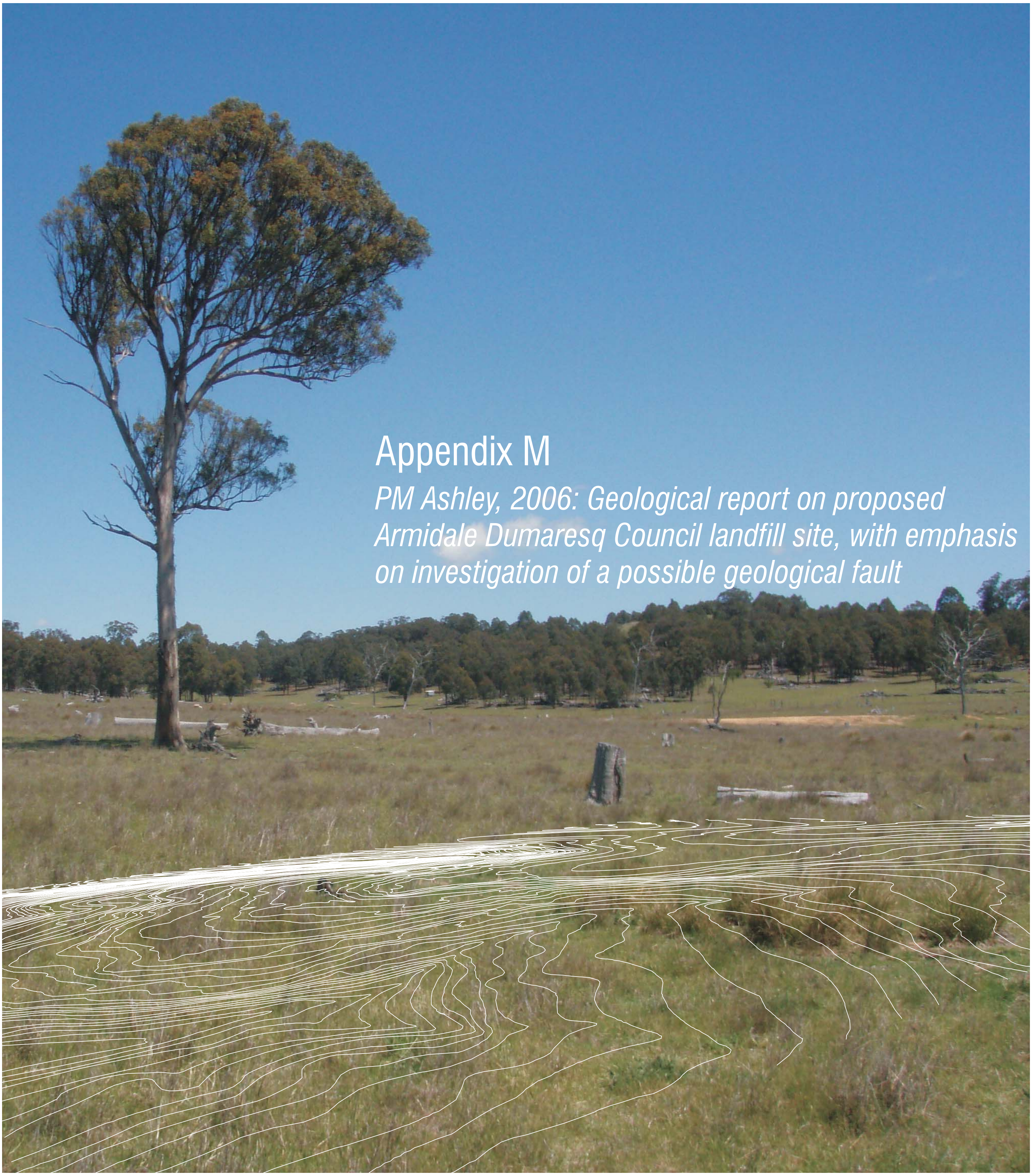
Appendix A. Results of the Soil Sampling Analyses

Site Name	Collection Date	Location	Latitude	Longitude	Surface Slope	Sample Number	Horizon_From mm	Horizon_To mm	Colour	Texture
ADC Land fill	28-9-05	Pit 1	383405	6619103	1%	155301	0	200	10yr 4/2 dark grayish brown	Fine sandy loam
ADC Land fill	28-9-05	Pit 1	383405	6619103	1%	155302	200	350	10yr 5/2 Graysih brown	Sandy clay
ADC Land fill	28-9-05	Pit 1	383405	6619103	1%	155303	350	550	5yr 5/8 yellowish red or 7.5 yr 5/8 strong brown	Heavy clay
ADC Land fill	28-9-05	Pit 1	383405	6619103	1%	155304	550	850	10yr 5/8 yellowish brown	Heavy clay
ADC Land fill	28-9-05	Pit 1	383405	6619103	1%	155305	850	1200	10yr 6/6 brownish yellow	Heavy clay
ADC Land fill	28-9-05	Pit 6	383288	6618773	5-6%	155306	0	300	10yr 4/2 dark grayish brown	Sandy clay loam
ADC Land fill	28-9-05	Pit 6	383288	6618773	5-6%	155307	300	1100	10yr 6/8 brownish yellow	Heavy clay
ADC Land fill	28-9-05	Pit 6	383288	6618773	5-6%	155308	1100	1400	2.5yr 6/8 olive yellow	Heavy clay
ADC Land fill	28-9-05	Pit 7	383514	6619319	1%	155309	0	100	10yr 4/2 dark grayish brown	Sandy clay loam
ADC Land fill	28-9-05	Pit 7	383514	6619319	1%	155310	100	300	10yr 5/3 Brown	medium clay
ADC Land fill	28-9-05	Pit 7	383514	6619319	1%	155311	400	800	10yr 5/6 yellow brown	medium clay
ADC Land fill	28-9-05	Pit 8	383609	6619714	1%	155312	0	150	10yr 4/2 dark grayish brown	Fine sandy loam
ADC Land fill	28-9-05	Pit 8	383609	6619714	1%	155313	105	320	7.5yr strong brown	sandy clay
ADC Land fill	28-9-05	Pit 8	383609	6619714	1%	155314	320	700	10yr 5/8 yellowish brown	Heavy clay
ADC Land fill	28-9-05	Pit 8	383609	6619714	1%	155315	700	1200	no colour decayed rock	Heavy clay

PointName	pHw	pHca	EC dS/m	Texture Factor (EC Multiplier)	ECe dS/m	Dispersion test Emerson class	Exc.Al+H meq/100g	Ca mg/kg	K mg/kg	Mg mg/kg	Na mg/kg	ESP %	ECEC me/100g	Ca/Mg ratio
Pit 1	5.76	4.56	0.038	12.00	0.46	8	0.4	496.8	69.83	111.9	19.76	2.1	4.1	2.7
Pit 1	6.1	4.95	0.018	10.00	0.18	3	0.16	323	20.66	129.1	41.26	5.9	3.1	1.5
Pit 1	6.4	5.16	0.043	6.00	0.26	6	0.32	734.8	60.22	1026	319.2	9.9	14.0	0.4
Pit 1	7.58	6.35	0.183	6.00	1.10	2	0	786.2	60.33	1283	733.6	17.9	17.8	0.4
Pit 1	7.85	6.5	0.147	6.00	0.88	1	0.08	921.4	54.14	1228	931.5	21.4	19.0	0.5
Pit 6	5.23	4.41	0.017	11.00	0.19	7	1.68	288.5	36.26	114.7	15.25	1.6	4.2	1.5
Pit 6	5.21	4.2	0.023	6.00	0.14	6	4.72	117.9	22.15	405.7	69.11	3.3	9.0	0.2
Pit 6	4.94	3.83	0.058	6.00	0.35	6	13.92	28.3	47.26	1156	289.7	5.0	25.0	0.0
Pit 7	5.45	4.64	0.031	11.00	0.34	8	0.56	438.3	35.21	89.07	23.4	2.8	3.7	3.0
Pit 7	6.23	4.95	0.03	8.00	0.24	3	0.24	225.9	9.241	83.54	74.45	13.5	2.4	1.6
Pit 7	7.63	6.26	0.09	8.00	0.72	2	0.32	656.8	34.23	613.7	639.1	24.1	11.5	0.6
Pit 8	5.17	4.4	0.018	12.00	0.22	7	1.12	400.5	25.95	75.39	11.96	1.3	3.9	3.2
Pit 8	5.78	4.64	0.014	10.00	0.14	6	0.72	520.4	26.96	230.5	37.14	3.0	5.4	1.4
Pit 8	5.66	4.56	0.026	6.00	0.16	6	2.32	1659	96.59	1104	183	3.8	20.7	0.9
Pit 8	6.63	5.54	0.068	6.00	0.41	6	1.2	2422	71.63	1365	440.3	7.2	26.6	1.1
Min	4.9	3.8	0.0	6.0	0.1	1.0	0.0	28.3	9.2	75.4	12.0	1.3	2.4	0.0
Mean	6.1	5.0	0.1	8.3	0.4	5.1	1.9	668.0	44.7	601.0	255.2	8.2	11.4	1.3
Max	7.9	6.5	0.2	12.0	1.1	8.0	13.9	2422.0	96.6	1365.0	931.5	24.1	26.6	3.2

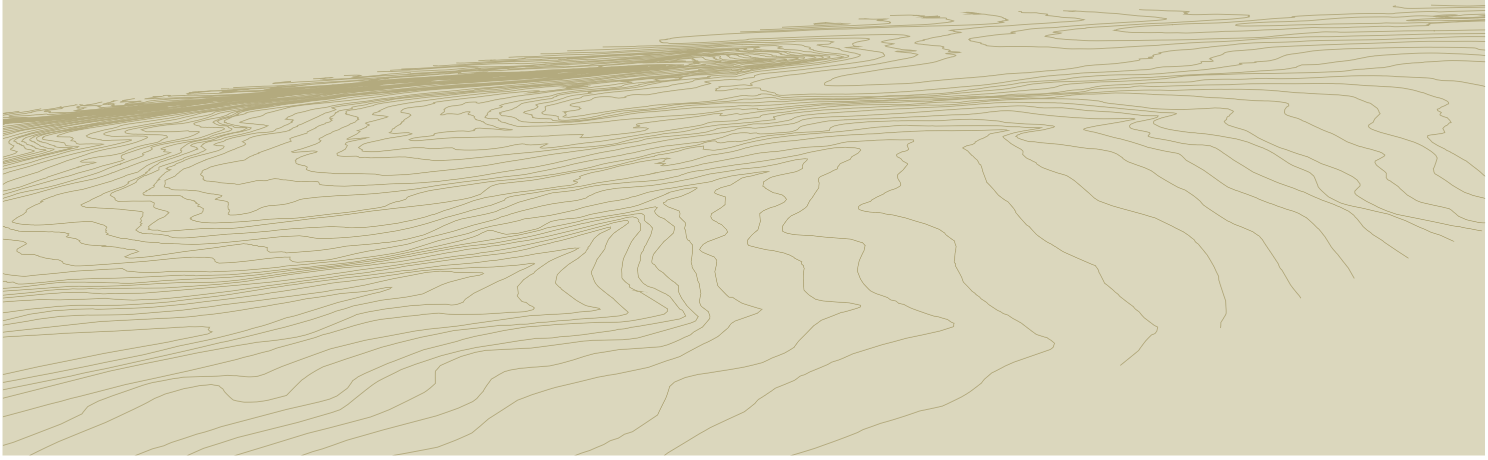
Appendix M

PM Ashley, 2006: Geological report on proposed Armidale Dumaresq Council landfill site, with emphasis on investigation of a possible geological fault



ARMIDALE REGIONAL LANDFILL

Environmental Assessment



Geological report on proposed Armidale Dumaresq Council landfill site, with emphasis on investigation of a possible geological fault

For

EA Systems Pty Ltd

Reference: Purchase Order # 3653

P.M. Ashley
Paul Ashley Petrographic and Geological Services
16 Lambs Avenue
Armidale
NSW 2351

ABN 59 334 039 958

February, 2006

P. M. Ashley

EXECUTIVE SUMMARY

The published 1:250 000 Dorrigo-Coffs Harbour geological map covering the Armidale region, including the area of the proposed landfill site for Armidale-Dumaresq Council, shows a linear fault trace marked as “position approximate”, striking about 050° across the southern portion of the proposed landfill site. If the fault existed and displayed any evidence for activity (e.g. earthquakes) or zones of increased porosity and permeability, it may pose geotechnical concern for the siting of the landfill. There may be possible issues of landfill stability and groundwater contamination as a result of potential activity. In order to ascertain if the mapped fault could be identified in the area of the proposed landfill site, a geological mapping program was performed, making observations on rock types and structures and attempting to identify any characteristics that might confirm the presence of a fault and any geologically recent tectonic activity.

Mapping indicated that the previous regional scale map did not have adequate detail to display the distribution of rock types (greywacke, siltstone, mudstone-argillite and chert of the Sandon Beds, and Tertiary sedimentary rocks, basalt and regolith). Measurement of structures indicated that although there is a statistical peak of rock fabric orientations (foliation, cleavage, fractures) at ~040°, it did not conform to the projected “fault” strike of ~050°. Moreover, in the projected position of the “fault”, there was no field evidence for a concentration of features indicative of the presence of a fault, e.g. increased penetrative fabrics such as foliation and cleavage, brittle fracturing or brecciation, or hydrothermal alteration. In addition, there was no topographic expression of the “fault” to suggest any geologically relatively recent motion.

Remote sensing imagery (air photo, Landsat imagery, digital terrain model and inferences from adjacent aeromagnetic and radiometric data sets) did not provide any evidence for the existence of a fault in the position implied from the published geological map.

In conclusion, it is considered that the fault shown on the map has no basis in fact, at least in the proposed landfill site area and for 1-2 km along strike to the northeast and southwest. There should not be a significant bedrock geological reason mitigating against the siting of the proposed landfill (e.g. earthquake risk, groundwater leakage along a fault). However, all other environmental aspects regarding groundwater and surface water migration, soils and slope stability would need to be thoroughly assessed.

Objective of the investigation

To perform geological mapping in the area within and surrounding the proposed Armidale Dumaresq Council landfill site near the Gara River, east of Armidale, with emphasis on identifying evidence for or against the occurrence of a geological fault that has been indicated on published maps as passing across the landfill site.

Background to investigation

A proposed site for a new landfill has been indicated near the Gara River about 12 km east of Armidale and just south of the Waterfall Way (Fig. 1). It is of geotechnical concern that most modern published geological map of the region (Dorrigo-Coffs Harbour 1:250 000 geological sheet; Gilligan et al., 1992) shows a northeast-striking fault passing across the southern portion of the landfill site (Fig. 2). A fault could have implications for (a) egress of groundwater (and leachate) out of, or into the landfill and (b) stability of the structure(s) in the rare case of a seismic event (earthquake).

A geological investigation was sought in order to perform mapping of the landfill site and surrounding area, with emphasis on identifying criteria that would provide evidence for or against the presence of a fault.

Published geology of the proposed landfill site and surrounding area

The earliest detailed semi-regional mapping of the Armidale area including the landfill sites was published in 1967 (Binns et al., 1967). This map does not show the occurrence of a fault in the landfill area or general location. The first edition of the Dorrigo-Coffs Harbour 1:250 000 geological map published in 1969 by the Geological Survey of NSW and the subsequently updated metallogenic map published in 1992 (Gilligan et al, 1992) do show a fault striking approximately northeast (about 050°) across what would be the southern part of the landfill site (Fig. 2). As shown, the fault is about 20 km in length and the map symbol is for it to be “position approximate”.

As shown on the 1992 Dorrigo-Coffs Harbour geological map, the fault is indicated to cross over geological boundaries, but yet there is no displacement indicated. The rationale for showing the fault on the map remains enigmatic and there is no explanation in the notes of Gilligan et al. (1992). In 2001, the then NSW Department of Mineral Resources had an airborne geophysical survey flown over the southern part of the New England region, with the eastern margin of the survey area being very close (within a kilometre) of the landfill site. Interpretation of the geophysical data by Brown (2003) did not show any evidence of a fault (based on magnetic or radiometric results) in the vicinity of the landfill site.

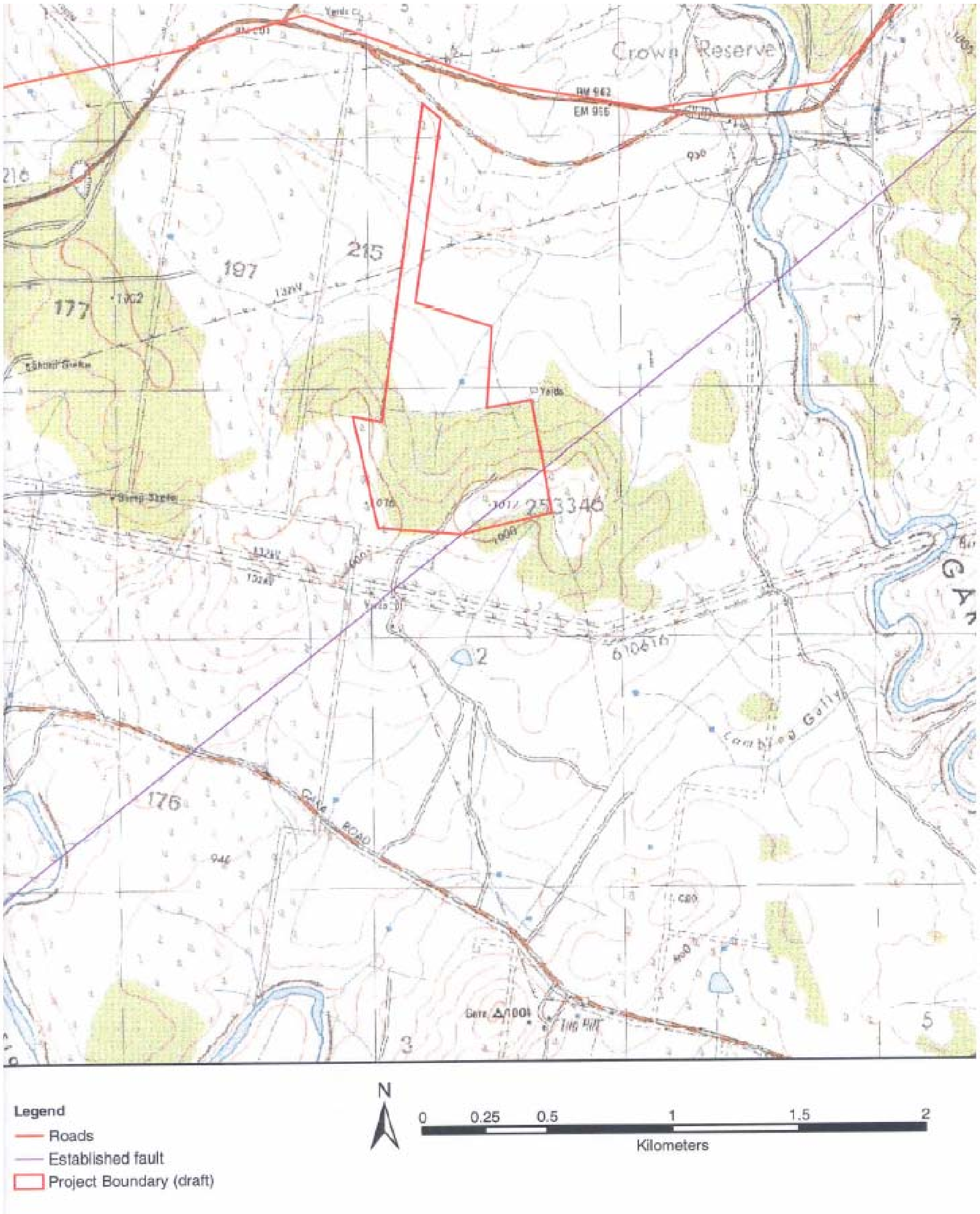


Figure 1: Portion of the Hillgrove 1:25 000 topographic map with the position of the proposed landfill site indicated by the red boundary. The projected trace of the fault indicated on the Dorrigo-Coffs Harbour 1:250 000 geological map is shown by the purple diagonal line. The term "established fault" in the legend was added by EA Systems. The term does not conform to that on the geological map which has the fault designated as "position approximate". The road towards the northern margin of the map is the Waterfall Way.

Using the available mapping and remote sensing data sets

Prior to the field mapping being performed, inspection of available data sets was undertaken. This entailed examination and interpretation of geological and topographic features from the 1969 and 1992 geological maps, the published Hillgrove 1:25 000 topographic map, air photo (supplied by EA Systems) and Landsat

TM imagery (supplied by the Geological Survey of NSW). The latter organisation also gave access to imagery from the magnetic and radiometric survey performed in 2001, and a digital terrain model image.

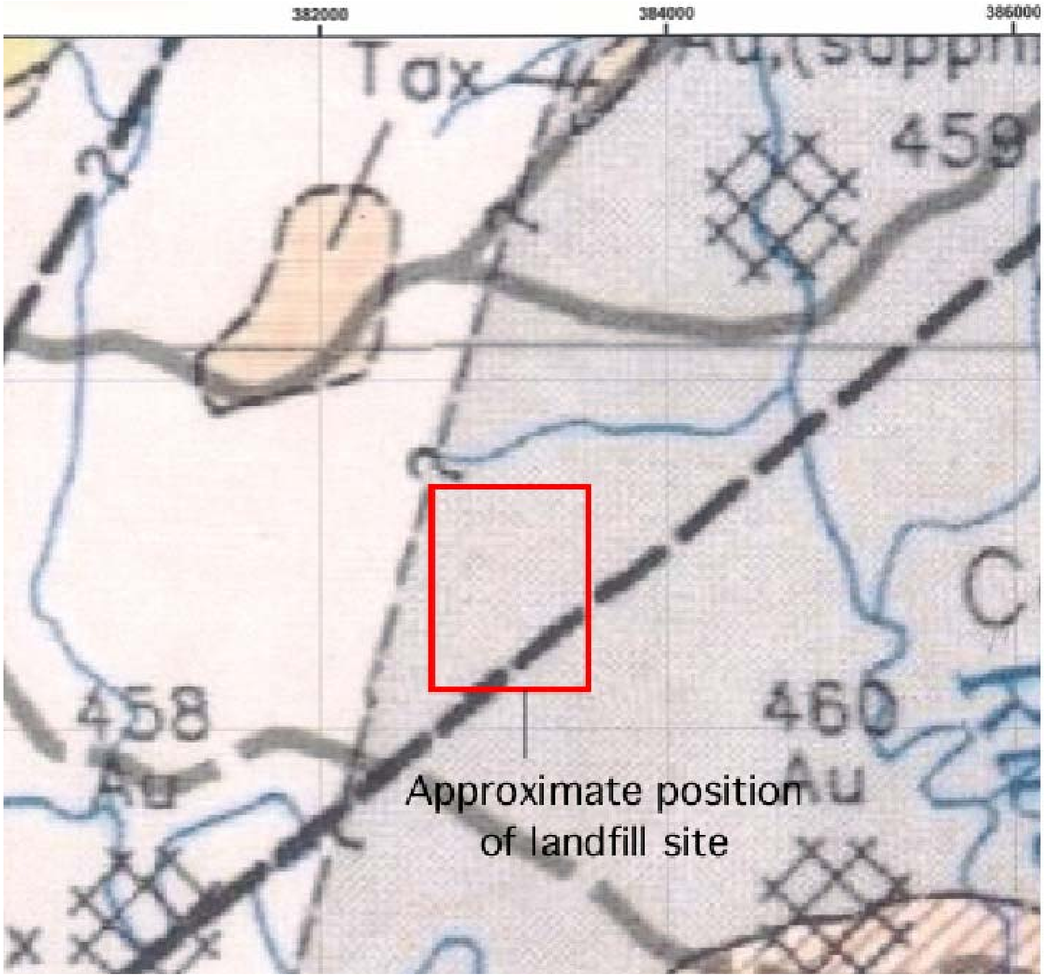


Figure 2: Portion of the Dorrigo-Coffs Harbour geological map (Gilligan et al., 1992), with the approximate position of the landfill site superimposed. The fault symbol (dashed diagonal line) designates "position approximate" on the published map. The pale mauve shading is designated as Girrakool Beds on the geological map.

Although the 1992 Dorrigo-Coffs Harbour regional geological map indicates that the rock unit underlying the landfill site and environs is the late Palaeozoic age Girrakool Beds, the most recent interpretation by Brown (2003), based on the geophysical data, indicates that the rocks are most likely part of the late Palaeozoic Sandon Beds, a unit of low grade metamorphosed and folded deep marine sedimentary rocks that crop out extensively in the central and western parts of the New England region. The mapping performed at the landfill site and surrounds (see later) indicates that the rocks are most likely part of the Sandon beds as interpreted by Brown (2003).

Inspection of the following remote sensing data gave the following results:

a) air photo interpretation: no linears or other features are indicated in the topography to suggest the presence of a fault in the projected position (Fig. 3).
b) Landsat TM: same result.
c) Digital terrain model (DTM): There are no linears in the projected position or strike (050°) of the fault, although there is a single weak linear just southeast of the landfill site with a strike of 025° (Fig. 4).
d) Aeromagnetic survey image (first vertical derivative {1VD}): The survey area has its eastern boundary about 1 km west of the landfill site. However, weak northeast-striking linears are apparent to the southwest of the landfill site but cannot necessarily be interpreted as representing faults. They could well be representing subtle changes in rock type.
e) Airborne radiometric survey: Like the magnetic survey, the eastern boundary is about 1 km west of the landfill site. Data from the eastern-most portion of the survey area do not display any linear features and the variation in radiometric properties on the image is interpreted as reflecting differences in rock type, not a fault.

Figure 3: Aerial photograph of the landfill site and immediate surrounding area. The projected fault trace has been omitted, but it trends approximately northeast across the image from near the southwest corner to the northeast corner. The landfill site occupies much of the wooded area just left of centre. The image is approximately 2 km east-west. It is relevant to note that there is no topographic expression or photo-linear corresponding to the projected position of the fault.

As indicated above, there is no published information on the rationale for the fault trace being shown on the geological maps. It is speculated that it might represent a linear feature interpreted from air photos, perhaps by geologists or geology students at the University of New England in the late 1960's.

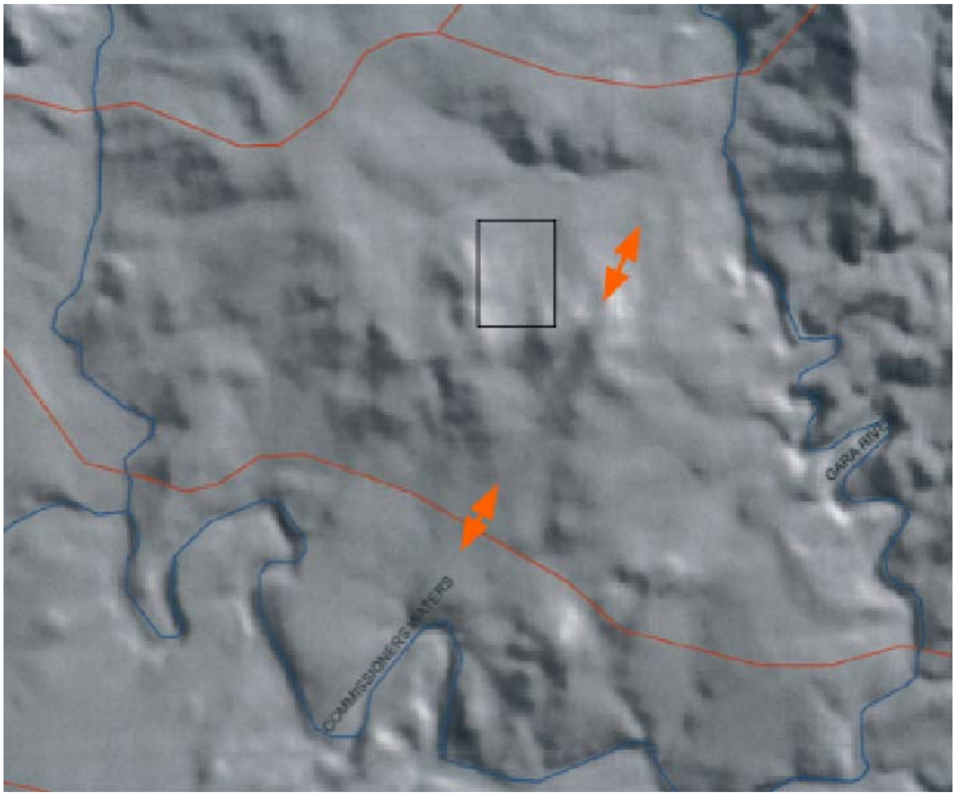


Figure 4: Portion of the digital terrain model supplied by the Geological Survey of NSW, covering the area of the landfill site (shown approximately by the rectangle) and surrounds. A single weak linear (indicated by arrows) is evident to the southeast of the site, but has a strike of ~025°, whereas the projected fault has a strike of ~050°.

Anticipated indicators of the presence of a fault from surface mapping

If there were likely to be an underlying fault, or zone of faulting, one or more of the following criteria might be anticipated to occur, and be recognisable assuming that there is sufficient surface outcrop:

1) evidence of shearing, fracturing, brecciation or stronger cleavage development in the rocks, particularly that having a NE-trending strike (consistent with the strike of the proposed fault line).
2) evidence of hydrothermal alteration focussed along a fault (might change the texture, mineralogy, colour and competency of the rock).
3) abrupt changes in rock type, or in structural style, e.g. bedding or cleavage orientation.
4) topographic evidence. e.g. presence of a linear scarp, or depression (valley). Topographic indications might be expected if there had been geologically relatively recent motion on a fault (e.g. in the past few tens of millions of years).

Methodology for surface mapping

Following the acquisition of maps and remote sensing data sets, surface mapping was performed at the landfill site and its surrounds on January 31 and February 1, 2006. Mapping was guided by an aerial photo and the topographic map and plotted in the field at a scale of 1:12 500. Mapping was performed by traversing, with recording of rock type and structural data in detail at 34 locations, with many other casual observations. Structural measurements had strike directions measured with respect to magnetic north (about 12° east of true north). These are designated by the suffix "M" in the text. Locations were recorded by GPS and several photographs were taken of lithological and structural features. The total area covered by the traverses was approximately 3 km^2, but covering a roughly elliptical area 4 km long and up to 1.2 km wide, elongate in an approximately northeast direction, largely between Commissioners Waters and the Gara River (Fig. 5). Mapping was performed at the main landfill site and on the surrounding properties of Waters, Crisp and Quaife.

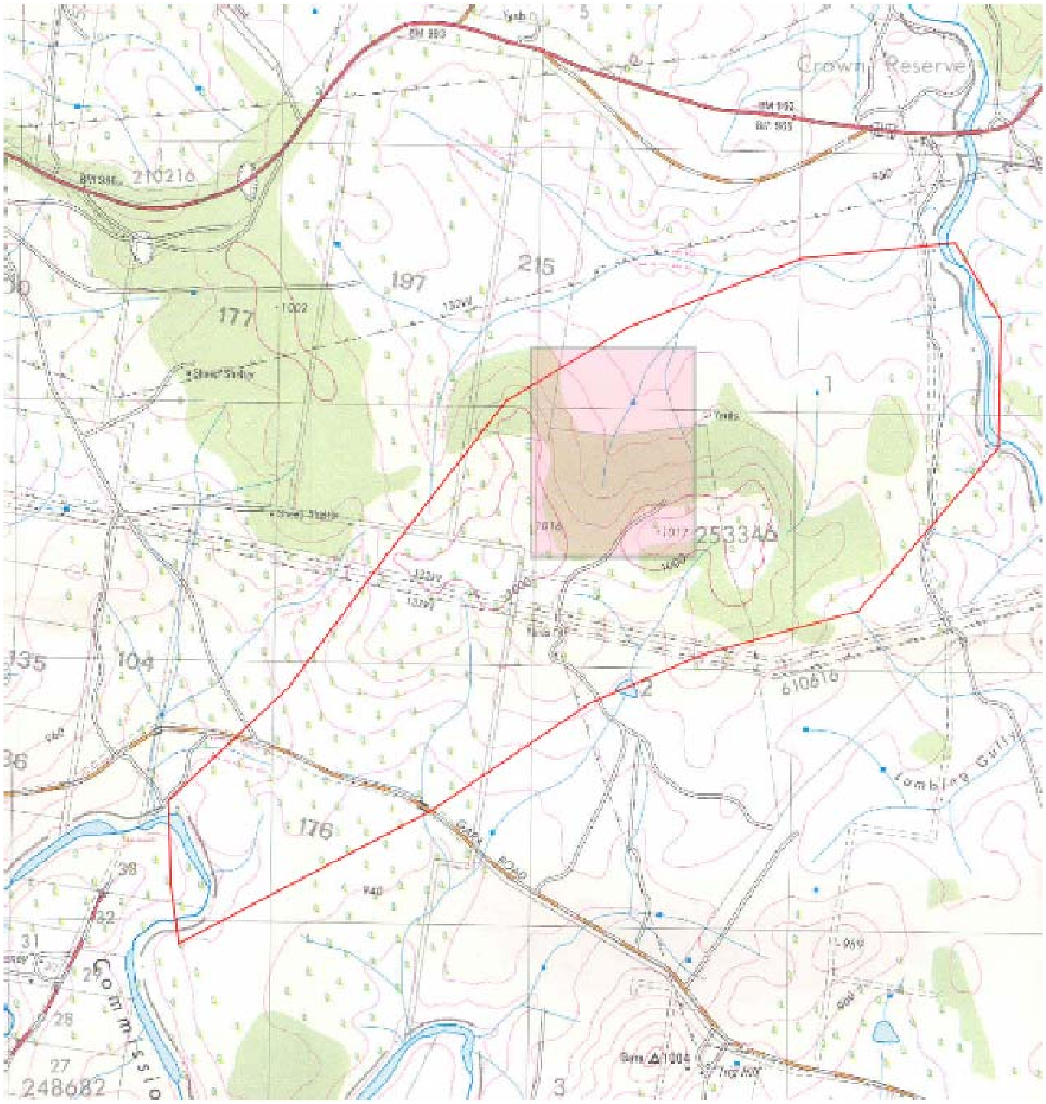


Figure 5: Area mapped (red boundary), with approximate site of landfill site (pink).

Results

Rock types and regolith

The relatively detailed mapping at 1:12 500 scale produced a different picture of the rock types than what is conveyed by the published geological maps. The underlying substrate rocks are interpreted to be part of the Sandon Beds (rather than Girrakool Beds) because of the presence of thick (hundreds of metres) packages of medium to coarse grained greywacke. This forms one of the two main lithological suites of the area, viz: massive to weakly foliated greywacke (Fig. 6), apparently intercalated in places with siltstone and mudstone-argillite and very minor chert. The greywacke-dominated association crops out mainly to the west (Commissioners Waters to just west of Crisp's homestead) and in the northeast (Gara River area and northeast of the landfill site) (Fig. 7). The other lithological package largely occupies the central part of the area, including the landfill site (Fig. 7). It is dominated by fine grained mudstone-argillite and chert (Fig. 8). Although the latter rock crops out prominently (e.g. forming many hilltops), it apparent abundance may be exaggerated because it is resistant. Several outcrops of chert form linear masses with a strike of 330°-340°M. This orientation is parallel with rare weak, steeply dipping bedding phenomena observed in some greywacke outcrops and suggests that the overall rock package may have a northwest to northerly strike and is steeply dipping. This is obviously at variance with the strike of the projected fault.

Figure 6: Weakly cleaved greywacke at grid reference 381682mE, 6617358mN. Strike of cleavage is 010°-015°M.

On the southeastern, southern and southwestern sides of the hills forming the southern margin of the landfill site, there are several poorly outcropping areas of interpreted Tertiary age sedimentary rocks (ferruginous and siliceous cemented quartz-rich gravel {conglomerate} and sandstone, along with a few masses of ferruginous cemented transported regolith (Figs 7, 9). These sedimentary materials appear to form only a thin, discontinuous veneer (up to a few metres thick) resting unconformably on the Sandon Beds. They probably represent remnants of former fluvial deposits. Closely associated with the Tertiary sediments about 0.5 km east of the Crisp homestead, there is a small (50-100 m diameter) mass of Tertiary basalt (Fig. 7), perhaps representing an erosional remnant of a lava flow or small intrusion.

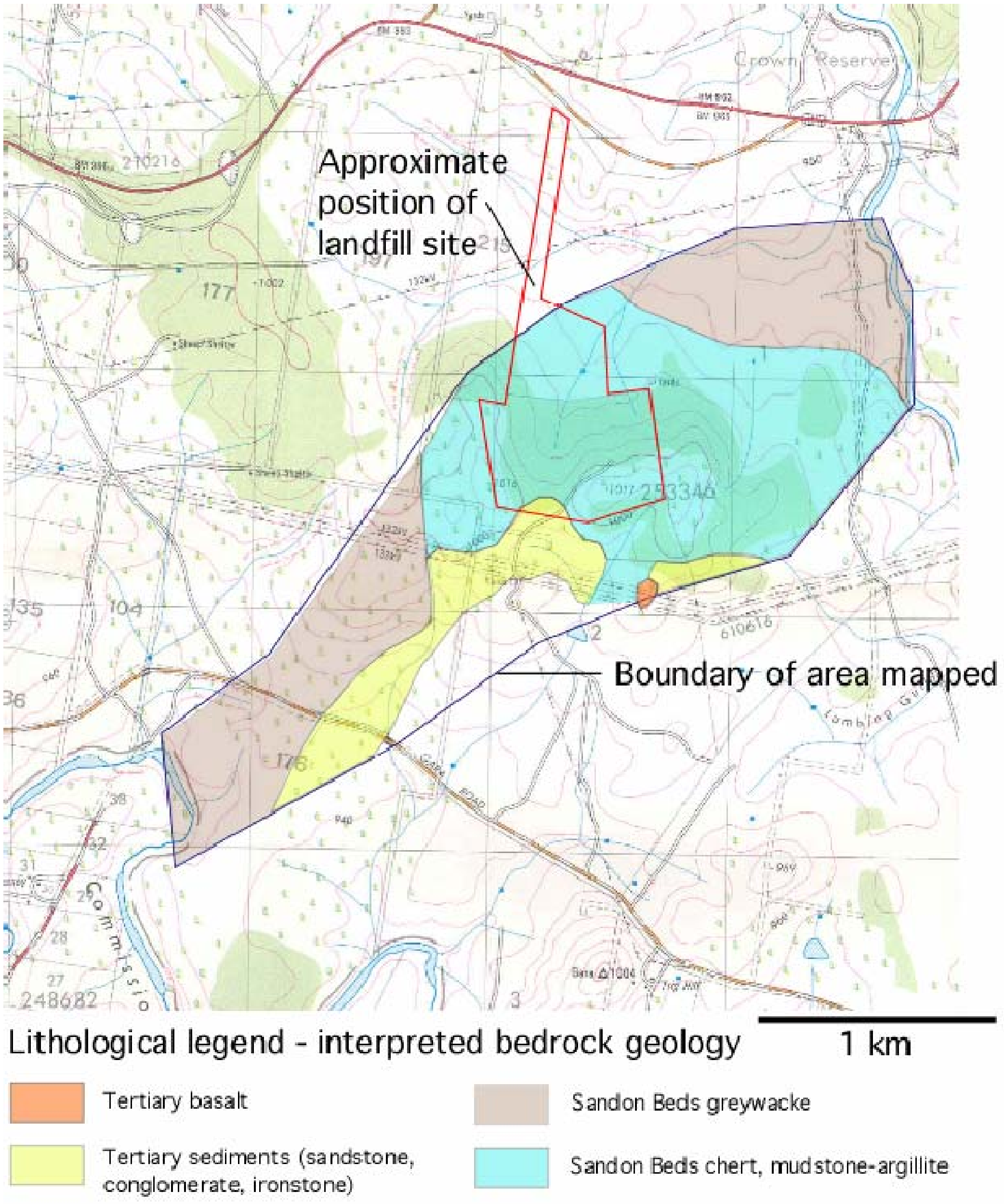


Figure 7: Bedrock geology (rock types) interpreted from reconnaissance mapping, including the area of the landfill site.

Figure 8: Fractured chert, with associated sheared zone in cherty mudstone (centre) at grid reference 383750mE, 6618650mN. Strike of foliation is 060°M.

Figure 9: Cleaved greywacke-siltstone (bottom of image) overlain by transported Tertiary gravel and ironstone regolith at grid reference 382206mE, 6617524mN. Strike of foliation in bedrock is 020°M.

Structures

Many outcrops in the mapped area display some form of structural fabric. Measurements of the strike orientation of the various fabrics are listed in the Appendix. Fabrics include a moderately developed cleavage in the finer grained rocks such as mudstone-argillite, fracture sets and locally anastomosing cleavage in chert-mudstone package (Fig. 8), and weak cleavage, grading to a faint elongation of outcrop pattern, in the greywacke (Fig. 6). Sedimentary bedding layering is very rare and is mainly inferred from orientation of chert outcrops. Penetrative structures such as cleavage and fractures display a relatively narrow range of orientations, mostly between 005°-060°M (Figs 10, 11). Of the 58 structural measurements made, 50 fall within this sector and all have steep dips (>70°). The remaining 8 structural measurements fall in the sectors 315°-340°M and 060°-070°M, with some of these being possible bedding orientations. The average orientation of the main array of measurements is 028°M, with a statistical peak at 030°M (Fig. 10).

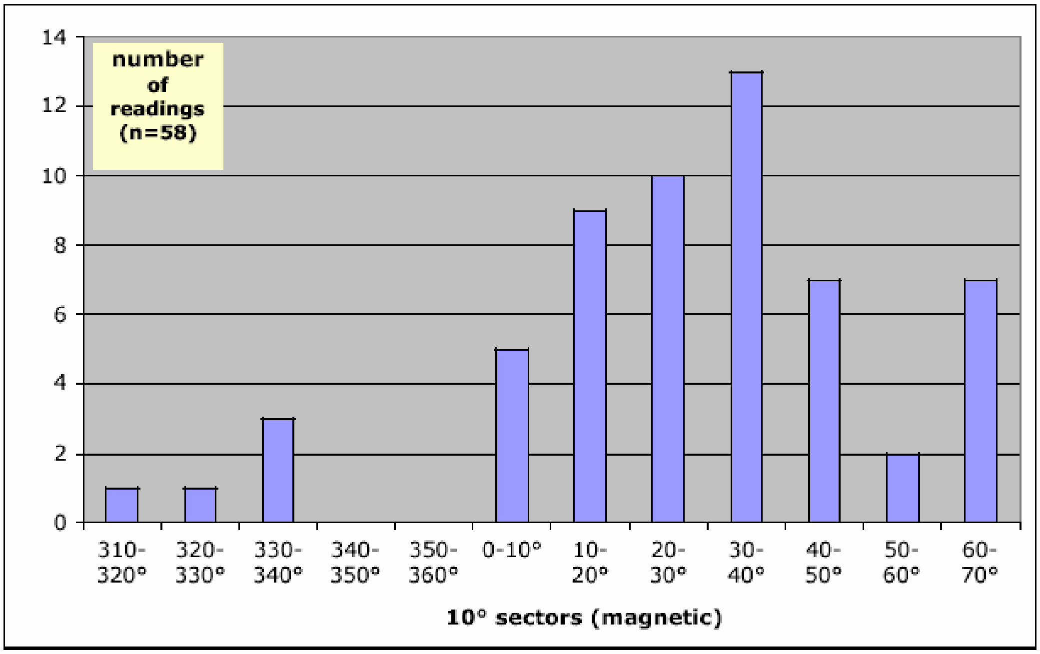


Figure 10: Histogram of azimuths (magnetic) measured from rock fabrics (cleavage, foliation, fractures, bedding, fault) in the area mapped. Note that the majority of measurements (50) fall into the sector 005°-060°M, with a mean value of 028°M (about 040° true north) and median value of 030°M (about 042° true north). The strike of the projected "fault" is approximately 052° true north.

Although the average orientation of the main array of measurements is similar to the strike of the fault shown on the Dorrigo-Coffs Harbour geological map, it is not co-incident. Converting the magnetic orientations to true north orientations, the average orientation is 040°, whereas the strike of the fault shown is 052°. In the projected position of the fault, surface outcrops do not display any increased concentration of penetrative structures, e.g. shear zones, stronger cleavage development, or of zones of brecciation or hydrothermal alteration. On the DTM (Fig. 4), there is a single weak linear feature (corresponding in the field to a shallow valley), with a strike of 025°.

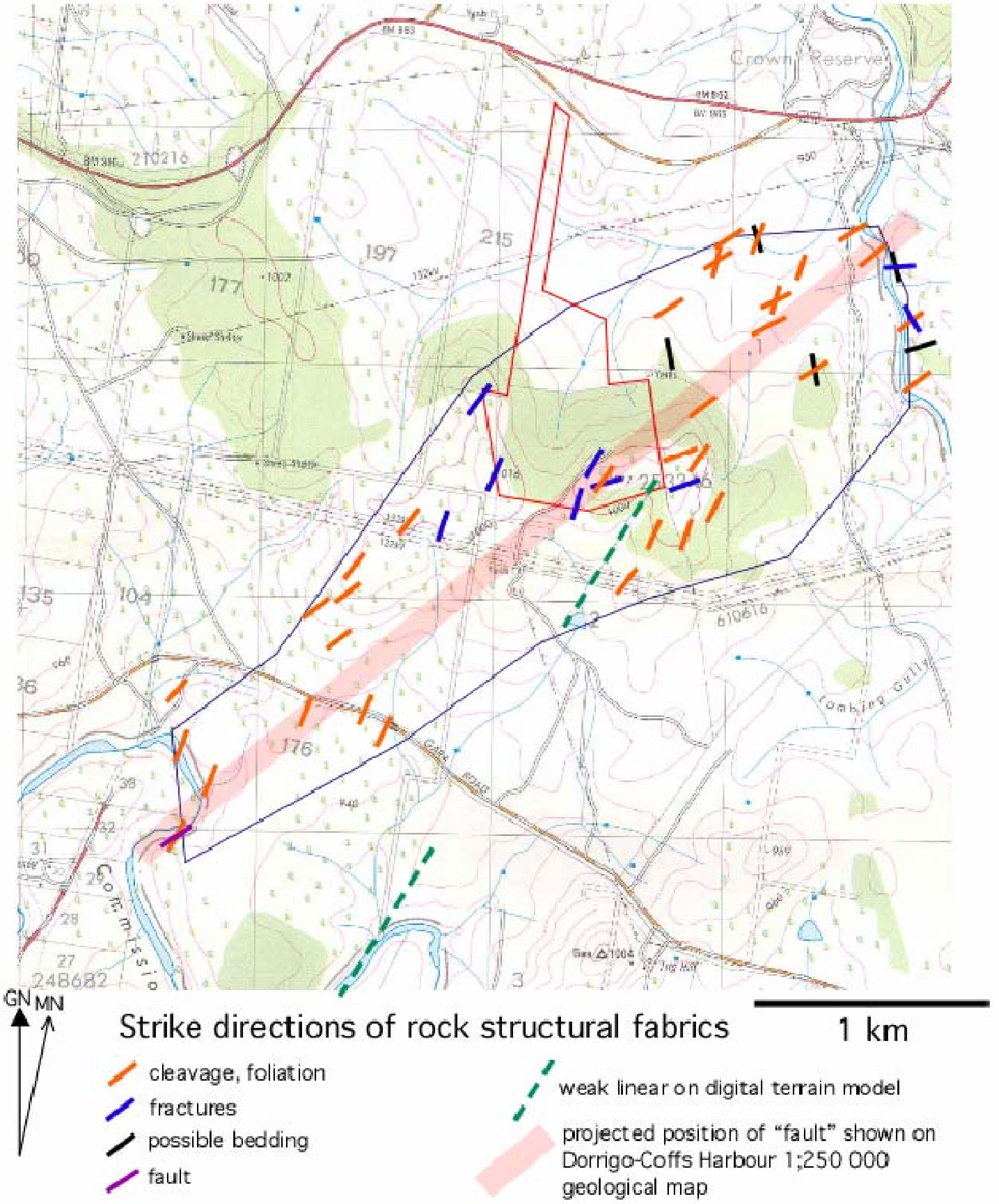


Figure 11: Strike directions of rock structural fabrics (cleavage, foliation, fractures, bedding, fault) in the area mapped (blue boundary). Also displayed are the weak linear from the digital terrain model (see Fig. 4), the projected position of the "fault" shown on the Dorrigo-Coffs Harbour 1:250 000 geological map and the approximate position of the landfill site (red boundary).

Sedimentary bedding phenomena are rare in the mapped area and are largely inferred from (a) orientation of a few of the elongate chert bodies, (b) possible steeply dipping thin bedding layers in the greywacke, (c) possible layering in "broken formation" mudstone-argillite and (d) boundaries between the greywacke-dominated and chert-mudstone-dominated sedimentary packages. It may be inferred from (a), (b) and (d) that bedding orientations strike largely north-northwest to northwest, although criteria from (c) along the Gara River could indicate steeply dipping bedding striking at 060°-070°M.

Evidence for or against a fault

From the detailed field observations and structural measurements, and the examination of remote sensing data and maps, it is interpreted that there is no well-defined fault in the vicinity of the landfill site. It is surmised that the fault shown on the 1:250 000 geological maps is not based on fact, at least in the regional surrounding the landfill site. It could have been inferred from some form of photo-linears to the northeast or southwest of the landfill site, but there is no explanation in published geological notes (e.g. Gilligan et al., 1992). Field observations do not support the occurrence of a fault. None of the following criteria were observed:

(a) Zones of stronger shearing or cleavage development co-linear with the projected position of the fault
(b) Zones of brecciation or hydrothermal alteration co-linear with the projected position of the fault
(c) Offsetting of rock units or changes in structural style across the projected position of the fault
(d) Topographic expression, e.g. a valley or a scarp

No field criteria could be confidently stated to be supportive of the presence of a fault. In places, the rocks of the landfill area and surrounds do have structural fabrics (e.g. cleavage, local fracture zones) that are within 10-15° of the projected fault strike, but these are no different to the same features at considerable distance (e.g. hundreds of metres) away from the projected position of the fault. In addition, the remote sensing data (air photo, Landsat image and DTM) are not indicative of a fault in the position indicated and projections of weak magnetic linears from the margin of the aeromagnetic survey area cannot unequivocally be considered as due to a fault.

Conclusions

Detailed field mapping and structural measurements, along with examination of publically available remote sensing and map data, did not show evidence of a fault in the area of the planned landfill site for Armidale Dumaresq Council and the surrounding region (up to 1-2 km away).

Although the sedimentary rocks forming the substrate to the area (greywacke, mudstone and chert) do contain weak to moderate cleavage, grading into a foliation, and regions of fracturing, they are not concentrated into any particular zone (e.g. co-linear with the position of the fault shown on the 1992 edition of the Dorrigo-Coffs Harbour geological map). It is considered that the fault shown on the map has no basis in fact, at least in the proposed landfill site area and for 1-2 km along strike to the northeast and southwest.

Acknowledgement

Nancy Vickery of the NSW Geological Survey, Armidale office, kindly supplied remote sensing imagery over the area of interest.

References

Binns, R.A. and others, 1967. Geological map of New England 1:250 000 – New England Tableland, southern part, with explanatory text. University of New England, Armidale.

Brown, R.E., 2003. Peel South Exploration NSW geophysics – interpretation of new data for exploration and geological investigations in the western New England area of New South Wales. Quarterly Notes of the Geological Survey of NSW, 114, 1-27.

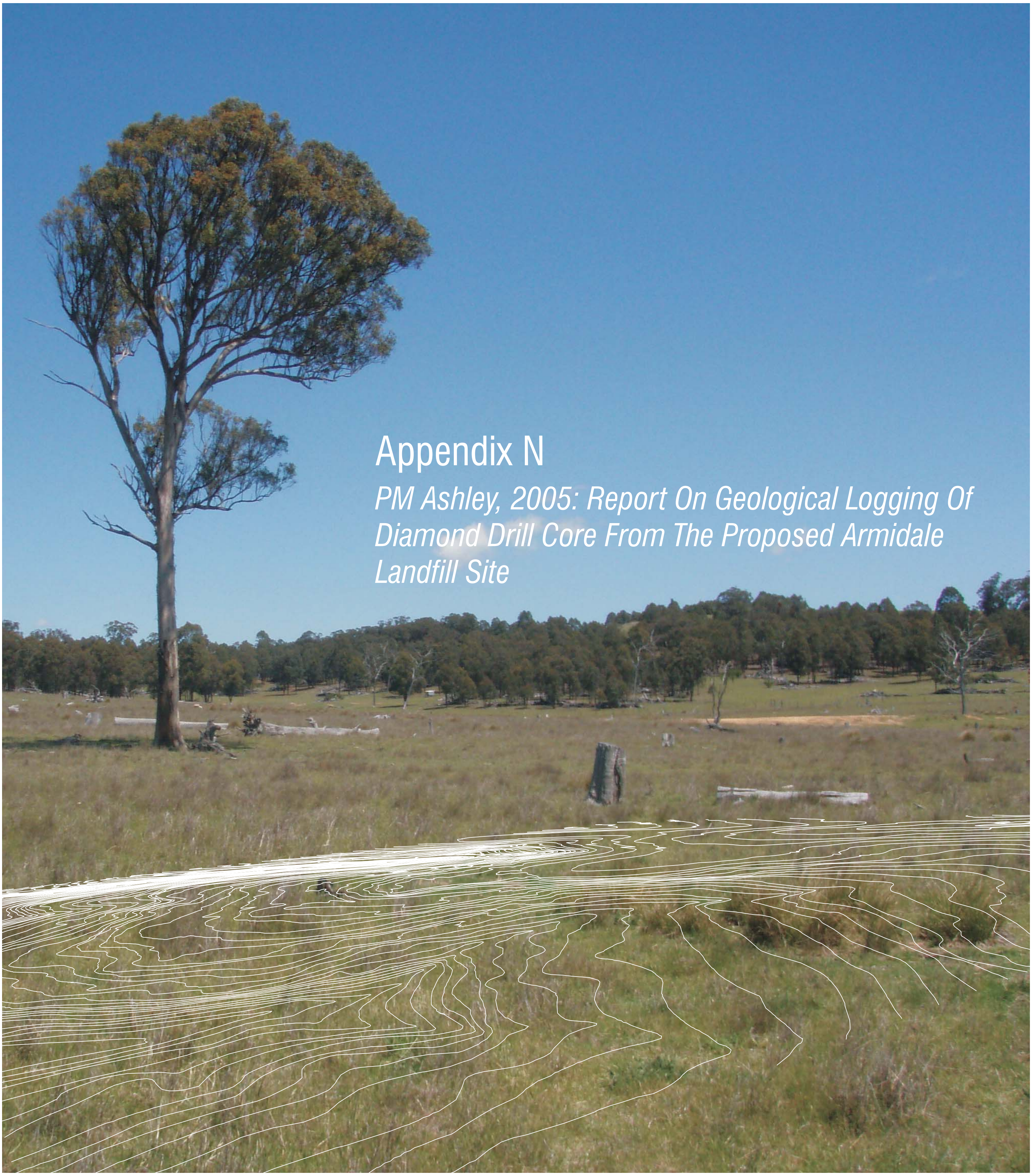
Gilligan, L.B., Brownlow, J.W., Cameron, R.G. and Henley, H.F., 1992. Dorrigo-Coffs Harbour 1:250 000 metallogenic map. Metallogenic study and mineral deposit data sheets. New South Wales Geological Survey, Sydney, 509 pp.

Appendix

Record of strike measurements of rock fabrics (cleavage, foliation, fractures, bedding). Grid references conform with those on the published Hillgrove 1;25 000 topgraphic map. All azimuths are magnetic. All dips on fabrics are steep and range between 70°-90°.

Location	Easting	Northing	Strike	Type
1	383750	6618650	030-060	foliation
2	383835	6618646	035	foliation
3	383800	6618578	060	fractures
4	383945	6618439	020-035	foliation
5	383946	6618196	020-025	fractures
6	383632	6618022	035	foliation
7	383505	6618039	035	cleavage
8	383753	6618325	020-030	cleavage
9	383500	6618526	060, 025	fractures, foliation
10	383425	6618597	020	fractures
11	382981	6618548	010	fractures
12	382957	6618843	025	fractures
14	383388	6618849	010-015	fractures, foliation
16	382435	6617524	020	cleavage
17	382206	6617517	015-020	cleavage
18	382287	6617829	035	cleavage
19	382434	6618142	025-030	cleavage
20	382811	6618311	005-010	fractures
21	381693	6617609	030	cleavage
22	381682	6617358	010-015	cleavage
nearby			005-010	cleavage
23	381676	6616969	015	cleavage
nearby			040	fault, quartz vein
24	384160	6619240	050	cleavage

nearby			005, 050	cleavage
25	384041	6619588	005-010	cleavage
			330	?bedding
nearby			040	cleavage
			320	?bedding
26	383919	6619497	005, 040	cleavage
27	383778	6619272	040	cleavage
28	383690	6619068	335	?bedding
29	383885	6618816	035-040	cleavage
30	384371	6618980	335	?bedding
			030-060	cleavage
31	384570	6619591	030-050	cleavage
32	384661	6619497	330	?bedding
			070	fractures
33	384731	6619244	040, 315	fractures
34	384769	6619116	060-070	?bedding
nearby			030-040	cleavage

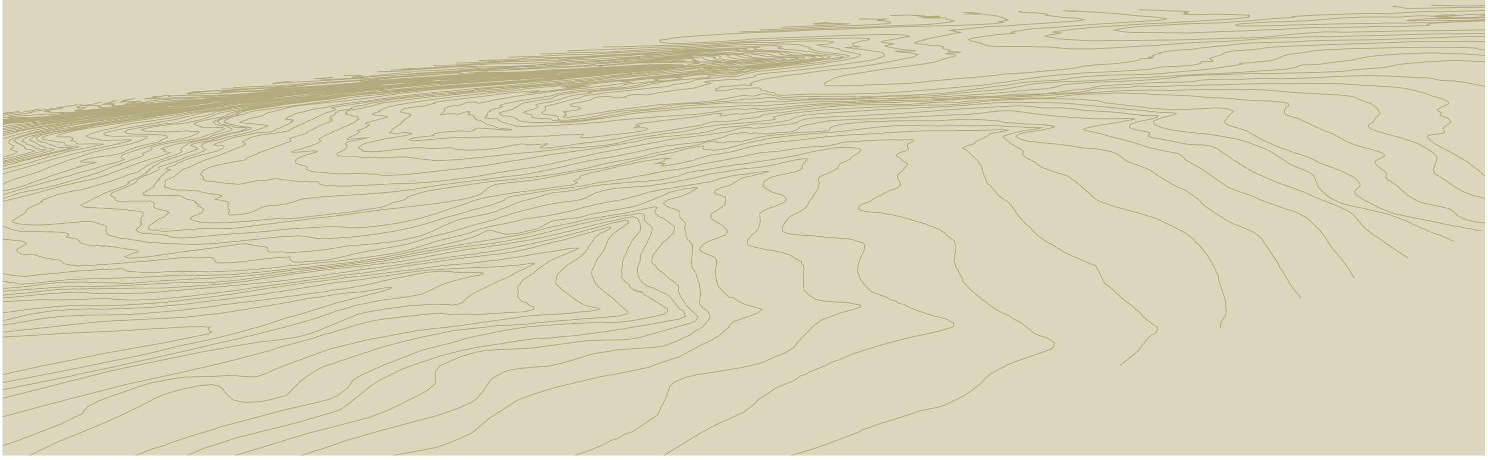


Appendix N

PM Ashley, 2005: Report On Geological Logging Of Diamond Drill Core From The Proposed Armidale Landfill Site

ARMIDALE REGIONAL LANDFILL

Environmental Assessment



REPORT ON GEOLOGICAL LOGGING OF DIAMOND DRILL CORE FROM THE PROPOSED ARMIDALE LANDFILL SITE

For

E.A. Systems Pty Ltd

Purchase Order 2945

P.M. Ashley
Paul Ashley Petrographic and Geological Services
16 Lambs Avenue
Armidale
NSW 2350

ABN 59 334 039 958

December, 2005.

OBJECTIVES

A 26 metre vertical borehole had been drilled at the site of the proposed new landfill for the Armidale Dumaresq Council for E.A. Sytems Pty Ltd (EAS). The borehole is at grid reference 383471.27 mE, 6619105.1 mN and had been cored from 5 m to 26 m, with the top 5 m not being cored due to it being weathered and soft, leading to poor to nil recovery. EAS sought professional geological logging of the drill core, with reference to identification of rock type, structures that might have geotechnical implications (e.g. groundwater migration, site stability) and weathering effects.

GEOLOGICAL SETTING

The general site of the proposed landfill site is approximately 12 km ESE of Armidale. According to the 1:250 000 geological map of the region (Gilligan et al., 1992), the proposed landfill site is underlain by Late Palaeozoic deep marine sedimentary rocks of the Girrakool Beds, but close to the contact with the nearby Sandon Beds. The latter sequence is also largely deep marine sedimentary in character and of Late Palaeozoic age. Both of these rock units are composed largely of low grade metamorphosed greywacke, mudstone and chert and have been folded (Gilligan et al., 1992). As a consequence of folding, it is common for the rock sequence to be steeply dipping. The proposed landfill site is in an undulating landscape on the New England plateau and weathering has affected all rocks types. It is common to have weathering effects manifest to depths of metres to tens of metres on the plateau.

METHODS

The drill core was provided on December 5, 2005 and was subsequently logged in detail on December 5-6. The 21 m of core was logged for rock types, weathering phenomena and structures. Photographs were taken of whole trays of core as well as specific rock types and structures.

RESULTS

A detailed drill core log for the interval from 5 m to the end-of-hole at 26 m is displayed in Appendix 1. Photographs of each of the core trays containing 5 m intervals are shown in Appendix 2.

Rock types

The core contains two primary rock types. The somewhat more dominant one is a medium grained, rather massive **greywacke** (quartz-feldspar-lithic sandstone). Original detrital grains are up to 0.5-1 mm across, are tightly packed and the rock is not porous. Where fresh, the rock is grey in colour, with a slightly greenish tinge. Apart from the detrital components (quartz, feldspar, lithic grains), the rock probably has a small amount of low grade metamorphic derived chlorite and sericite. The other rock type is similar, but is characterised by containing scattered to abundant larger lithic grains, typically up to 5 mm – 20 mm across (Fig. 1). Lithic grains are commonly angular and are composed of dark grey, fine grained sedimentary rock, e.g. mudstone. Because of the conspicuous presence of these larger mudstone lithic grains, this rock type is termed **“mud chip greywacke”** and is shown as such on the drill log.

The mud chip greywacke is much the same colour as the fine grained greywacke when fresh. Contacts between the two rock types are commonly difficult to discern, as they are probably rather diffuse. Intervals of mud chip greywacke range from about 15 cm to nearly 3 m in thickness. At approximately 8.5 m depth, there is a “bleached zone” about 15 cm long in the greywacke. This could represent a small zone of hydrothermal alteration.

Figure 1: Fresh mud chip greywacke at 23.4 m. Dark fine grained angular to elongate mudstone lithic grains are enclosed in a medium grained greywacke matrix, in places containing a few slightly larger pale coloured quartz-rich grains. Blue scale on left hand side has centimetre markings.

Structures

Definite evidence of sedimentary bedding is lacking in the drill core. For example, there are no distinct different sedimentary rock units, or graded bedding. However, there are a few possible thin bedding laminations, marked by thin (<1 cm) finer grained units. These layering effects are steeply dipping, i.e. are shallowly oblique to the core axis. An implication of this observation is that the vertical drill hole would be unable to obtain a significant representative sample of the possible rock types at the site (i.e. a vertical drill hole would intersect a very limited portion of a steeply dipping sequence of rock types).

Much of the greywacke and mud chip greywacke is rather massive and homogeneous. However, in places, a weak foliation is evident. This is due to tectonic effects imposed on the rock when it was deeply buried in the crust of the earth. Foliation is defined by development of a weak cleavage in places and by preferred orientation and elongation of mud chips (Figs 2 and 3). Foliation is always at a low to moderate angle to the core axis (Figs 2 and 3), implying that it is steeply dipping.

Figure 2: Weathered mud chip greywacke at 14.2 m showing zone of foliation to the right of the coin.

Figure 3: Slightly weathered mud chip greywacke at 13.4 m showing weak foliation defined by preferred orientation of elongate dark mudstone fragments.

Rare thin veins of quartz have been observed in the core. They are sub-planar, less than 1 cm thick and are at low to moderate angles to the core axis, implying that they are steeply dipping.

Planar to arcuate and irregular fractures are common in the core. They are slightly more abundant where weathering effects are stronger. Fracturing has occurred after the formation of foliation. There are two main orientations of fractures. One, interpreted to be earlier, is typified by steeply dipping fractures (i.e. at low angles to the core axis – generally <20°). These fractures may be co-planar with the foliation. A second fracture set is typified by fractures at a moderate to high angle to the core axis (e.g. 50°-90°). This fracture set is interpreted to be later and could be due to unloading of the rocks due to weathering and erosion as it is sub-planar with the landscape surface. In a few places, there are zones of strong dislocation, resulting in rubbly intervals up to a few tens of centimetres in length. These could be due to multiple intersecting fractures and accentuated by weathering effects. The core exhibits several zones of strong clay alteration as a result of weathering imposed on strongly fractured rock. The clay-rich zones can be up to 10 cm wide (Fig. 4).

Figure 4: Weathered mud chip greywacke and greywacke with several sub-planar to irregular zones of fracturing and strong clay alteration (e.g. to the right of the coin and in the lower left of the image). Coin is located at 12.6 m.

Weathering

The effects of weathering are common in the drill core. It is manifest by brown staining of the rock, due to the presence of iron oxide minerals and the breakdown of rock components to clay. Most of the core displays pervasive weathering to a depth of about 19.5 m, although there is a zone of mud chip greywacke between 16.3-17 m that is little weathered. Below 19.5 m, weathering effects tend to be more limited to zones of stronger fracturing, illustrating the importance of fracturing to allow the migration of shallow oxidising groundwater. Fracture sets commonly display development of clay zones (especially where fracturing is stronger, e.g. Fig. 4) and many fractures throughout the core show thin coatings of black to brown oxides, considered to be of iron and manganese. At about 8.7 m, fractures locally contain yellow-green nontronite clay as well as iron and manganese oxides (Fig. 5).

Figure 5: Weathered massive to weakly foliated greywacke, with prominent sub-planar fractures that are coated with brown iron oxide, black manganese oxide and a little yellow-green nontronite clay (centre). Coin is at approximately 8.7 m.

IMPLICATIONS

As the borehole was vertical, it is unlikely that it has been able to obtain a representative sampling of the steeply dipping sedimentary rocks of the proposed landfill site. Maybe this is of little consequence as it is likely that other rock types to be expected in the district (e.g. mudstone, chert, etc.) would not be greatly different in composition, structure or weathering effects than the greywacke type rocks that were sampled.

No wide zones of major faulting were recognised in the core, but again, the chances of intersecting such structures would be minimised because of the vertical borehole. Most geological faults in the region are near-vertical.

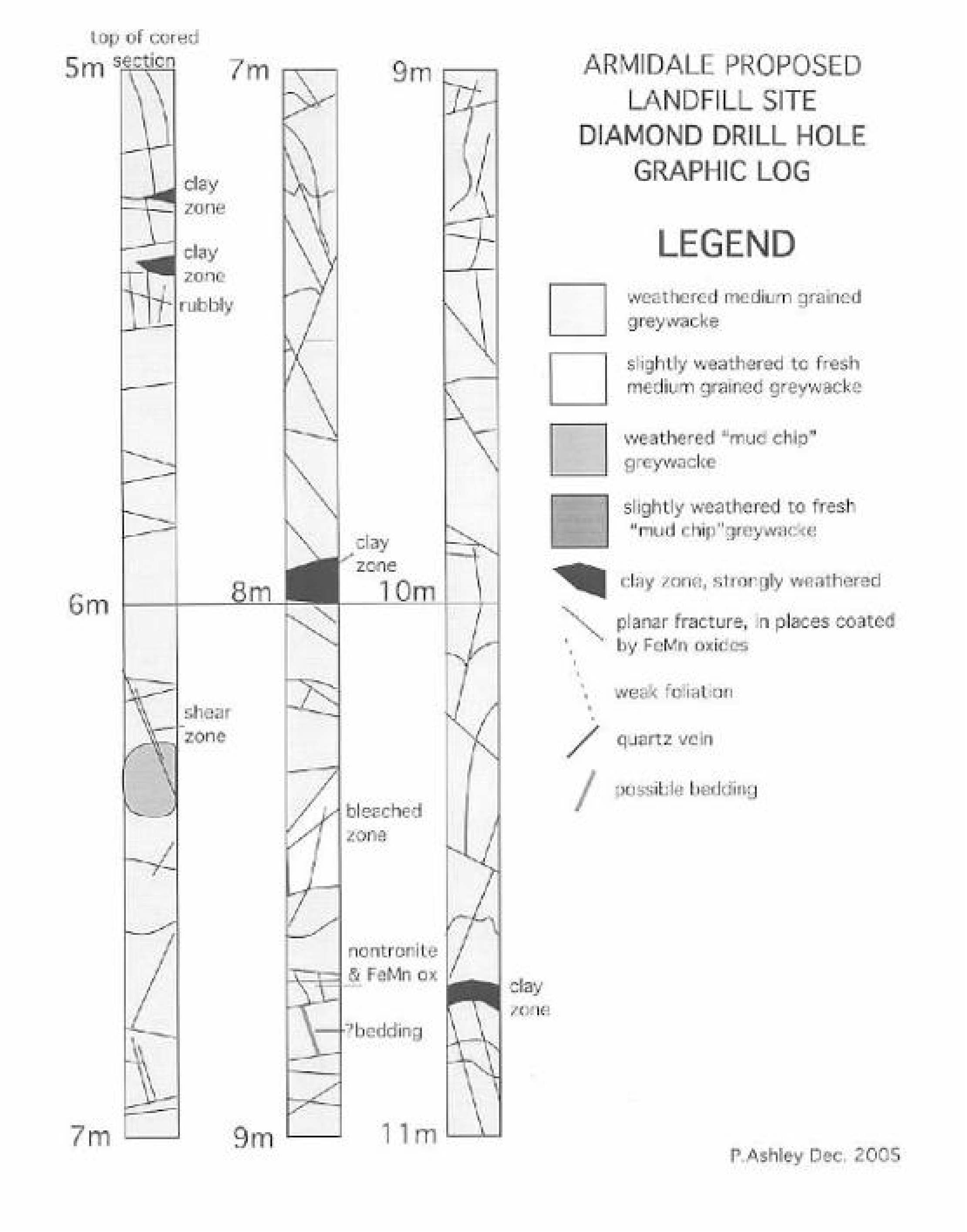
Fracturing and weathering effects observed in the drill core would have implications on the transmission of groundwater and potential leachate from a landfill. The fact that weathering effects in the deeper part of the drill core are concentrated along fractures indicates that oxidising groundwater penetrates at least to the depth of the bottom of the hole (26 m). Zones of strong fracturing and clay development in the weathered zone might have the potential for considerable groundwater transmission.

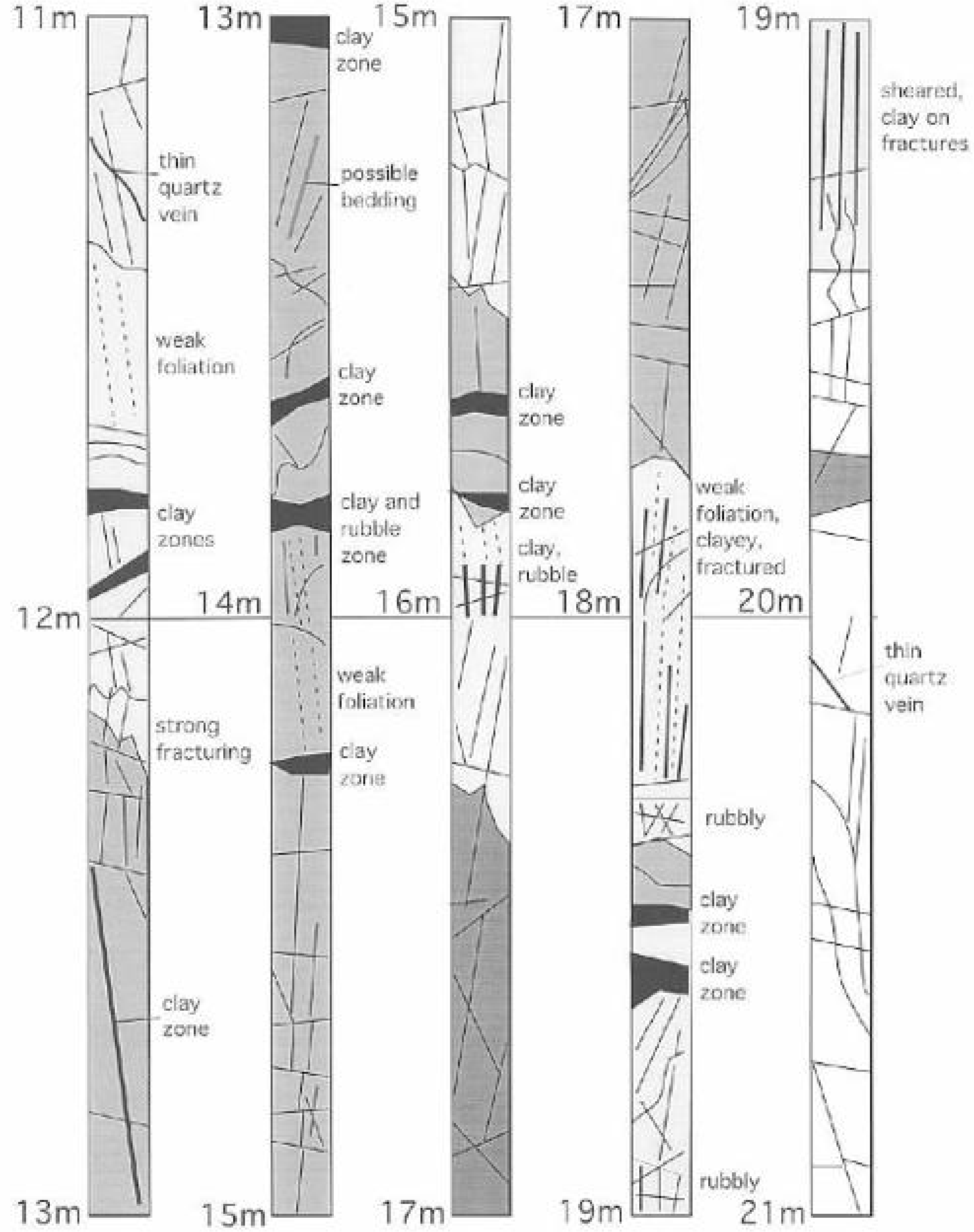
Reference

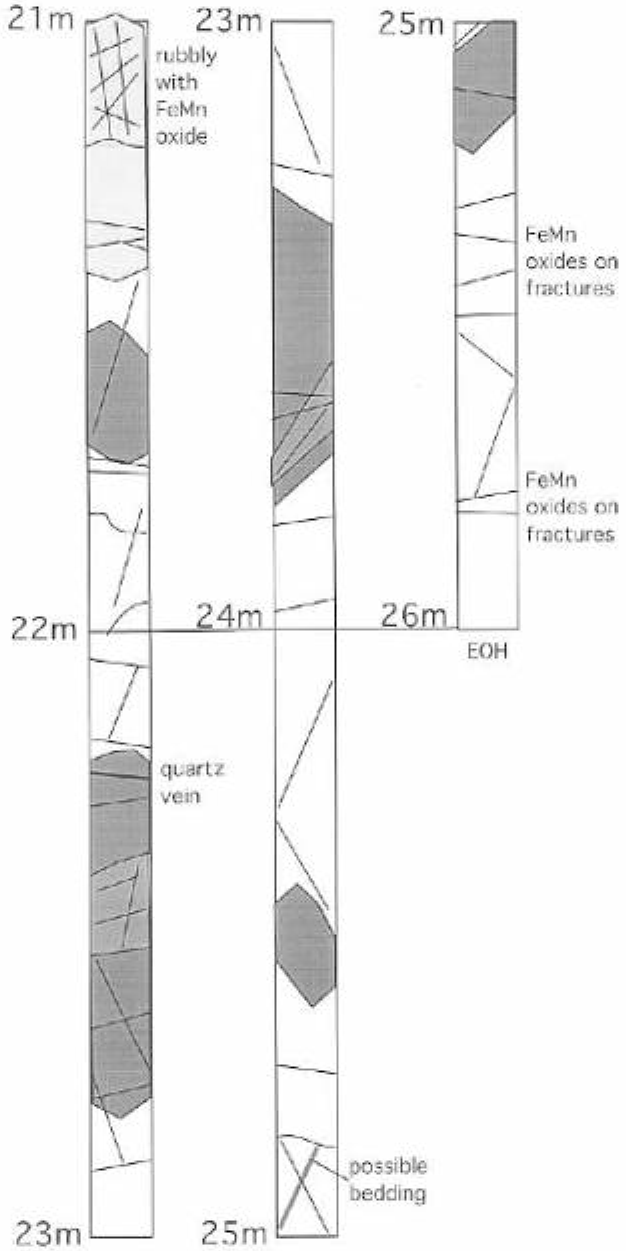
Gilligan, L.B., Brownlow, J.W., Cameron, R.G., Henley, H.F., 1992. Dorrigo-Coffs Harbour 1:250 000 Metallogenic Map. Metallogenic study and mineral deposit data sheets. NSW Geol. Survey, Sydney, 509 pp.

APPENDIX 1

DETAILED DRILL CORE LOG OF VERTICAL DRILL HOLE AT PROPOSED ARMIDALE LANDFILL SITE




11m
thin quartz vein
weak foliation
clay zones
12m
strong fracturing
clay zone
13m
13m
clay zone
possible bedding
clay zone
clay and rubble zone
14m
weak foliation
clay zone
15m
15m
clay zone
clay zone
clay, rubble
16m
17m
17m
weak foliation, clayey, fractured
18m
rubbly
clay zone
clay zone
rubbly
19m
19m
sheared, clay on fractures
20m
thin quartz vein
21m


21m
rubbly with FeMn oxide
22m
quartz vein
23m
23m
24m
possible bedding
25m
25m
FeMn oxides on fractures
FeMn oxides on fractures
26m
EOH

APPENDIX 2

PHOTOGRAPHS OF DRILL CORE
NOTE: INTERVAL FROM 0-5 m WAS NOT RECOVERED

Interval 5-10 m

Interval 10-15 m

Interval 15-20 m

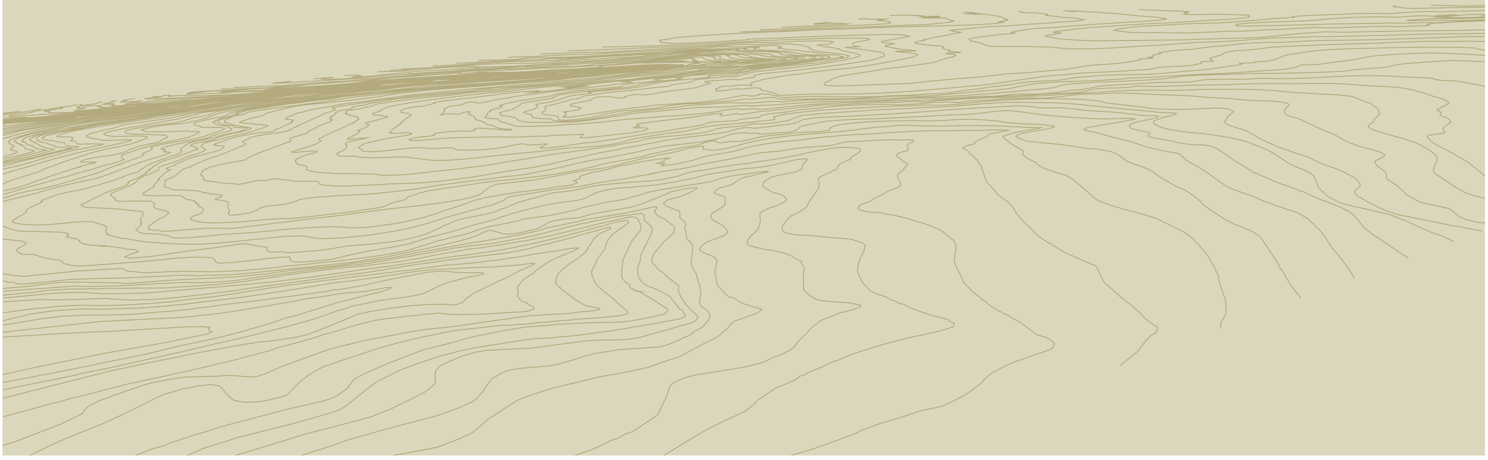
Interval 20-26 m

Appendix O

Holmes Air Sciences, 2009: Air Quality Assessment Report

ARMIDALE REGIONAL LANDFILL

Environmental Assessment



AIR QUALITY IMPACT ASSESSMENT - DRAFT
PROPOSED ARMIDALE LANDFILL

June, 2009

Prepared for

Maunsell Australia Pty Ltd

by

Holmes Air Sciences

Suite 2B, 14 Glen St
Eastwood NSW 2122
Phone : (02) 9874 8644
Fax : (02) 9874 8904
has@holmair.com.au

CONTENTS

TABLES

FIGURES

Figure 23 – Odour levels at the 99th percentile (ou) due to landfill operations – Staging 40-50 Years

(All figures at end of report)

1 INTRODUCTION

This report has been prepared by Holmes Air Sciences on behalf of Maunsell Australia Pty Ltd. The purpose of the report is to assess the air quality impacts from the operation of a proposed landfill near Armidale, NSW. The report assesses the impact of dust and odour emissions from the proposed facility.

The report presents the results of computer-based dispersion modelling for the proposed landfill. The impacts of emissions have been assessed by comparing predicted odour and dust levels with relevant air quality criteria. Modelling was undertaken in accordance with the Department of Environment and Conservation "Approved Methods for the Modelling and Assessment of Air Pollutants in NSW" (**NSW DEC, 2005**) using AUSPLUME version 6.0.

2 PROJECT DESCRIPTION

The proposed landfill will have a capacity of 750,000 tonnes, accommodating waste from Armidale City, Dumaresq and Uralla Shire Councils over a fifty year period. This equates to approximately 15,000 tonnes per year. This new facility will replace the existing landfill on Long Swamp Road. The existing waste transfer station will operate as the receival and recycling station for the proposed landfill.

The site of the proposed landfill is located approximately 12 km to the east of Armidale on Waterfall Way, as shown in **Figure 1**. The site comprises land from ‘Edington’ and ‘Sherraloy’ properties. **Figure 2** shows the layout of the proposed landfill including the proposed leachate pond and cell locations. The closest receivers to the project are to the south of the site (Crisp residence) and west of the site (Quaife residence). Other nearby receivers are located to the north and east of the site (Waters).

The proposed landfill will typically operate from 6am to 5:30pm Monday to Friday, and 8am to 6:30pm on weekends and public holidays. Construction hours will be from 7am to 5pm Monday to Friday and 8am to 5pm on Saturdays. Waste will be hauled to the site from the transfer station in 20 tonne transfer vehicles. Access roads up to the main landfill area from Waterfall Way will be sealed with an unsealed circuit around the tipping area. A wheel wash will be located at each end of the sealed access road.

Landfill activities will progress in a northerly direction through five cells as shown in **Figure 2**. While the cells are being filled, a daily cover will be placed over the waste overnight comprising material excavated on-site. A bulldozer will be used to shape the active tipping face and push the cover material. An excavator, compactor and bogie tipper will also be used on the site. Leachate material will be collected in a temporary pond to the east of the landfill, and in the final leachate pond after the completion of Cell 3. Cells will be capped and rehabilitated when the final height has been reached.

Dust will be generated primarily from vehicles on unpaved surfaces. A water cart will be used for dust suppression. Dumping of waste, shaping of the tipping face and wind erosion are also dust emitting activities.

While green waste and recycling material will be processed at the Long Swamp Road waste facility, the solid waste to be used for the landfill will still contain organic material. This will include paper, cardboard and wood products as well as putrescibles material. Whenever biodegradable material is deposited in a landfill site, landfill gas will be produced due to microbial activity. The majority of the landfill gas will consist of carbon dioxide and methane but there are also other trace gases produced. These include organic sulphides and volatile fatty acids which give the gas its characteristic odour. Landfill gas produced at the proposed landfill will be collected and treated over time during its operational life.

Odour from the landfill will be emitted from the active tipping face, leachate storage and risers, gas infrastructure, and daily and intermediate cover areas.

3 METEOROLOGY AND CLIMATE

The rate at which pollutants are dispersed is dependent on meteorological conditions including wind speed, wind direction, atmospheric stability class[1] and mixed-layer height[2]. This section describes the dispersion meteorology and climate of the study area. It provides information on prevailing wind patterns as well as historical data on temperature, humidity and rainfall. Hourly meteorological data are required by the dispersion model used in this study. The source of these data is discussed below.

3.1 Dispersion Meteorology

Meteorological data are collected by the Bureau of Meteorology at Armidale Airport using an automatic weather station. Cloud cover data was sourced from Glenn Innes from 2000. These data were used along with the concurrent wind speed data from Armidale Airport in 2000 to calculate hourly atmospheric stability using the method of **Turner** (**1970**).

Figure 4 presents annual and seasonal windroses compiled from wind speed data collected at the Armidale Airport in 2000. On an annual basis the winds are predominantly from the east, west and east-northeast. In summer and autumn, the easterly winds are the most common, while in winter the westerly winds dominate. In spring the winds are most often strong and from the west, however easterly and east-northeasterly winds are also common.

Stability is usually assigned according to six classes, A to F (see Footnote 1). The frequency of occurrence of each stability category expected in the Armidale area is shown in **Table 1**. The high frequency of D class stabilities (48.8%) indicates that emissions will disperse quickly for a significant proportion of the time. Joint wind speed, wind direction and stability class frequency tables for the 2000 data set are presented in **Appendix A**.

---

[1] In dispersion modelling stability class is used to categorise the rate at which a plume will disperse. In the Pasquill-Gifford stability class assignment scheme (as used in this study) there are six stability classes, A through to F. Class A relates to unstable conditions, such as might be found on a sunny day with light winds. In such conditions plumes will spread rapidly. Class F relates to stable conditions, such as occur when the sky is clear, the winds are light and an inversion is present. Plume spreading is slow in these circumstances. The intermediate classes B, C, D and E relate to intermediate dispersion conditions.

[2] The term mixed-layer height, refers to the height above the ground through which ground-based emissions will eventually be dispersed once a plume has been thoroughly mixed. An elevated plume, initially above the mixed-layer height will remain isolated from the ground until such time as the mixed-layer height reaches the height of the plume. In general the mixed-layer height will increase during the day as the sun causes convection to deepen the turbulent layer of the atmosphere close to the ground. Mixed-layer height will also increase if the wind speed increases because higher wind speeds will increase turbulence as the wind blows over the rough ground.

Table 1 – Frequency of occurrence of stability classes at Armidale

Stability class	Percentage frequency of occurrence
A	1.9
B	8.2
C	14.1
D	48.8
E	11.4
F	15.6
Total	**100.0**

3.2 Climate

Table 2 presents average temperature, humidity and rainfall data from Armidale Airport (**Bureau of Meteorology, 2006**). Temperature and humidity data consist of monthly averages of 9 am and 3 pm readings. Also presented are monthly averages of maximum and minimum temperatures. Rainfall data consist of mean and median monthly rainfall and the average number of raindays per month.

The annual average maximum and minimum temperatures experienced at Armidale are 20.3°C and 7.1°C respectively. On average January is the hottest month with an average maximum temperature of 27.1°C. July is the coldest month, with average minimum temperature of 0.3°C.

The annual average humidity reading collected at 9 am from the Armidale site is 68 percent, and at 3 pm the annual average is 47 percent. The month with the highest humidity on average is June with a 9 am average of 80 percent, and the lowest is November with a 3 pm average of 41 percent.

Rainfall data collected at Armidale shows that January is the wettest month, with an average rainfall of 104.5 mm over 10 days. The average annual rainfall is 790.1 mm with an average of 109 raindays.

Figure 5 shows a plot of the monthly average temperature and rainfall over the year. The graph shows that there is a strong seasonal pattern for both temperature and rainfall, with most rainfall occurring in the warmer summer months.

Table 2 – Temperature, humidity and rainfall data for Armidale Airport

(Station number 56002; Commenced: 1857, Last record: 1997; Latitude (deg S): -30.5167; Longitude (deg E): 151.6681)

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Year**
9 am Mean Dry-bulb and Wet-bulb Temperatures (°C) and Relative Humidity (%)													
Dry-bulb	19.8	18.8	17.0	13.6	9.1	6.0	4.8	6.9	11.3	15.4	17.7	19.8	13.3
Wet-bulb	15.9	15.6	14.0	11.0	7.3	4.6	3.2	4.8	7.9	11.1	13.3	15.1	10.3
Humidity	65	70	71	72	78	80	77	71	61	58	58	59	68
3 pm Mean Dry-bulb and Wet-bulb Temperatures (°C) and Relative Humidity (%)													
Dry-bulb	25.3	24.6	22.6	19.4	15.2	12.1	11.4	13.1	16.5	19.7	22.5	24.5	18.9
Wet-bulb	17.7	17.6	16.0	13.4	10.5	8.4	7.3	8.1	10.3	12.9	14.9	16.7	12.8
Humidity	45	48	48	48	53	58	53	47	42	43	41	43	47
Daily Maximum Temperature (°C)													
Mean	27.1	26.1	24.1	20.6	16.4	13.1	12.2	14.2	17.6	21.2	24.3	26.5	20.3
Daily Minimum Temperature (°C)													
Mean	13.4	13.3	11.3	7.5	3.9	1.6	0.3	1.1	3.7	7.0	9.8	12.2	7.1
Rainfall (mm)													
Mean	104.5	87.1	65.0	45.9	44.4	56.9	49.2	48.4	51.6	67.8	80.4	89.2	790.1
Median	91.6	72.3	53.9	39.4	35.2	48.3	43.3	42.0	47.0	62.2	75.0	80.2	767.7
Raindays (Number)													
Mean	10.3	9.7	9.5	7.9	8.3	9.9	8.9	8.5	7.7	9.0	9.3	10.0	108.9

Source: Bureau of Meteorology (2006)

3.3 Existing air quality

The project site is located in a rural agricultural area where background levels of pollution are typically low. Particulate matter comes from a multitude of sources and the concentration of particulates in the air is highly variable. The main source of particulate emissions will be from domestic wood fired heaters. Bushfires and wind-blown dust also have the potential to cause 24-hour average PM_{10} exceedances.

No air quality monitoring has been carried out specifically for this project, however as will be seen later in **Section 7.1**, the contribution of dust emissions from proposed activities to the local environment is predicted to be small. The existing background levels would be expected to be well within the current DEC criteria, except in extreme weather events such as dust storms and bushfires, when the 24-hour average PM_{10} goal may be exceeded.

4 AIR QUALITY ISSUES

4.1 Dust

The DEC has set out assessment procedures in a document entitled "Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales" (**NSW DEC, 2005**). This document includes methodology for the use of models and sets out relevant air quality criteria for PM_{10}, TSP, and dust deposition to be used in modelling assessments.

Table 3 and **Table 4** summarise the air quality assessment criteria that are relevant to this project. The air quality goals relate to the total dust burden in the air and not just the dust from the project.

Air quality at any particular location is determined by emissions from many sources, which will contribute various proportions to the overall pollutant burden in the air. This will depend on the location in relation to the dust source and on dispersion conditions and is particularly true in the case of particulate matter, where there are a large number of sources including agriculture, traffic, bushfires, wood fired heaters, and local and remote wind erosion sources.

Table 3 – NSW DEC criteria for particulate matter concentrations

POLLUTANT	STANDARD / GOAL	AVERAGING PERIOD	AGENCY
Total suspended particulate matter (TSP)	90 μg/m^3	Annual mean	National Health & Medical Research Council
Particulate matter < 10 μm (PM_{10})	50 μg/m^3	24-hour maximum	DEC
	30 μg/m^3	Annual mean	DEC long-term reporting goal
	50 μg/m^3	(24-hour average, 5 exceedances permitted per year)	National Environment Protection Council

In addition to health impacts, airborne dust also has the potential to cause nuisance impacts by depositing on surfaces. **Table 4** shows the maximum acceptable increase in dust deposition over the existing dust levels. The criteria for dust fallout levels are set to protect against nuisance impacts (**NSW DEC, 2005**).

Table 4 – NSW DEC criteria for dust fallout

Pollutant	**Averaging period**	**Maximum increase in deposited dust level**	**Maximum total deposited dust level**
Deposited dust	Annual	2 g/m^2/month	4 g/m^2/month

4.2 Odour emissions

Odour is measured using panels of people who are presented with samples of odorous gas diluted with decreasing quantities of clean odour-free air. The panellists then note when the smell becomes detectable. Odour in the air is then quantified in terms of odour units which is the number of dilutions required to bring the odour to a level at which 50% of the panellists can just detect the odour, defined as one odour unit. This process is known as olfactometry.

The determination of air quality goals for odour and their use in the assessment of odour impacts is recognised as a difficult topic in air pollution science. The topic has received considerable attention in the past five years and the procedures for assessing odour impacts have been refined considerably.

Odour impacts are determined by several factors, the most important of which are:

- the **F**requency of the exposure
- the **I**ntensity of the odour
- the **D**uration of the odour episodes
- the **O**ffensiveness of the odour and
- the **L**ocation of the source (the so-called FIDOL factor)

In determining the offensiveness of an odour it needs to be recognised that for most odours the context in which an odour is perceived is also relevant. Some odours, for example the smell of sewage, hydrogen sulphide, butyric acid, and including landfill gas, are likely to be judged offensive regardless of the context in which they occur. Other odours such as the smell of jet fuel may be acceptable at an airport, but not in a house, and diesel exhaust may be acceptable near a busy road, but not in a restaurant.

Whether or not an individual considers an odour to be a nuisance will depend on the FIDOL factors outlined above and although it is possible to derive formulae for assessing odour annoyance in a community, the response of any individual to an odour is still unpredictable. Odour goals need to take account of these factors.

The NSW DEC have developed a draft policy "*Assessment and Management of Odour from Stationary Sources in NSW"* (**NSW EPA, 2001**) which includes some recommendations for odour criteria. They have been refined by the DEC to take account of population density in the area. **Table 5** lists the odour certainty[3] thresholds, to be exceeded not more than 1% of the time, for different population densities (**NSW DEC, 2005**).

Table 5 – Odour performance criteria for the assessment of odour

Population of affected community	Odour performance criteria (nose response odour certainty units at the 99th percentile)
Single residence (≤ ~2)	7
~10	6
~ 30	5
~ 125	4
~ 500	3
Urban (~ 2000)	2

The difference between odour goals is based on considerations of risk of odour impact rather than differences in odour acceptability between urban and rural areas. For a given odour level there will be a wide range of responses in the population exposed to the odour. In a densely populated area there will therefore be a greater risk that some individuals within the community will find the odour unacceptable than in a sparsely populated area. The goals assume that 7 odour units at the 99th percentile would be acceptable to the average person, but as the number of exposed people increases there is a chance that sensitive individuals would be exposed. The goal of 2 odour units at the 99th percentile is considered to be acceptable for the whole population. The population density in the area around the site

---

[3] In the process of odour measurement, the odour certainty threshold is, by definition, the minimum concentration at which the panellist is <u>certain</u> they can detect the odour.

is equivalent to a single residence. On this basis the odour criterion of 7 ou has been applied to the project.

It is common practice to use dispersion models to determine compliance with odour goals. This introduces a complication because Gaussian dispersion models are only able to directly predict concentrations over an averaging period of three-minutes or greater. The human nose, however, responds to odours over periods of the order of a second or so. During a three-minute period, odour levels can fluctuate significantly above and below the mean depending on the nature of the source.

To determine more rigorously the ratio between the one-second peak concentrations and three-minute and longer period average concentrations (referred to as the peak to mean ratio) that might be predicted by a Gaussian dispersion model, the NSW DEC commissioned a study by **Katestone Scientific Pty Ltd (1995, 1998)**. This study recommended peak to mean ratios for a range of source types. The ratio is also dependent on atmospheric stability and the distance from the source. A summary table of these ratios is presented in **Appendix B.** In this case peak to mean factors for area sources in the near field are relevant. The peak to mean ratios are 2.5 for unstable to neutral atmosphere conditions and 2.3 for stable atmosphere conditions.

The NSW DEC publication 'Draft Policy: Assessment and Management of Odour from Stationary Sources in NSW' (**NSW EPA, 2001**) takes account of this peaking factor and the goals shown in **Table 5** are based on nose-response time.

5 EMISSION ESTIMATES

5.1 Situation Analysis

Scenarios have been chosen to represent activities that will be occurring at a point in time within Stages 0-10 years, 10-20 years and 40-50 years of the landfill as shown in Figure 3. The location of the excavation area, tipping face and daily cover within the active cell will change throughout each 10 year period. The tipping face has been calculated as being an area of 32 square meters for daily tipping, based on a 15,000 tonnes per annum assumption. The tipping face is the only area of exposed waste and will be exposed during operational hours of the landfill only. The tipping face will be covered at the end of the day.

The following three scenarios were modeled to predict the maximum dust impacts from the landfill:

0-10 years
- Tipping face in Cell 1, part b
- Daily cover in Cell 1, parts a and b
- Excavation in Cell 1, parts c and d
- Stockpile in western section of Cell 2

10-20 years
- Tipping face in Cell 2, part b
- Daily cover in Cell 2, parts a and b
- Excavation in Cell 2, parts c and d
- Stockpile in western section of Cell 3
- Intermediate cover over Cell 1

40-50 years
- Tipping face in Cell 5, part c
- Daily cover in Cell 5, parts c and d
- No excavation
- Stockpile to the north of the landfill

- Intermediate cover over Cell 5 parts a and b, and Cell 4
- Final cover over Cells 1, 2 and 3

5.2 Dust emissions

Dust emissions arise from various activities at landfills. Total dust emissions due to the operations of the proposed landfill have been estimated by analysing the excavation and landfilling operations for three stages of the proposal. Rates of excavation and landfilling for each stage have been adjusted to determine rates on a yearly basis.

Estimated dust emissions of Total Suspended Particulates (TSP) are presented in **Table 6**. To show how these values have been calculated, details of the calculations for Staging 10-20 years are presented in **Appendix C**. These estimates assume that 75% control of dust is achievable due to the watering of haul roads. Regular watering on unsealed haul routes has been assumed for the purposes of the dust emission calculations.

The operations which apply in each case have been combined with emission factors developed, both locally and by the US EPA, to estimate the amount of dust produced by each activity. Haul road distances and routes, landfill areas, activity operating hours, truck movements and other details have been provided by Maunsell in order to estimate the dust emissions for the operations.

Table 6 – Dust emission estimates

Activity	**TSP (kg/y)**		
	Staging 0-10 years	**Staging 10-20 years**	**Staging 40-50 years**
Excavation			
Removing topsoil	1004	1004	-
Excavators in pit	3462	2935	-
Hauling material to stockpile	9233	7826	-
Dumping material at stockpile	371	314	-
Dozers shaping tipping face	23429	23429	-
Landfilling			
Dozers working in landfill (4h/d)	19600	19600	19600
Hauling waste on sealed road	121	121	121
Hauling waste on unsealed road	400	400	56
Dumping waste	3	2.8	3
Scraping and transporting cover material	118	118	128
Shaping covered area	23429	23429	23429
Wind erosion from exposed landfill excavation areas	3044	2840	2876
Wind erosion from stockpiles	1135	1135	1135

5.3 Odour emissions

Odour emission rates from area sources, such as landfills, are difficult to measure for a variety of reasons. Firstly the source is often heterogeneous. For example in the case of landfill sites, there will be different odour emission rates from different sections of the landfill. Secondly, unlike stack emissions, area emission rates are dependent upon atmospheric conditions including wind speed, degree of turbulence, temperature, etc. This adds another level of complexity to odour assessments.

A detailed odour measurement study was carried out by **Zib and Associates** (**2002**) for Eastern Creek Landfill (Stage 2) in western Sydney. Measurements were made on the major sources from the site, including the open face, 1-day cover, intermediate cover, restored surface and leachate pond. The leachate pond odour emission rate at Eastern Creek Landfill was 0.17 ou.m^3/s/m^2. A higher leachate pond odour emission rate of 0.28 ou.m^3/s/m^2 has been recorded by Holmes Air Sciences at another landfill in Sydney with a similar total leachate pond surface area to the proposed Armidale Landfill leachate pond. The results from this other odour testing are not currently in the public domain, however they represent the most conservative odour emission rate for this source and have therefore been used in this assessment.

Table 7 provides the quantitative information on odour emissions for the dispersion modelling. Three stages of operation have been modelled. These scenarios are described in more detail in **Section 6.1**. Odour emissions in the dispersion model have been multiplied by the recommended peak to mean ratios for different source types (see **Appendix A**) to predict odour levels for nose-response times. Peak to mean factors for the near field have been applied for the purposes of this assessment. For area sources, these factors have numerical values of 2.5 for unstable and neutral atmospheric conditions and 2.3 for stable conditions.

Table 7 – Estimated near field odour emissions for the proposed Armidale Landfill

Staging	**Source**	**Area (m^2)**	**Odour emission rate (ou.m^3/s/m^2)**	**Peak odour emission rate (Neutral) P/M = 2.5 (ou.m^3/s/m^2)**	**Peak odour emission rate (Stable) P/M = 2.3 (ou.m^3/s/m^2)**	**Total emissions (ou.m3/s) neutral**	**Total emissions (ou.m3/s) stable**
0-10 years	Leachate pond	2970	0.28	0.7	0.644	2079	1913
	Active tipping face	32	7.06	17.65	16.24	565	520
	1-day cover	15516	0.35	0.875	0.805	13576	12490
10-20 years	Leachate pond	2970	0.28	0.7	0.644	2079	1913
	Active tipping face	32	7.06	17.65	16.24	565	520
	1-day cover	15191	0.35	0.875	0.805	13292	12229
	Intermediate	34694	0.1	0.25	0.23	8674	7980
40-50 years	Leachate pond	2970	0.28	0.7	0.644	2079	1913
	Active tipping face	32	7.06	17.65	16.24	565	520
	1-day cover	15998	0.35	0.875	0.805	13998	12879
	Intermediate	50958	0.1	0.25	0.23	3811	3506
	Final capping	103403	0.05	0.125	0.115	8929	8214

6 APPROACH TO ASSESSMENT

6.1 Dust

The model used to predict dust impacts was the US EPA ISCST3 model (the ISC model). The model is fully described in the user manual and the accompanying technical description (**US EPA, 1995**).

It has been apparent for a number of years that the ISC model has a tendency to overestimate the 24-hour PM_{10} concentrations, while still predicting the longer term average concentrations reasonably accurately. In recent years the DEC have permitted the use of a calibration factor to correct for the tendency of ISC to over-predict 24-hour average PM_{10} concentrations. In most instances, the DEC has required that a site-specific calibration factor be developed from local model and monitoring results.

One of the earliest calibration studies was undertaken as part of the EIS for the Warkworth mine in the Hunter Valley (**Holmes Air Sciences, 2002**). The calibration was done by comparing the predicted maximum 24-hour average PM_{10} concentrations at the several mine operated monitors. The maximum measured PM_{10} concentrations were then determined by inspection of the monitoring data. From these investigations the average extent of over-prediction was found to be a factor of 2.6; that is, unadjusted model predictions appeared to over predict 24-hour PM_{10} concentrations by 260%. This factor was used to adjust the model predictions for the Warkworth EIS downwards to obtain a calibrated prediction of the worst-case 24-hour PM_{10} concentrations for all scenarios that were assessed.

Other studies undertaken at other locations have derived different calibration factors, both larger and smaller than 2.6. Further studies to develop a more scientifically robust methodology for dealing with the over-prediction of short-term concentrations by the ISC model are to be conducted as part of the approval conditions for the Mt Owen Mine.

Comparisons between ISC and AUSPLUME, an advanced Gaussian dispersion model based on ISC, (see **Holmes Air Sciences, 2003** for example) have suggested that a correction factor is appropriate for short term (that is, 24-hour average) ISC predictions. Although the comparison between AUSPLUME and ISC shows varying difference, AUSPLUME has consistently predicted almost 50% lower than uncorrected ISC predictions. Thus, AUSPLUME may have some advantages over ISC in that it more accurately predicts 24-hour average concentrations of PM_{10}, which are known to be consistently overestimated by ISC.

Results from a simplified model comparison of AUSPLUME and ISC showed that 1-hour average PM_{10} concentrations downwind of a source and along the plume centreline were between 2.8 and 3.5 times higher using ISC than for AUSPLUME (see Appendix C of **Holmes Air Sciences, 2006**). The difference between the models depends on the meteorological conditions. Different results from the two models were largely explained by the way in which each model has interpreted the plume dispersion curves.

These studies, and the recently completed calibration study undertaken as part of the Mt Owen Mine's conditions of approval, have lead to a better understanding of the reasons for the over-prediction. It appears that a substantial fraction of effect is due to the fact that the dispersion curves used in the ISC model have not been adjusted for differences in averaging times and the effects of the aerodynamic roughness. For most model runs for a particular site these will be different from the conditions where the original dispersion curves were developed.

To overcome this difficultly the ISC model has been modified to create a model that will be referred to as ISCMOD. ISCMOD is identical to ISC except that the horizontal plume spreading dispersion curves have been modified to adopt the recommendations of the American Meteorological Society's (AMS) expert panel on dispersion curves (**Hanna, 1977**) and the suggestions made by **Arya (1999)**. The suggested changes were recommended because, as the AMS panel notes, the original horizontal dispersion curves relate to an averaging time of three minutes and they recommend that these be adjusted to the one hour curves required by ISC. The change involves increasing the horizontal plume widths by a factor of 1.82 $(60 \text{ minutes} / 3 \text{ minute})^{0.2}$.

The ISCMOD model was used to predict 24-hour average PM_{10} and annual average dust deposition, TSP, and PM_{10} concentrations from the operation of the proposed Armidale landfill. These concentrations were determined at discrete receivers spread over the area shown in **Figure 2**. Receivers were chosen to be finely spaced in areas near the dust sources and at nearby residences.

Estimates of emissions for each source were developed on an hourly time step taking into account the activities that would take place at that location. Thus, for each source, for each hour, an emission rate was determined which depended upon the level of activity and the wind speed. It is important to do this to ensure that long-term average emission rates are not combined with worst-case dispersion conditions which are associated with light winds. Light winds at a mine site would correspond with periods of low dust generation because wind erosion and other wind dependent emissions rates will be low. Light winds also correspond with periods of poor dispersion. If these measures are not taken then the model has the potential to significantly overstate impacts.

6.2 Odour

Odour impacts were assessed for the three stages used in the dust modelling. Potential odour impacts of the proposed facility on the surrounding receivers have been assessed using AUSPLUME v6.0.

The AUSPLUME model has been used to predict the 1-hour average odour levels, expressed in odour units, at a grid of receivers 5 x 5 km centred on the project site and at discrete receiver points located at nearby receivers. For the purpose of presenting the results, the 99th percentile and maximum predicted 1-hour odour level at each receiver has been retained by the model and contour plots have been prepared showing the distribution of these levels. The contour plots do not represent the dispersion pattern at any particular instant in time, but show the 99th and 100th percentile odour levels that occurred at each location. The 100th percentile levels are used to show odour levels which can possibly be reached under the modelled conditions. The 99th percentile levels relate to the DEC odour goals.

7 ASSESSMENT OF IMPACTS

7.1 Dust impacts

This section provides an interpretation of the predicted dust concentration contours and dust deposition levels for three stages in the life of the landfill operation. For each stage four isopleth diagrams have been produced showing the following:

- The predicted maximum 24-hour average PM_{10} concentrations;
- The predicted annual average PM_{10} concentrations;
- The predicted annual average TSP concentrations;
- The predicted annual average dust deposition.

The isopleths do not include dust contributions from sources other than the proposed landfill. These plots are shown for the three stages of operation in **Figure 6** to **Figure 17**. The predicted dust concentrations and deposition levels at all residential receivers were within the DEC criteria. Note that these predictions do not take account of background levels, as required by the DEC. However, the model predictions are very low and it was concluded that the proposed activities would be unlikely to cause exceedances of the DEC air quality criteria.

The highest dust impacts during each stage are concentrated around the section of the landfill where the dust generating activity will be occurring. For example, during Stage 0-10 Years the highest impacts are at the southern end of the proposed site, as most of the dust generating activity occurs in Cell 1 during this stage. The highest predicted concentrations at residential receivers for each stage are shown in **Table 8**.

Table 8 – Predicted dust concentrations

Stage	Dust prediction	Receiver (see **Figure 8**)						Relevant air quality goal
		1	2	3	4	5	6	
0-10 years	Maximum 24-hour PM_{10}	3.71	8.91	1.27	0.70	0.79	1.61	50
	Annual PM_{10}	0.25	0.60	0.10	0.03	0.04	0.03	30
	Annual TSP	0.36	0.98	0.13	0.05	0.05	0.03	90
	Annual dust deposition	0.08	0.10	0.03	0.01	0.01	0.00	4
10-20 years	Maximum 24-hour PM_{10}	4.28	6.21	1.37	0.79	0.90	1.66	50
	Annual PM_{10}	0.32	0.39	0.11	0.04	0.04	0.03	30
	Annual TSP	0.47	0.62	0.15	0.05	0.06	0.04	90
	Annual dust deposition	0.10	0.06	0.03	0.01	0.01	0.00	4
40-50 years	Maximum 24-hour PM_{10}	2.85	1.55	0.85	0.69	0.70	1.37	50
	Annual PM_{10}	0.30	0.09	0.08	0.03	0.03	0.03	30
	Annual TSP	0.43	0.14	0.11	0.04	0.05	0.03	90
	Annual dust deposition	0.09	0.01	0.02	0.01	0.01	0.00	4

7.2 Odour impacts

The dispersion model results for odour levels at off-site receivers are presented in **Table 9** and odour contours are shown in **Figure 18** to **Figure 23**. The figures include plots of predicted maximum odour levels (corrected for nose response times) and odour levels at the 99th percentile to compare with the DEC odour goals.

Table 9 – Predicted 99th percentile odour concentrations

Stage	Receiver (see **Figure 8**)					
	1	2	3	4	5	6
0-10 years	0.15	1.48	0.16	0.04	0.04	0.02
10-20 years	0.27	2.09	0.26	0.06	0.06	0.03
40-50 years	0.63	1.08	0.38	0.09	0.09	0.04

The DEC goal for a single rural receiver is 7 ou at the 99th percentile. The odour levels at the 99th percentile are well within the 7 ou odour goal for all three stages. It is therefore concluded that the off-site odour impacts from the landfill will be at acceptable levels.

8 CONCLUSIONS

This report has assessed the air quality impacts associated with the proposed Armidale landfill. Dust and odour impacts have been addressed and dispersion modelling has been used to predict off-site dust and odour levels due to landfill operations. The dispersion modelling took account of the local meteorology and terrain information and used emission estimates to predict off-site air quality impacts.

The conclusions of the assessment can be summarised as follows:

- Dust impacts due to the landfill operations are predicted to be low and are unlikely to cause exceedances of the DEC criteria;
- Odour impacts due to the landfill operations are predicted to be at acceptable levels.

9 REFERENCES

Arya S P (1999)

"Air Pollution Meteorology and Dispersion" Published by Oxford University Press (Page 202 and 208)

Bureau of Meteorology (2006)
http://www.bom.gov.au/climate/averages/

Hanna S. R., Briggs G. A., Deardorff J. C., Egan B. A., Gifford F. A. and Pasquill F. (1977)
"AMS Workshop on Stability Classification Schemes and Sigma Curves - Summary of Recommendations" concerning the adjustment of sigma-curves" Bulletin American Meteorological Society, Volume 58, Number 12, 1305-1309.

Holmes Air Sciences (2002)
"Air Quality Assessment: Warkworth Mine", Prepared by Holmes Air Sciences

Holmes Air Sciences (2003)
"Air Quality Impact Assessment : Proposed Concrete Batching Plant at Kellogg Road, Rooty Hill", Prepared by Holmes Air Sciences for National Environmental Consulting Services, August 2003.

Holmes Air Sciences (2006)
"Air Quality Impact Assessment: Bengalla Mine – Mine Plan Modifications". Prepared for Hansen Consulting Pty Limited, 28 February 2006.

Katestone Scientific Pty Ltd (1995)
"The evaluation of peak to mean ratios for odour assessments" Volume 1 - Main Report, May 1995

Katestone Scientific (1998)
"Report from Katestone Scientific to Environment Protection Authority of NSW, Peak to Mean Ratios for Odour Assessments"

NERDDC (1988)
"Air pollution from surface coal mining: Volume 2 Emission factors and model refinement", National Energy Research and Demonstration Council, Project 921.

NSW DEC (2005)
"Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales", Department of Environment and Conservation, August 2005

NSW EPA (1998)
"Action for Air", the NSW Government's 25-Year Air Quality Management Plan

NSW EPA (2001)
"Draft Policy: Assessment and Management of Odour from Stationary Sources in NSW".

Turner, D.B. (1970)
"Workbook of Atmospheric Dispersion Estimates", United States Environmental Protection Agency, Office of Air Programs, Research Triangle Park, North Carolina, Revised 1970, Office of Air Programs Publication Number AP-26.

US EPA (1985)

“Compilation of Air Pollutant Emission Factors”, AP-42, Fourth Edition United States Environmental Protection Agency, Office of Air and Radiation Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina 27711.

US EPA (1995)

“User’s Guide for the Industrial Source Complex (ISC3) Dispersion Models - Volume 1 User’s Instructions” and “Volume 2 Description of Model Algorithms” US Environmental Protection Agency, Office of Air Quality Planning and Standards Emissions, Monitoring and Analysis Division, Research Triangle Park, North Carolina 27711.

Zib & Associates (2002)

“Eastern Creek WMC: Odour assessment of proposed modification to Stage 2 Landfill Operations” prepared for Waste Services NSW, June 2002.

APPENDIX A

JOINT WIND SPEED, WIND DIRECTION AND STABILITY CLASS FREQUENCY TABLES

```
PASQUILL STABILITY CLASS 'A'

                        Wind Speed Class (m/s)

             0.50      1.50      3.00      4.50      6.00      7.50      9.00  GREATER
 WIND         TO        TO        TO        TO        TO        TO        TO     THAN
SECTOR       1.50      3.00      4.50      6.00      7.50      9.00     10.50     10.50    TOTAL
-----------------------------------------------------------------------------------------

   NNE   00000004 00000002 00000000 00000000 00000000 00000000 00000000 00000000 00000006
    NE   00000008 00000007 00000000 00000000 00000000 00000000 00000000 00000000 00000015
   ENE   00000002 00000014 00000000 00000000 00000000 00000000 00000000 00000000 00000016
     E   00000008 00000004 00000000 00000000 00000000 00000000 00000000 00000000 00000012
   ESE   00000003 00000005 00000000 00000000 00000000 00000000 00000000 00000000 00000008
    SE   00000000 00000007 00000000 00000000 00000000 00000000 00000000 00000000 00000007
   SSE   00000002 00000005 00000000 00000000 00000000 00000000 00000000 00000000 00000007
     S   00000003 00000006 00000000 00000000 00000000 00000000 00000000 00000000 00000009
   SSW   00000004 00000009 00000000 00000000 00000000 00000000 00000000 00000000 00000013
    SW   00000003 00000010 00000000 00000000 00000000 00000000 00000000 00000000 00000013
   WSW   00000005 00000010 00000000 00000000 00000000 00000000 00000000 00000000 00000015
     W   00000008 00000004 00000000 00000000 00000000 00000000 00000000 00000000 00000012
   WNW   00000002 00000006 00000000 00000000 00000000 00000000 00000000 00000000 00000008
    NW   00000000 00000001 00000000 00000000 00000000 00000000 00000000 00000000 00000001
   NNW   00000002 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000002
     N   00000006 00000002 00000000 00000000 00000000 00000000 00000000 00000000 00000008

  CALM                                                                           00000010
-----------------------------------------------------------------------------------------
  TOTAL  00000060 00000092 00000000 00000000 00000000 00000000 00000000 00000000 00000162

   MEAN WIND SPEED (m/s) = 1.68
  NUMBER OF OBSERVATIONS = 162
```

```
                     PASQUILL STABILITY CLASS 'B'

                        Wind Speed Class (m/s)

             0.50      1.50      3.00      4.50      6.00      7.50      9.00  GREATER
 WIND         TO        TO        TO        TO        TO        TO        TO     THAN
SECTOR       1.50      3.00      4.50      6.00      7.50      9.00     10.50     10.50    TOTAL
-----------------------------------------------------------------------------------------

   NNE   00000011 00000006 00000004 00000000 00000000 00000000 00000000 00000000 00000021
    NE   00000020 00000029 00000007 00000001 00000000 00000000 00000000 00000000 00000057
   ENE   00000008 00000023 00000026 00000002 00000000 00000000 00000000 00000000 00000059
     E   00000010 00000018 00000056 00000010 00000000 00000000 00000000 00000000 00000094
   ESE   00000009 00000011 00000017 00000005 00000000 00000000 00000000 00000000 00000042
    SE   00000007 00000008 00000006 00000000 00000000 00000000 00000000 00000000 00000021
   SSE   00000006 00000005 00000010 00000000 00000000 00000000 00000000 00000000 00000021
     S   00000004 00000003 00000004 00000002 00000000 00000000 00000000 00000000 00000013
   SSW   00000009 00000006 00000007 00000000 00000000 00000000 00000000 00000000 00000022
    SW   00000009 00000014 00000025 00000002 00000000 00000000 00000000 00000000 00000050
   WSW   00000017 00000025 00000040 00000009 00000000 00000000 00000000 00000000 00000091
     W   00000028 00000025 00000060 00000011 00000000 00000000 00000000 00000000 00000124
   WNW   00000012 00000014 00000017 00000001 00000000 00000000 00000000 00000000 00000044
    NW   00000006 00000007 00000003 00000001 00000000 00000000 00000000 00000000 00000017
   NNW   00000008 00000002 00000001 00000000 00000000 00000000 00000000 00000000 00000011
     N   00000005 00000001 00000000 00000000 00000000 00000000 00000000 00000000 00000006

  CALM                                                                           00000010
-----------------------------------------------------------------------------------------
  TOTAL  00000169 00000197 00000283 00000044 00000000 00000000 00000000 00000000 00000703

   MEAN WIND SPEED (m/s) = 2.65
  NUMBER OF OBSERVATIONS = 703
```

```
                     PASQUILL STABILITY CLASS 'C'

                        Wind Speed Class (m/s)

             0.50     1.50     3.00     4.50     6.00     7.50     9.00  GREATER
 WIND         TO       TO       TO       TO       TO       TO       TO     THAN
SECTOR       1.50     3.00     4.50     6.00     7.50     9.00    10.50    10.50    TOTAL
-----------------------------------------------------------------------------------------

   NNE   00000009 00000003 00000003 00000006 00000000 00000000 00000000 00000000 00000021
    NE   00000011 00000021 00000021 00000014 00000000 00000000 00000000 00000000 00000067
   ENE   00000008 00000020 00000043 00000030 00000003 00000001 00000000 00000000 00000105
     E   00000004 00000023 00000077 00000086 00000012 00000001 00000000 00000000 00000203
   ESE   00000003 00000011 00000022 00000030 00000003 00000001 00000000 00000000 00000070
    SE   00000002 00000012 00000010 00000005 00000000 00000000 00000000 00000000 00000029
   SSE   00000002 00000006 00000003 00000003 00000002 00000000 00000000 00000000 00000016
     S   00000003 00000005 00000007 00000004 00000000 00000000 00000000 00000000 00000019
   SSW   00000003 00000010 00000008 00000010 00000004 00000000 00000000 00000000 00000035
    SW   00000002 00000009 00000017 00000018 00000005 00000004 00000001 00000000 00000056
   WSW   00000012 00000015 00000045 00000049 00000023 00000019 00000012 00000001 00000176
     W   00000016 00000023 00000045 00000092 00000027 00000017 00000017 00000021 00000258
   WNW   00000010 00000015 00000025 00000022 00000007 00000007 00000006 00000003 00000095
    NW   00000004 00000002 00000006 00000005 00000001 00000001 00000000 00000000 00000019
   NNW   00000007 00000004 00000001 00000004 00000000 00000000 00000000 00000000 00000016
     N   00000001 00000001 00000001 00000001 00000000 00000000 00000000 00000000 00000004

  CALM                                                                           00000012
-----------------------------------------------------------------------------------------
  TOTAL  00000097 00000180 00000334 00000379 00000087 00000051 00000036 00000025 00001201

   MEAN WIND SPEED (m/s) = 4.51
  NUMBER OF OBSERVATIONS = 1201
```

```
                     PASQUILL STABILITY CLASS 'D'

                        Wind Speed Class (m/s)

             0.50     1.50     3.00     4.50     6.00     7.50     9.00  GREATER
 WIND         TO       TO       TO       TO       TO       TO       TO     THAN
SECTOR       1.50     3.00     4.50     6.00     7.50     9.00    10.50    10.50    TOTAL
-----------------------------------------------------------------------------------------

   NNE   00000005 00000013 00000008 00000018 00000007 00000000 00000000 00000000 00000051
    NE   00000017 00000047 00000115 00000078 00000025 00000007 00000000 00000000 00000289
   ENE   00000018 00000092 00000225 00000260 00000109 00000013 00000000 00000000 00000717
     E   00000005 00000085 00000284 00000388 00000223 00000053 00000002 00000000 00001040
   ESE   00000006 00000024 00000075 00000064 00000059 00000008 00000002 00000000 00000238
    SE   00000001 00000008 00000018 00000013 00000003 00000000 00000000 00000000 00000043
   SSE   00000006 00000007 00000005 00000002 00000002 00000000 00000000 00000000 00000022
     S   00000003 00000011 00000008 00000010 00000003 00000001 00000000 00000000 00000036
   SSW   00000002 00000008 00000020 00000015 00000004 00000000 00000000 00000000 00000049
    SW   00000004 00000018 00000030 00000021 00000023 00000005 00000001 00000001 00000103
   WSW   00000006 00000026 00000037 00000079 00000091 00000065 00000013 00000009 00000326
     W   00000012 00000053 00000070 00000130 00000122 00000110 00000046 00000051 00000594
   WNW   00000012 00000052 00000072 00000066 00000086 00000042 00000017 00000013 00000360
    NW   00000007 00000037 00000042 00000033 00000050 00000023 00000010 00000006 00000208
   NNW   00000004 00000015 00000013 00000006 00000003 00000000 00000003 00000002 00000046
     N   00000007 00000010 00000011 00000005 00000002 00000000 00000000 00000000 00000035

  CALM                                                                           00000011
-----------------------------------------------------------------------------------------
  TOTAL  00000115 00000506 00001033 00001188 00000812 00000327 00000094 00000082 00004168

   MEAN WIND SPEED (m/s) = 5.18
  NUMBER OF OBSERVATIONS = 4168
```

```
                     PASQUILL STABILITY CLASS 'E'

                        Wind Speed Class (m/s)

             0.50     1.50     3.00     4.50     6.00     7.50     9.00  GREATER
 WIND         TO       TO       TO       TO       TO       TO       TO     THAN
SECTOR       1.50     3.00     4.50     6.00     7.50     9.00    10.50    10.50    TOTAL
-----------------------------------------------------------------------------------------

   NNE   00000000 00000011 00000001 00000002 00000000 00000000 00000000 00000000 00000014
    NE   00000000 00000029 00000056 00000014 00000000 00000000 00000000 00000000 00000099
   ENE   00000000 00000053 00000124 00000040 00000000 00000000 00000000 00000000 00000217
     E   00000000 00000075 00000115 00000034 00000000 00000000 00000000 00000000 00000224
   ESE   00000000 00000014 00000019 00000011 00000000 00000000 00000000 00000000 00000044
    SE   00000000 00000010 00000006 00000001 00000000 00000000 00000000 00000000 00000017
   SSE   00000000 00000008 00000003 00000002 00000000 00000000 00000000 00000000 00000013
     S   00000000 00000010 00000003 00000001 00000000 00000000 00000000 00000000 00000014
   SSW   00000000 00000010 00000010 00000002 00000000 00000000 00000000 00000000 00000022
    SW   00000000 00000008 00000020 00000002 00000000 00000000 00000000 00000000 00000030
   WSW   00000000 00000014 00000037 00000026 00000000 00000000 00000000 00000000 00000077
     W   00000000 00000021 00000044 00000036 00000000 00000000 00000000 00000000 00000101
   WNW   00000000 00000019 00000029 00000008 00000000 00000000 00000000 00000000 00000056
    NW   00000000 00000009 00000017 00000003 00000000 00000000 00000000 00000000 00000029
   NNW   00000000 00000004 00000005 00000002 00000000 00000000 00000000 00000000 00000011
     N   00000000 00000007 00000002 00000001 00000000 00000000 00000000 00000000 00000010

  CALM                                                                           00000000
-----------------------------------------------------------------------------------------
  TOTAL  00000000 00000302 00000491 00000185 00000000 00000000 00000000 00000000 00000978

   MEAN WIND SPEED (m/s) = 3.51
  NUMBER OF OBSERVATIONS = 978
```

```
                     PASQUILL STABILITY CLASS 'F'

                        Wind Speed Class (m/s)

             0.50     1.50     3.00     4.50     6.00     7.50     9.00  GREATER
 WIND         TO       TO       TO       TO       TO       TO       TO     THAN
SECTOR       1.50     3.00     4.50     6.00     7.50     9.00    10.50    10.50    TOTAL
-----------------------------------------------------------------------------------------

   NNE   00000028 00000020 00000002 00000000 00000000 00000000 00000000 00000000 00000050
    NE   00000042 00000078 00000020 00000000 00000000 00000000 00000000 00000000 00000140
   ENE   00000027 00000091 00000037 00000000 00000000 00000000 00000000 00000000 00000155
     E   00000030 00000081 00000036 00000000 00000000 00000000 00000000 00000000 00000147
   ESE   00000017 00000012 00000002 00000000 00000000 00000000 00000000 00000000 00000031
    SE   00000014 00000011 00000002 00000000 00000000 00000000 00000000 00000000 00000027
   SSE   00000008 00000008 00000003 00000000 00000000 00000000 00000000 00000000 00000019
     S   00000009 00000013 00000007 00000000 00000000 00000000 00000000 00000000 00000029
   SSW   00000012 00000020 00000003 00000000 00000000 00000000 00000000 00000000 00000035
    SW   00000015 00000026 00000010 00000000 00000000 00000000 00000000 00000000 00000051
   WSW   00000045 00000069 00000022 00000000 00000000 00000000 00000000 00000000 00000136
     W   00000067 00000099 00000030 00000000 00000000 00000000 00000000 00000000 00000196
   WNW   00000047 00000079 00000012 00000000 00000000 00000000 00000000 00000000 00000138
    NW   00000016 00000024 00000009 00000000 00000000 00000000 00000000 00000000 00000049
   NNW   00000019 00000005 00000002 00000000 00000000 00000000 00000000 00000000 00000026
     N   00000026 00000010 00000001 00000000 00000000 00000000 00000000 00000000 00000037

  CALM                                                                           00000065
-----------------------------------------------------------------------------------------
  TOTAL  00000422 00000646 00000198 00000000 00000000 00000000 00000000 00000000 00001331

   MEAN WIND SPEED (m/s) = 1.97
  NUMBER OF OBSERVATIONS = 1331
```

```
                   ALL PASQUILL STABILITY CLASSES

                        Wind Speed Class (m/s)

             0.50     1.50     3.00     4.50     6.00     7.50     9.00  GREATER
 WIND         TO       TO       TO       TO       TO       TO       TO     THAN
SECTOR       1.50     3.00     4.50     6.00     7.50     9.00    10.50    10.50    TOTAL
-----------------------------------------------------------------------------------------

   NNE   00000057 00000055 00000018 00000026 00000007 00000000 00000000 00000000 00000163
    NE   00000098 00000211 00000219 00000107 00000025 00000007 00000000 00000000 00000667
   ENE   00000063 00000293 00000455 00000332 00000112 00000014 00000000 00000000 00001269
     E   00000057 00000286 00000568 00000518 00000235 00000054 00000002 00000000 00001720
   ESE   00000038 00000077 00000135 00000110 00000062 00000009 00000002 00000000 00000433
    SE   00000024 00000056 00000042 00000019 00000003 00000000 00000000 00000000 00000144
   SSE   00000024 00000039 00000024 00000007 00000004 00000000 00000000 00000000 00000098
     S   00000022 00000048 00000029 00000017 00000003 00000001 00000000 00000000 00000120
   SSW   00000030 00000063 00000048 00000027 00000008 00000000 00000000 00000000 00000176
    SW   00000033 00000085 00000102 00000043 00000028 00000009 00000002 00000001 00000303
   WSW   00000085 00000159 00000181 00000163 00000114 00000084 00000025 00000010 00000821
     W   00000131 00000225 00000249 00000269 00000149 00000127 00000063 00000072 00001285
   WNW   00000083 00000185 00000155 00000097 00000093 00000049 00000023 00000016 00000701
    NW   00000033 00000080 00000077 00000042 00000051 00000024 00000010 00000006 00000323
   NNW   00000040 00000030 00000022 00000012 00000003 00000000 00000003 00000002 00000112
     N   00000045 00000031 00000015 00000007 00000002 00000000 00000000 00000000 00000100

  CALM                                                                           00000108
-----------------------------------------------------------------------------------------
  TOTAL  00000863 00001923 00002339 00001796 00000899 00000378 00000130 00000107 00008543

   MEAN WIND SPEED (m/s) = 4.12
  NUMBER OF OBSERVATIONS = 8543
```

APPENDIX B

PEAK TO MEAN TABLES

Table A1 – Recommended factors for estimating peak concentrations for different source types, distances and stabilities

		Near field				Far field			
Source type	**Stability**	**i_{max}**	**x_{max}**	**P/M 60**	**P/M 3**	**i**	**P/M 60**	**P/M 3**	**p**
Area	Neutral, Convective Stable	0.5 0.5	500 – 1000 300 – 800	2.5 2.3	1.9 1.7	0.4 0.3	2.3 1.9	1.7 1.4	0.15 0.10
Line	Neutral, Convective Stable	1.0 1.0	350 250	6 6	2.8 2.8	0.75 0.65	6 6	2.8 2.8	0.25 0.25
Surface point	Neutral Stable Convective	2.5 2.5 2	200 200 1000	25 25 12	10 10 7	1.2 1.2 0.6	5 - 7 5 - 7 3 - 4	3 3 2.5	0.2 0.2 0.15
Tall point	Neutral, Stable Convective	4.5 2.3	5 h 2.5 h	35 17	8 4	1.0 0.5	6 3	1.3 1.1	0.5 0.5
Wake affected point	Neutral, Convective	0.4	-	2.3	1.4	-	2.3	1.4	0.1
Volume	Neutral, Convective	0.4	-	2.3	1.4	-	2.3	1.4	0.1

Source: Katestone Scientific (1998)

i_{max} is maximum centreline intensity of concentration
x_{max} is the approximation location of i_{max} in metres
P/M 60 is the peak to mean ratio for long averaging times (typically 1 hour), at a probability of 10^{-3}
P/M 3 is the best estimates of the peak to mean ratio for 3 minute averages, at probability 10^{-3}
p is the averaging time power law exponent
h is stack height

APPENDIX C

ESTIMATED DUST EMISSIONS FOR STAGE 10-20 YEARS

STAGING 10-20 YEARS EMISSION FACTORS

Introduction

Estimated emissions are presented for all significant dust generating activities associated with the proposed landfill operations during Staging 10-20 Years.

The dust emissions inventory has been estimated using information and assumptions provided by Maunsell Australia Pty Ltd. Emission factors have been developed using emission factor equations provided in the **US EPA (1985)** (and subsequent updates) publication referred to as AP-42 and from factors determined by **NERDDC (1986)**.

It has been assumed that excavation activities will occur 10 hours per day from 7 am to 5 pm, 7 days per week, while landfilling will occur for 12 hours per day from 6 am to 6 pm, 7 days per week. It should be noted that this is a conservative assumption since construction will not typically occur on Sundays and working hours will be slightly restricted for all activities on weekends and public holidays.

Dust from wind erosion is assumed to occur over 24 hours per day, but wind erosion is also assumed to be proportional to the third power of wind speed. Generally, this will mean that most wind erosion occurs during the day when wind speeds are highest.

Excavation operations:

Removing Topsoil

Topsoil will be removed using a dozer. The rate at which dust will be generated by a dozer is calculated using Equation 1.

Equation 1

$$E_{TSP} = \frac{2.6 \times s^{1.2}}{M^{1.3}} \qquad \text{kg/hour}$$

where,

$s = \text{silt content}(\%), \text{and}$

$M = \text{moisture content}(\%)$

Taking M to be 2% and s to be 10%, the emission factor is estimated to be approximately 16.735 kg/hour. Assuming that the dozer is working for approximately 60 hours/y, the total dust emissions would be approximately 1,004 kg/y [60 h/y x 16.735 kg/h].

Excavators in pit

In Staging 10-20 Years, approximately 65215 bcm/y of material will be excavated [16304 m^2 x 4 m]. Assuming a density of 1.8 t/bcm, this equates to a total of 117,387 t/y, which will then be loaded into trucks and transported to the stockpile area. Each tonne of material excavated will generate approximately 0.025 kg of dust (**NERDDC, 1988**). Therefore, the total dust generated will be approximately 2935 kg/y [117,387 t/y x 0.025 kg/t] in Staging 10-20 Years.

Hauling material to stockpile

Approximately 117,387 t/y of material will be hauled to the stockpile area, using 12 t trucks. Assuming a return travel distance of 0.2 km, a dust generation rate of 4 kg/VKT and 75% control of dust by watering of the haul road, the total dust generated is expected to be 7826 kg/y [(117,387 t/y / 12 t) x 0.2 km x 4 kg/km x 25/100].

Dumping material at stockpile

During Staging 10-20 Years, approximately 117,387 t/y of material will be dumped from trucks to the stockpile area. Each tonne of material dumped will generate a certain amount of dust, depending on the wind speed and the moisture content. Equation 2 (**US EPA, 1995, 13.2.4-3**) shows the relationship between these variables.

Equation 2

$$E_{TSP} = k \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}} \right) \qquad \text{kg/t}$$

where,

$E_{TSP} = \text{TSP emissions}$

$k = 0.74$

$U = \text{wind speed}(m/s)$

$M = \text{moisture content}(\%)$

$[\text{where } 0.25 \leq M \leq 4.8]$

The moisture content is assumed to be 2%. A "wind speed factor" (that is, the $(U/2.2)^{1.3}$ part of Equation 2) will vary from hour to hour. This factor has been calculated for each hour in the meteorological data file and an annual average determined to be approximately 2.26. The total emission rate will therefore be approximately 314 kg/y [117,387 t/y x 0.001184 x 2.26].

Dozers shaping tipping face

The TSP emission factor for dozers shaping material is given by Equation 1. Taking M to be 2% and s to be 10%, the emission factor is estimated to be approximately 16.735 kg/hour. Assuming that the dozer is working for approximately 4 hours/day, 350 days per year, the total dust emissions would be approximately 24,429 kg/y [1,400 h/y x 16.735 kg/h].

Landfilling operations:

Dozers working in landfill
Topsoil will be removed using a dozer. The rate at which dust will be generated by a dozer is calculated using Equation 1. Assuming that the dozer is working for approximately 4 hours/day for 350 days/y, the total dust emissions would be approximately 1,004 kg/y [1400 h/y x 16.735 kg/h].

Hauling waste to tipping face
Waste material will be hauled to the landfill tipping face on both sealed and unsealed roads. Approximately 15,000 t/y of waste will be delivered to the site in 20 t trucks. This gives 750 vehicle movements per year. Over 350 days in the year, this rounds up to 3 vehicle movements per day [750 veh/y / 350 days/y].

The return travel distance on sealed roads is approximately 1.15 km. Assuming a dust generation rate of 0.4 kg/VKT on sealed roads and 75% control using a water cart, the total dust generated by this operation will be approximately 121 kg/y [3 trips/day x 350 days/y x 1.15 km x 0.4 kg/VKT x 25/100].

The rate at which dust will be generated by a vehicle travelling on unsealed haul roads is calculated using Equation 3.

Equation 3

$$E_{TSP} = k(1.7)\left(\frac{s}{12}\right)\left(\frac{S}{48}\right)\left(\frac{W}{2.7}\right)^{0.7}\left(\frac{w}{4}\right)^{0.5}\left(\frac{365-p}{365}\right)$$

(kg/VKT)

where,

k = particulate size multiplier (0.8 for particles in

range $\leq 30\ \mu m$

in equivalent aerodynamic diameter

s = silt content of road surface material (%)

S = mean vehicle speed (km/h)

W = mean vehicle weight (Mg)

w = mean number of wheels

p = number of days with at least 0.254 mm of

precipitation per year

Assuming a silt content of 10%, mean vehicle speed of 20 km/h, mean weight of the waste trucks with 6 wheels at 20 t and 109 raindays per year, E_{TSP} is approximately 0.82 kg/VKT.

The return travel distance on unsealed roads is approximately 1.85 km. Assuming a dust generation rate of 0.82 kg/VKT on unsealed roads and 75% control using a water cart, the total dust generated by this operation will be approximately 400 kg/y [(3 trips/day x 350 days/y x 1.85 km x 0.82 kg/VKT x 25/100].

Scraping and transporting cover material
Scrapers will transport approximately 31,765 t/y of cover material in Staging 10-20 Years. The rate at which dust will be generated by this process is calculated using Equation 4.

Equation 4

$$E_{TSP} = 9.6 \times 10^{-6} (s)^{1.3} (W)^{2.4} \text{ kg/VKT}$$

where :

s = silt content (%)

W = mean vehicle weight (t)

Assuming a silt content of 10% and the mean weight of the scraper to be 50 t, including 75% control of dust by watering, E_{TSP} is approximately 2.29 kg/VKT. For a 34 t scraper and a return travel distance of 0.22 km, the total dust generated will be 118 kg/y [(31,765 t/y / 34 t) x 0.22 km x 2.3 kg/VKT x 25/100].

Shaping covered area
The TSP emission factor for dozers shaping material is given by Equation 1. Assuming an emission factor of 16.735 kg/hour, and that the dozer operates for 4 hours/day for 350 days/year on this activity, the total dust emissions would be approximately 23429 kg/y [1,400 h/y x 16.735 kg/h].

Wind erosion

Wind erosion from exposed excavation areas
The emission factor for wind erosion is given in Equation 2 below.

$$E_{TSP} = 1.9 \times \left(\frac{s}{1.5}\right) \times \left(\frac{365-p}{235}\right) \times \left(\frac{f}{15}\right) \qquad \text{kg/ha/day}$$

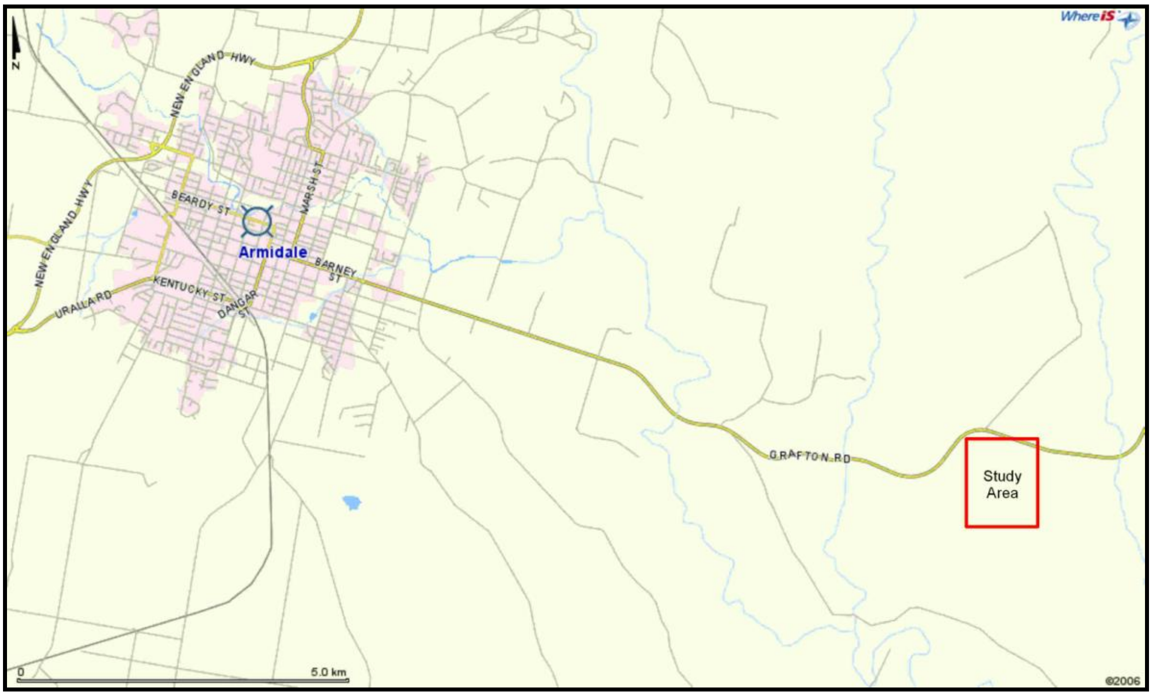
Where,
s = silt content (%)
p = number of raindays per year, and
f = percentage of the time that wind speed is above 5.4 m/s

Assuming a silt content of 10%, the average number of raindays in Armidale is 109 and the percentage of wind above 5.4 m/s is approximately 23%. Over 350 days/year, E_{TSP} is 3700.5 kg/ha/year. Cell 2 sections c and d cover an area of approximately 0.767 ha. The total dust emissions from wind erosion from exposed excavation areas will be 2840 kg/y [3700.5 kg/ha/y x 0.767 ha].

Wind erosion from stockpiles
Assuming that the total area of the stockpiles is approximately 0.3 ha, the total dust emissions from wind erosion from stockpiles will be

approximately 1136 kg/y [3700.5 kg/ha/y x 0.307 ha].

FIGURES



(Source: http://www.whereis.com.au)

Figure 1 – Location of study area

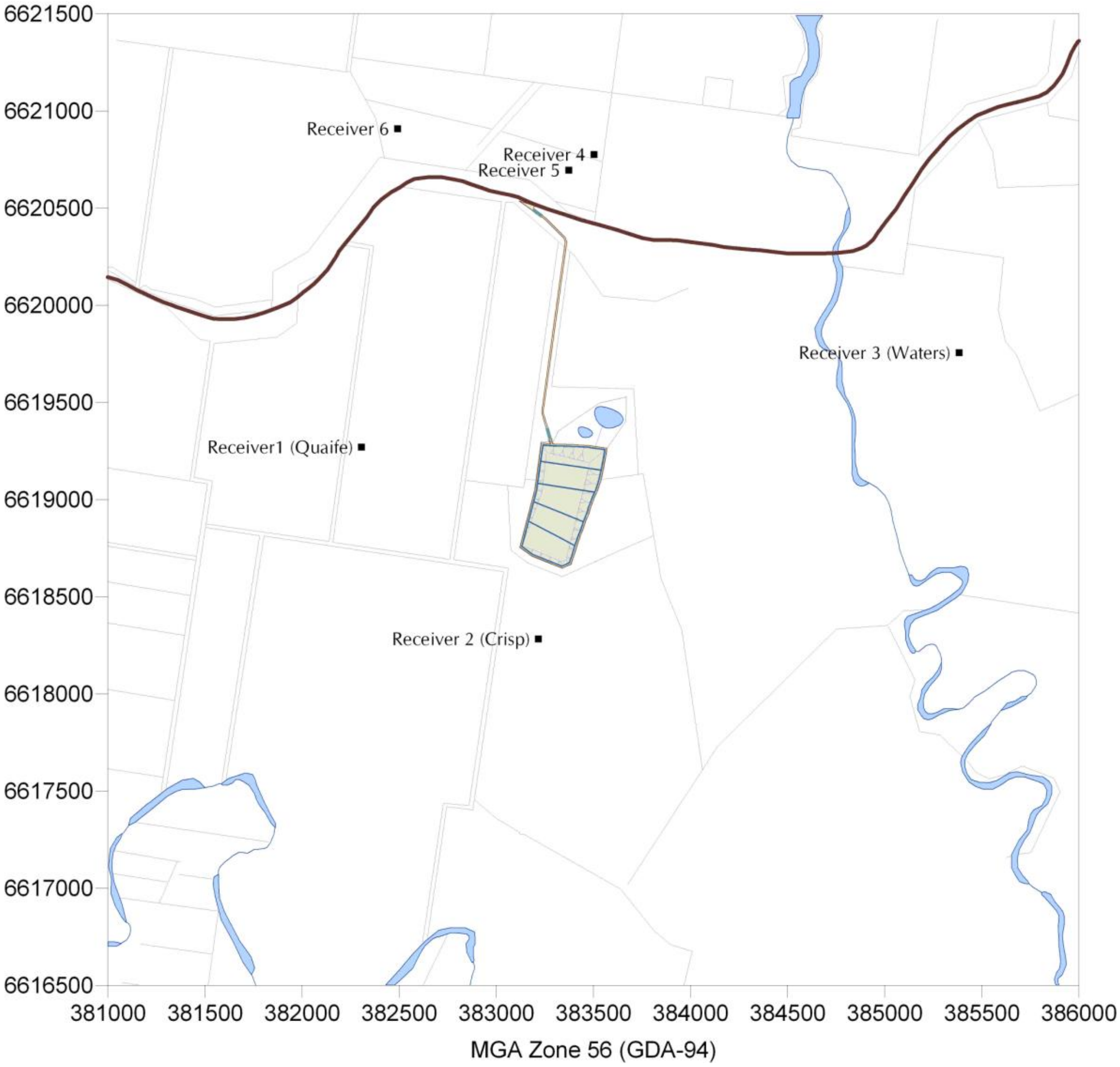


Figure 2 – Proposed site layout and nearby receivers

Figure 3 – Modelled scenarios representing Stages 0-10 years, 10-20 years and 40-50 years

Figure 4 – Annual and seasonal windroses for Armidale Airport, 2000

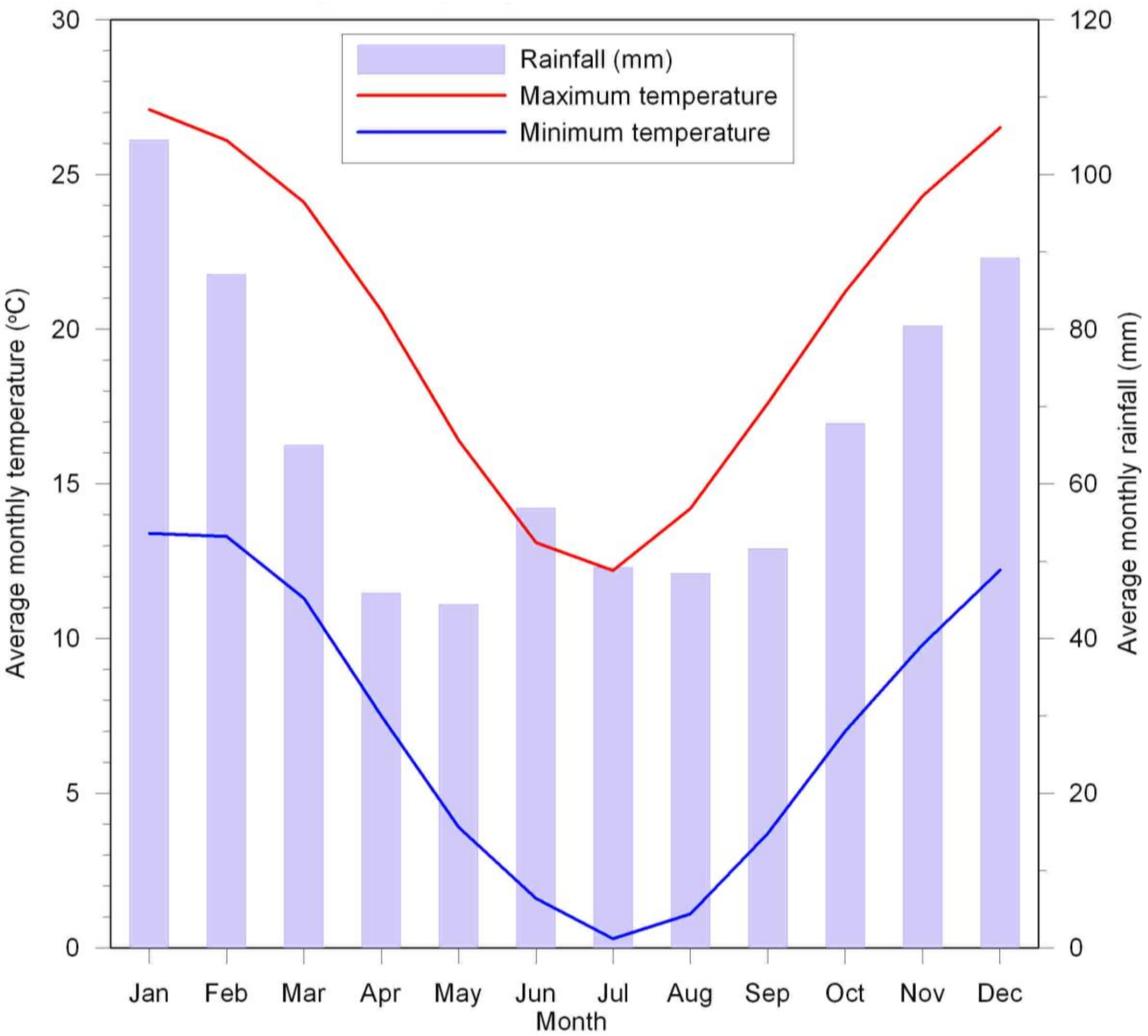
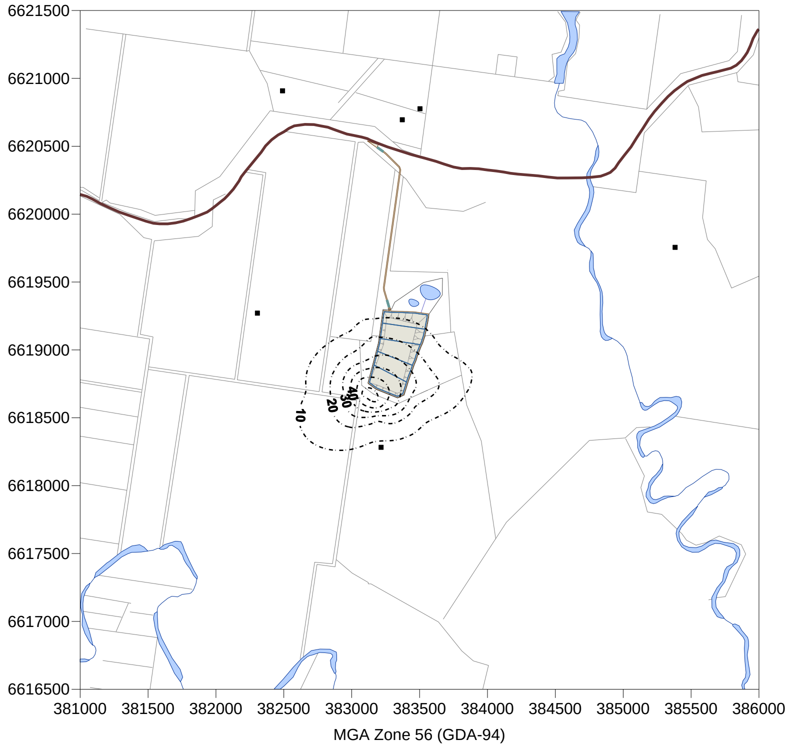


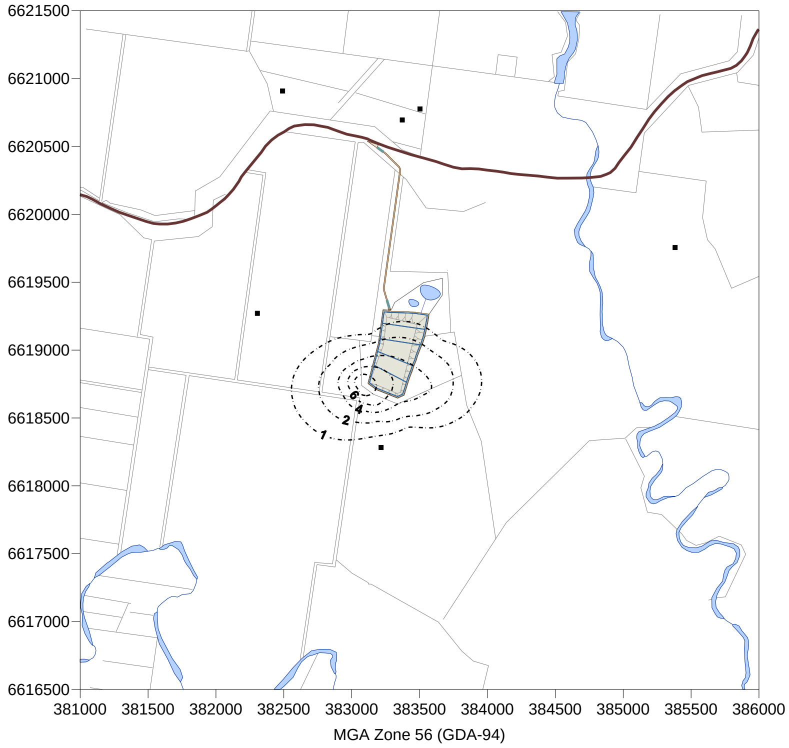
Figure 5 – Average monthly temperature and rainfall at Armidale Airport



Case A

PM10 1d

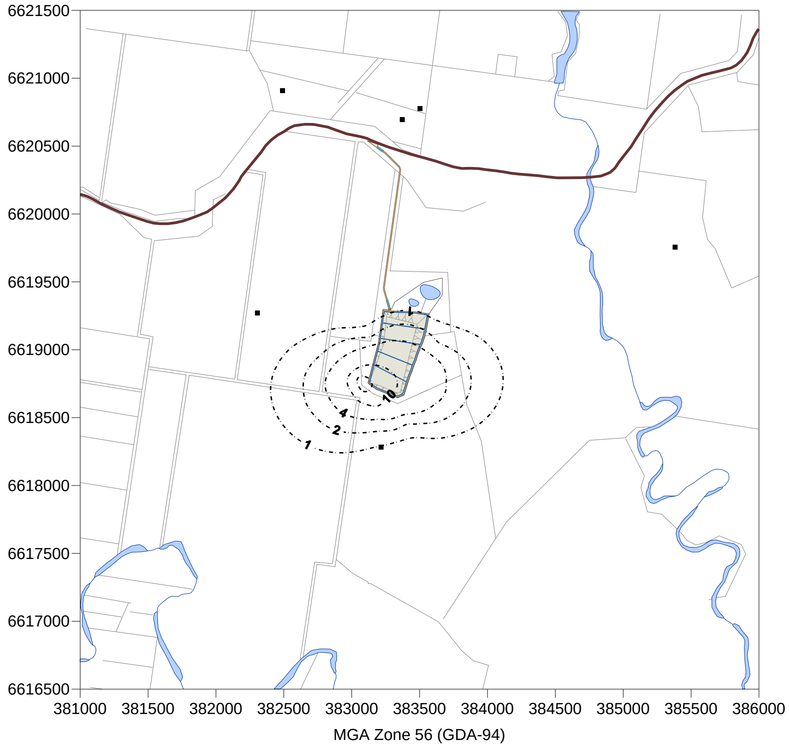
Figure 6 – Highest predicted 24-hour average PM_{10} concentrations, Staging 0-10 Years



Case A

PM10 1Y

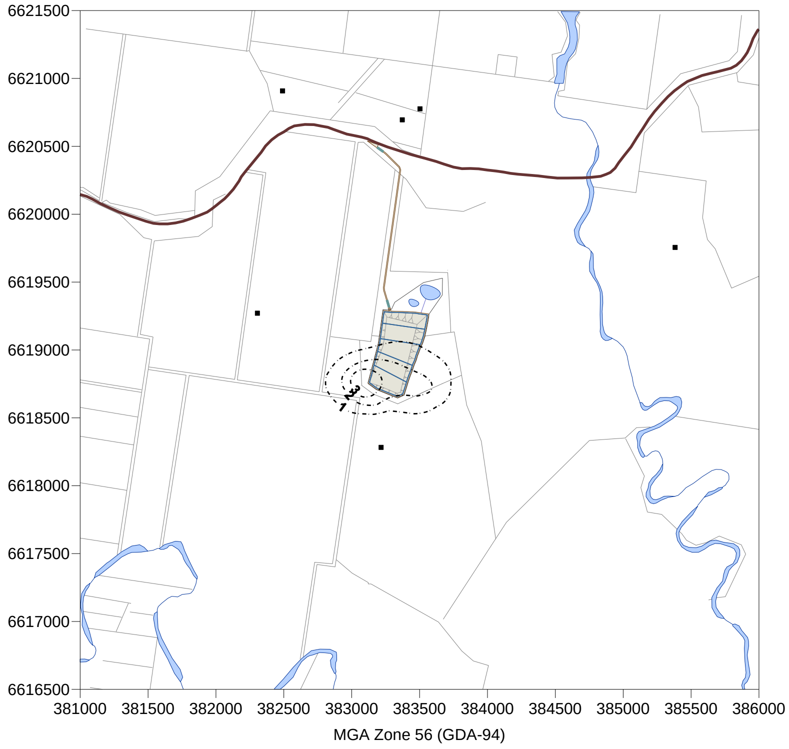
Figure 7 – Highest predicted annual average PM_{10} concentrations, Staging 0-10 Years



Case A

TSP 1y

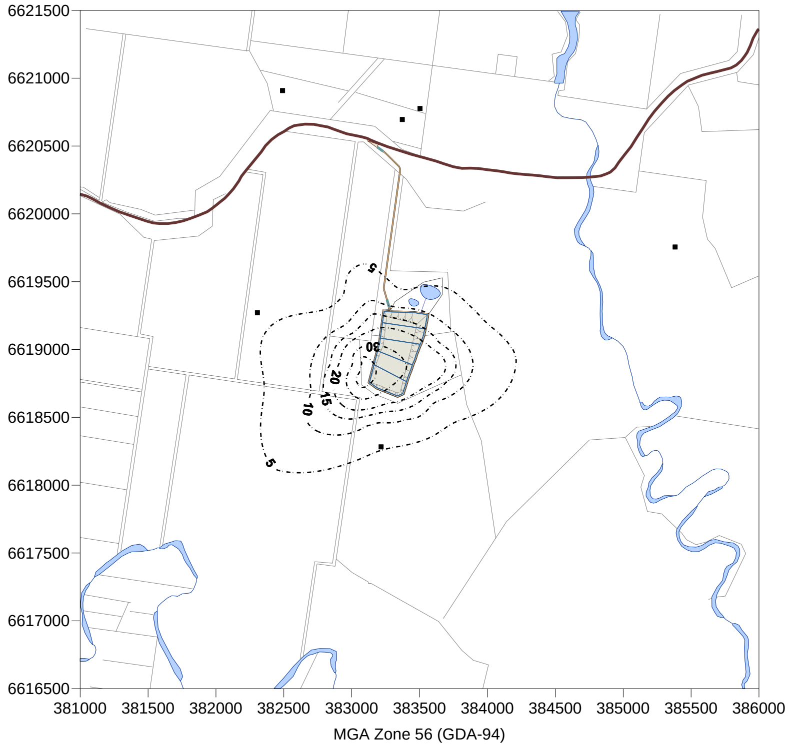
Figure 8 – Highest predicted annual average TSP concentrations, Staging 0-10 Years



Case A

DDEP 1y

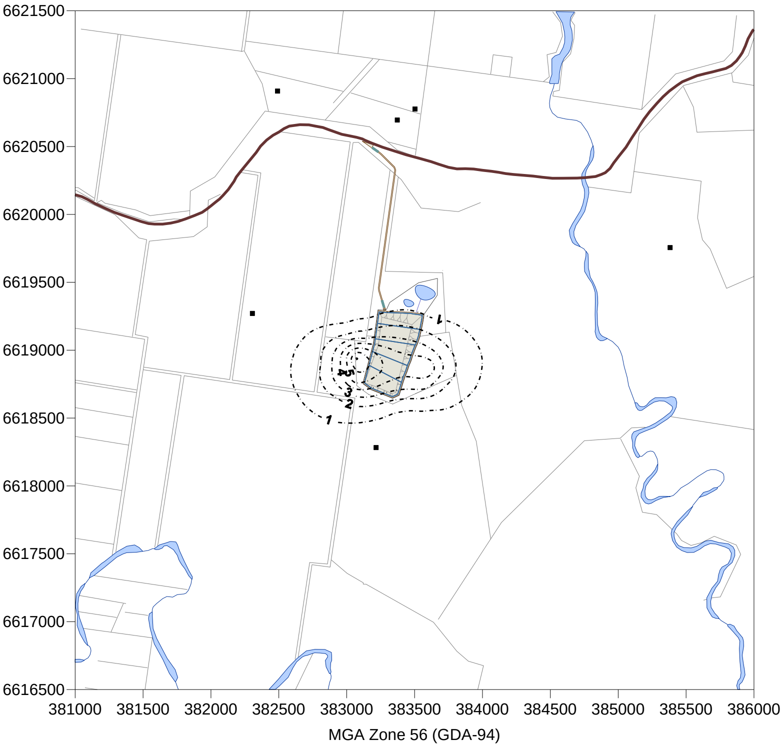
Figure 9 – Highest predicted annual average dust deposition, Staging 0-10 Years



Case A

PM10 1d

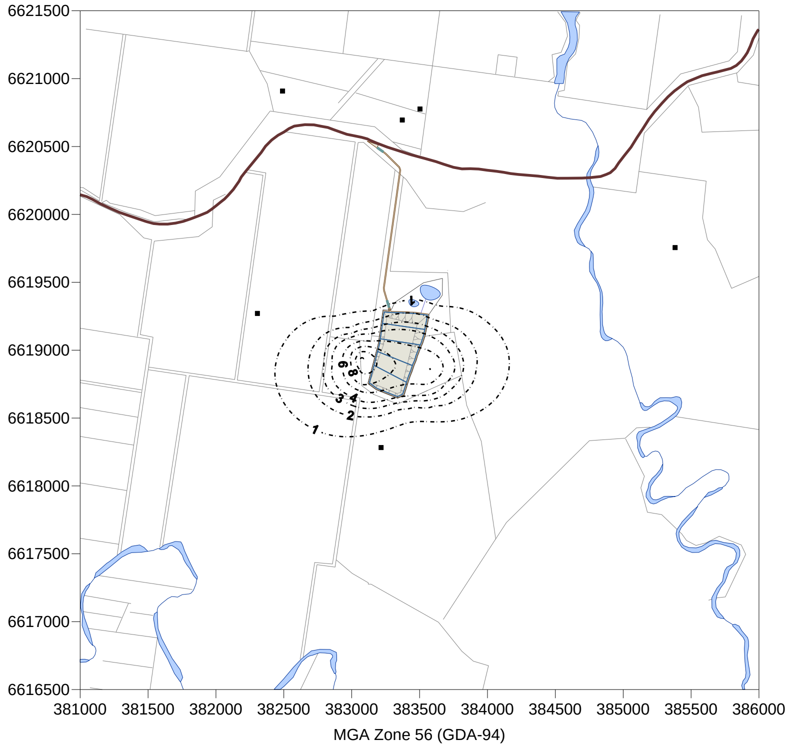
Figure 10 – Highest predicted 24-hour average PM_{10} concentrations, Staging 10-20 Years



Case B

PM10 1Y

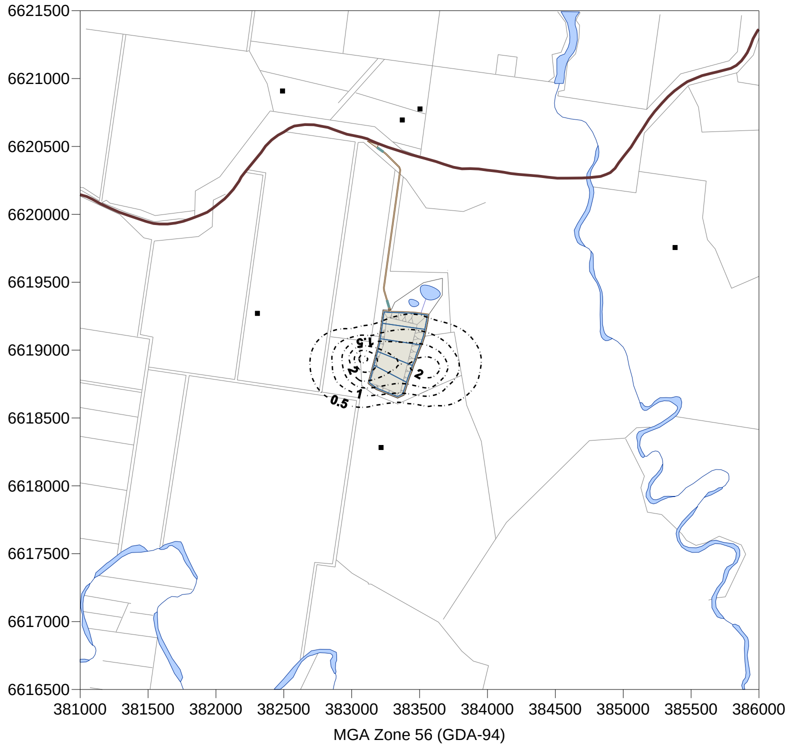
Figure 11 – Highest predicted annual average PM_{10} concentrations, Staging 10-20 Years



Case B

TSP 1y

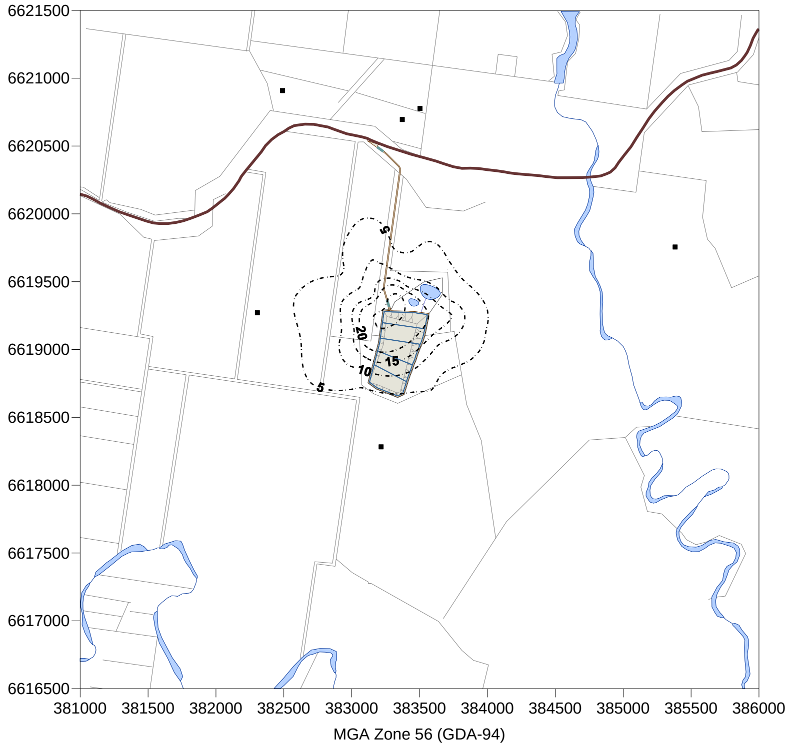
Figure 12 – Highest predicted annual average TSP concentrations, Staging 10-20 Years



Case B

DDEP 1y

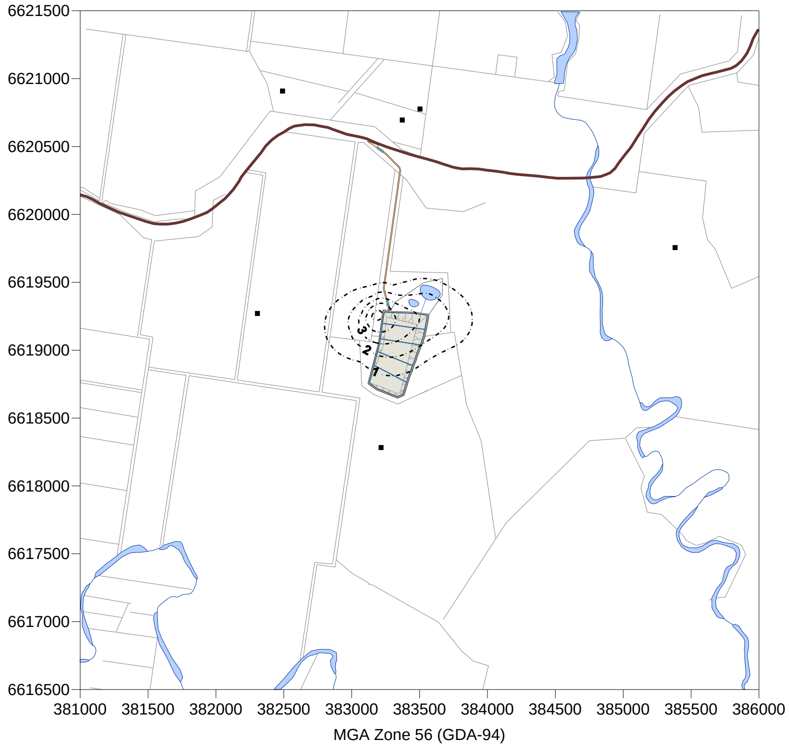
Figure 13 – Highest predicted annual average dust deposition, Staging 10-20 Years



Case C

PM10 1d

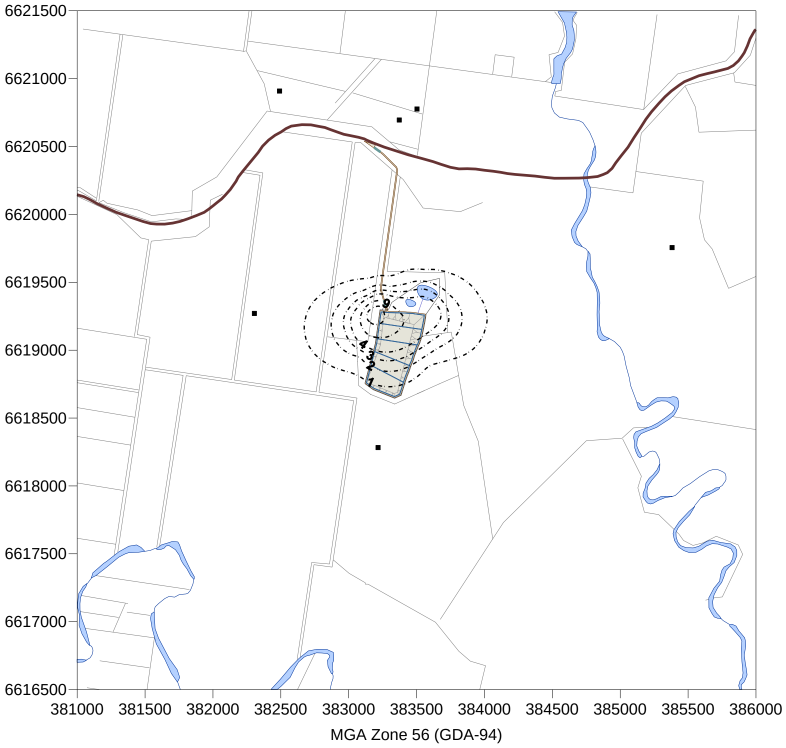
Figure 14 – Highest predicted 24-hour average PM$_{10}$ concentrations, Staging 40-50 Years



Case C

PM10 1Y

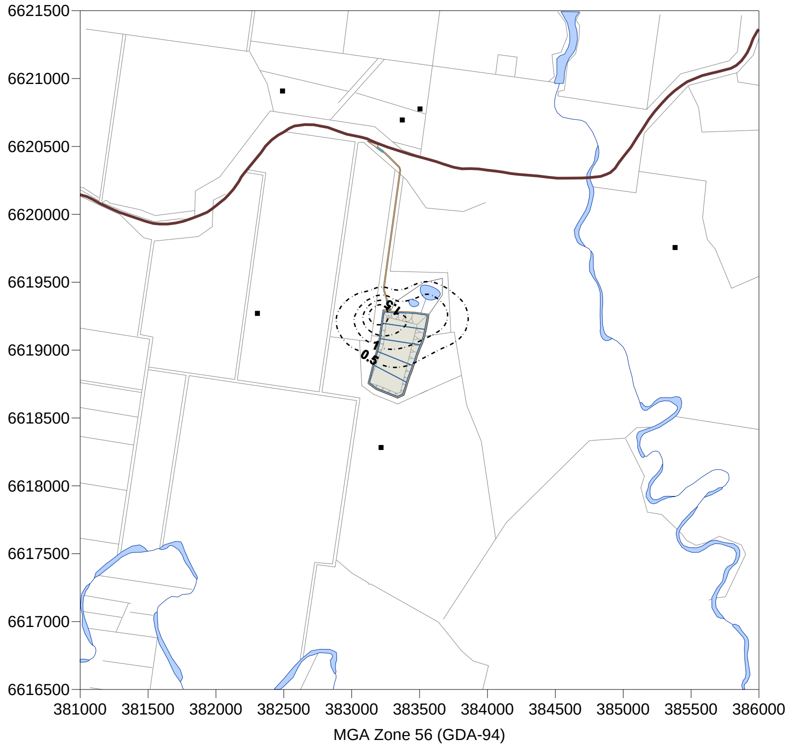
Figure 15 – Highest predicted annual average PM_{10} concentrations, Staging 40-50 Years



Case C

TSP 1y

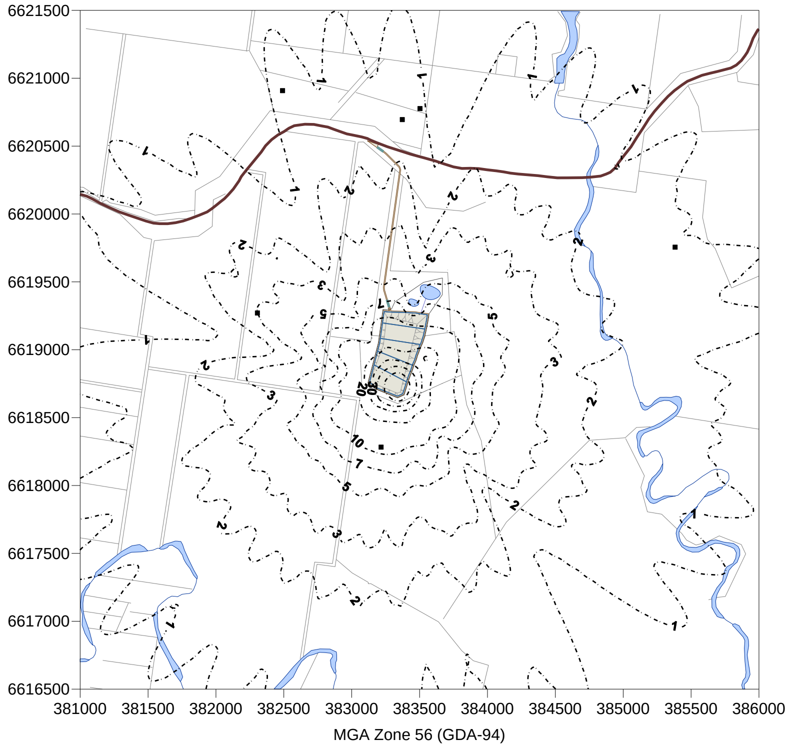
Figure 16 – Highest predicted annual average TSP concentrations, Staging 40-50 Years



Case C

DDEP 1y

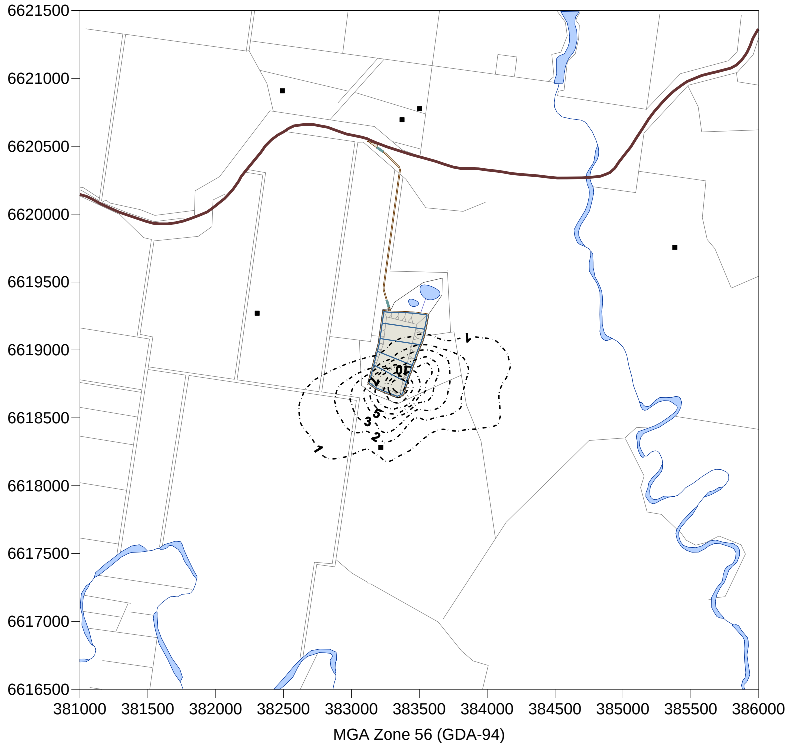
Figure 17 – Highest predicted annual average dust deposition, Staging 40-50 Years



Case A

Odour Maximum

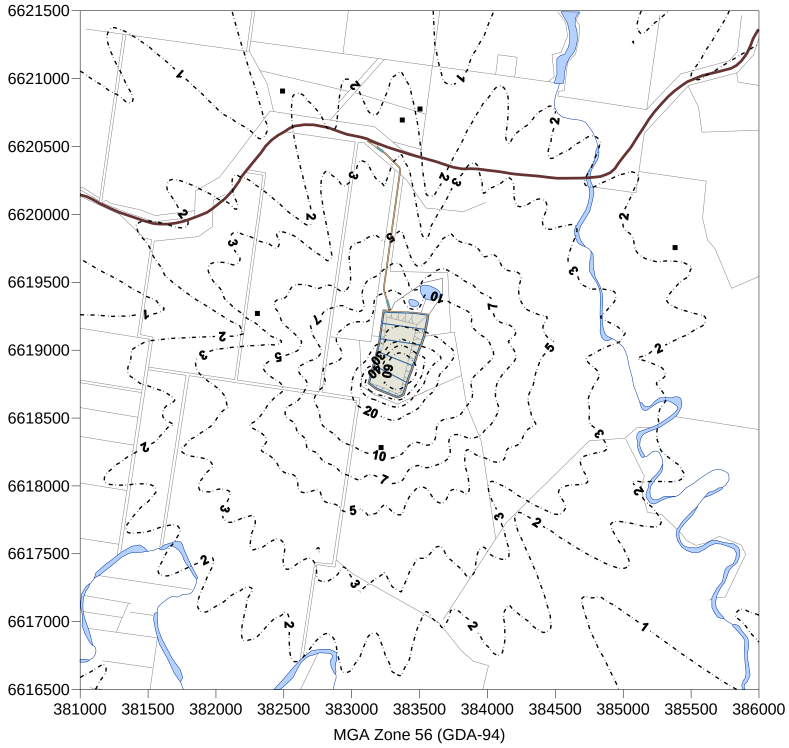
Figure 18 – Maximum odour levels (ou) due to landfill operations – Staging 0-10 Years



Case A

Odour 99th percentile

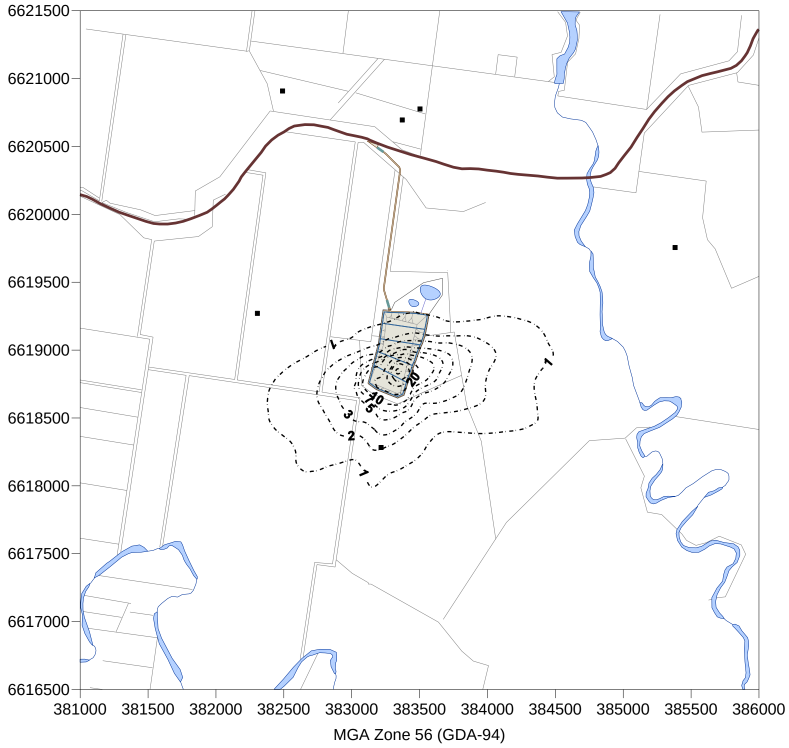
Figure 19 – Odour levels at the 99th percentile (ou) due to landfill operations – Staging 0-10 Years



Case B

Odour Maximum

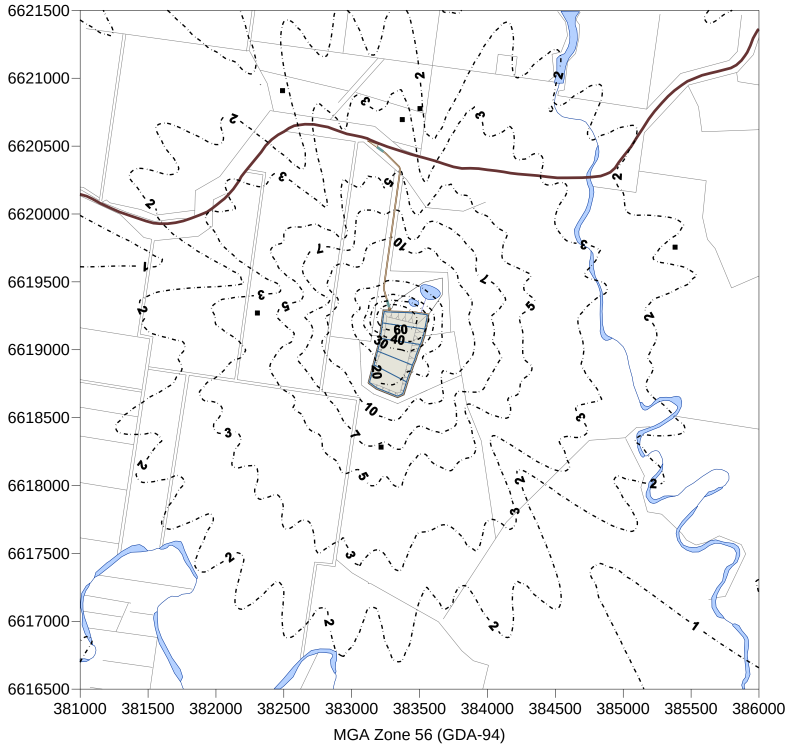
Figure 20 – Maximum odour levels (ou) due to landfill operations – Staging 10-20 Years



Case B

Odour 99th percentile

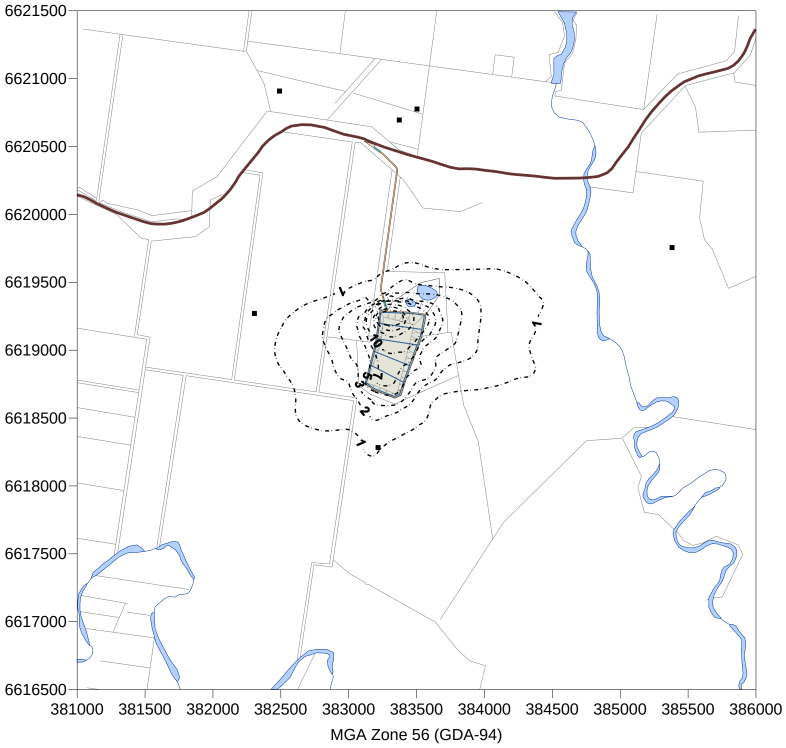
Figure 21 – Odour levels at the 99th percentile (ou) due to landfill operations – Staging 10-20 Years



Case C

Odour Maximum

Figure 22 – Maximum odour levels (ou) due to landfill operations – Staging 40-50 Years



Case C

Odour 99th percentile

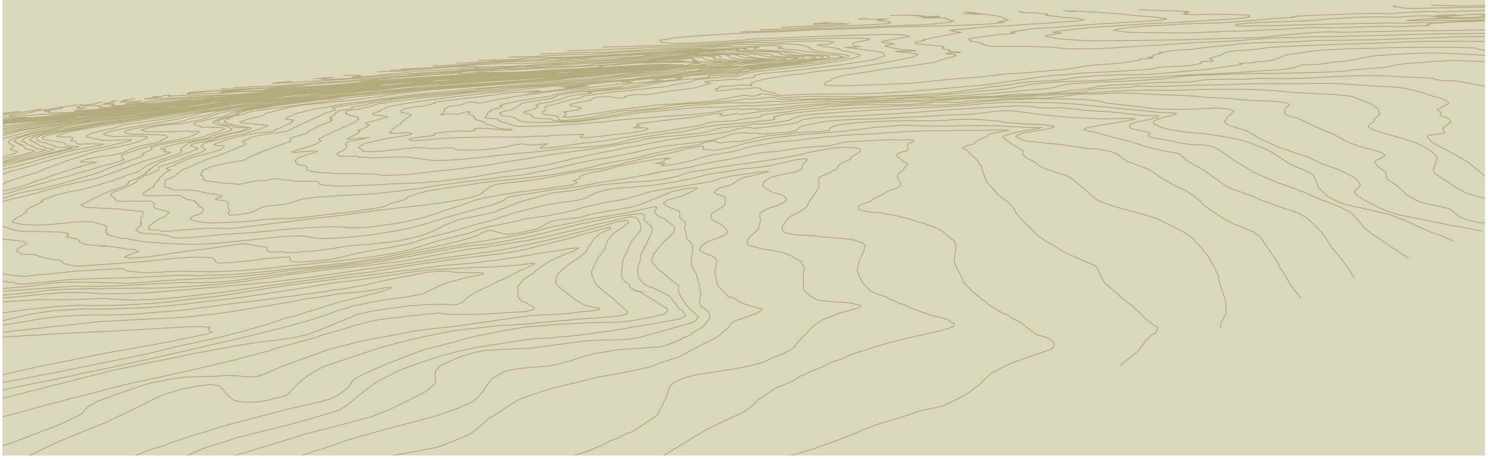
Figure 23 – Odour levels at the 99th percentile (ou) due to landfill operations – Staging 40-50 Years

Appendix P

AECOM, 2010: Greenhouse Gas Inventory

ARMIDALE REGIONAL LANDFILL

Environmental Assessment



Armidale Regional Landfill

Armidale Dumaresq Council

12 February 2010

Greenhouse Gas Inventory

Greenhouse Gas Inventory

Prepared for

Armidale Dumaresq Council

Prepared by

AECOM Australia Pty Ltd
Level 11, 44 Market Street, Sydney NSW 2000, PO Box Q410, QVB Post Office NSW 1230, Australia
T +61 2 8295 3600 F +61 2 9262 5060 www.aecom.com
ABN 20 093 846 925

12 February 2010

20017605

Quality Information

Document	Greenhouse Gas Inventory
Ref	k:\20017605.00 armlandfill\eng-plan\environment\ea studies\greenhouse gas\rev f - ghg inventory 20100217\armidale landfill greenhouse gas inventory - final.docx
Date	12 February 2010
Prepared by	Roweena McKenzie and Nicole Hansen
Reviewed by	Darryl Patching

Revision History

Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
B	12-Feb-2010	Final	Danielle Phillips Project Manager	DPhillips

Table of Contents

1.0 Introduction

1.1 Project Background

Armidale Dumaresq Council (ADC) is planning to establish a landfill facility to service the Armidale, Guyra, Uralla Shire and Walcha Local Government Areas (LGAs).

The proposed Armidale Regional Landfill (the project) site is located 12km east of Armidale. It will be classed as a General Solid Waste (putrescibles) landfill and accept approximately 15,000 tonnes of waste per annum and over 750,000 tonnes over the life of the landfill. Based on this capacity and the estimated annual waste acceptance quantities, the landfill will have an expected life of approximately 50 years.

In order to allow the initial commencement of landfilling operations it is Council's intention to seek an operating licence to landfill General Solid Waste (putrescible) material, including putrescible material and other general waste recognised by the Department of Environment, Climate Change and Water (DECCW) under this "putrescible" definition for general solid wastes. It is Council's longer term objective, however, to begin operating the landfill, as soon as possible in the future (and then until final closure) only as a General Solid Waste (non-putrescible) facility, when appropriate additional off-site sorting and/or treatment technologies are able to be procured and successfully employed.

The majority of waste will be received and processed at the existing waste transfer station at Long Swamp Road (the site of the former Armidale Landfill), prior to being transported to the new facility. There will be no direct public access to the landfill. Special waste loads with no recoverable content may also be directed to unload directly at the landfill.

1.2 Purpose and Objectives

This Greenhouse Gas (GHG) Inventory as been prepared to provide a quantitative estimate the potential scope 1, 2 and 3 GHG emissions associated with the construction and operation of the proposed project.

The purpose of this inventory is to:

- Identify the sources of GHG emissions associated with the project
- Quantify the GHG emissions associated with each GHG source
- Present the Scope 1, 2 and 3 GHG emissions associated with the project
- Identify opportunities which may be implemented to reduce the GHG emissions associated with the project.
- Provide a detailed description of the measures which will be implemented to ensure that the project is energy efficient.

1.3 Greenhouse Gas Emissions

GHG emissions will be generated during the construction and operation of the proposed project.

Greenhouse gases (GHG's) are emitted into the Earth's atmosphere as a result of natural processes (e.g. forest fires) and human activities (e.g. burning of fossil fuels to generate electricity). GHG's absorb and re-radiate heat from the sun. Since the industrial revolution there has been an increase in the amount of anthropogenic (human induced) GHG's emitted into the atmosphere which has increased the concentration of GHG emissions in the atmosphere. The increased concentration of GHG's in the Earth's atmosphere has led to an increase in the Earth's average temperature (surface temperature), this is known as the Greenhouse Effect (or enhanced greenhouse effect). The Greenhouse Effect has caused the phenomenon of Climate Change to occur. Climate Change (also known as global warming) refers to the change in climate patterns due to an increase in the average temperature of the Earth.

1.3.1 Measurement of Greenhouse Gas Emissions

GHGs are reported for accounting purposes as tonnes of carbon dioxide equivalent (t CO_2-e). There are numerous GHGs which contribute to the Greenhouse Effect. These gases have varying Global Warming Potential (GWP). The higher GWP, the higher the intensity of effect each tonne of that gas has on the Enhanced Greenhouse Effect. GHGs are standardised by expressing them as carbon dioxide equivalent emissions (CO_2-e) where carbon dioxide has a GWP of 1. For example, the GHG methane has a GWP of 21, thus one tonne of methane has a Greenhouse Effect equivalent to 21 tonnes of carbon dioxide. The GWP of the six GHGs used in carbon accounting, commonly known as the Kyoto GHGs, are shown in the following table.

Table 1 Global Warming Potential of Greenhouse Gases

Greenhouse Gas	Global Warming Potential (GWP)
Carbon Dioxide (CO_2)	1
Methane (CH_4)	21
Nitrous Oxide (N_2O)	310
Sulphur Hexafluoride (SF_6)	23,900
Hydrofluorocarbons (HFCs)	HFC_5 – 1,300-11,700 (depending on the HFC)
Perfluorocarbons* (PFCs)	CF_4 – 6,500. C2F6 – 9,200

Note: *Varies depending on compound. Source: DCC, 2009, *National Greenhouse Accounts (NGA) Factors*.

1.3.2 Scope of Greenhouse Gas Emissions

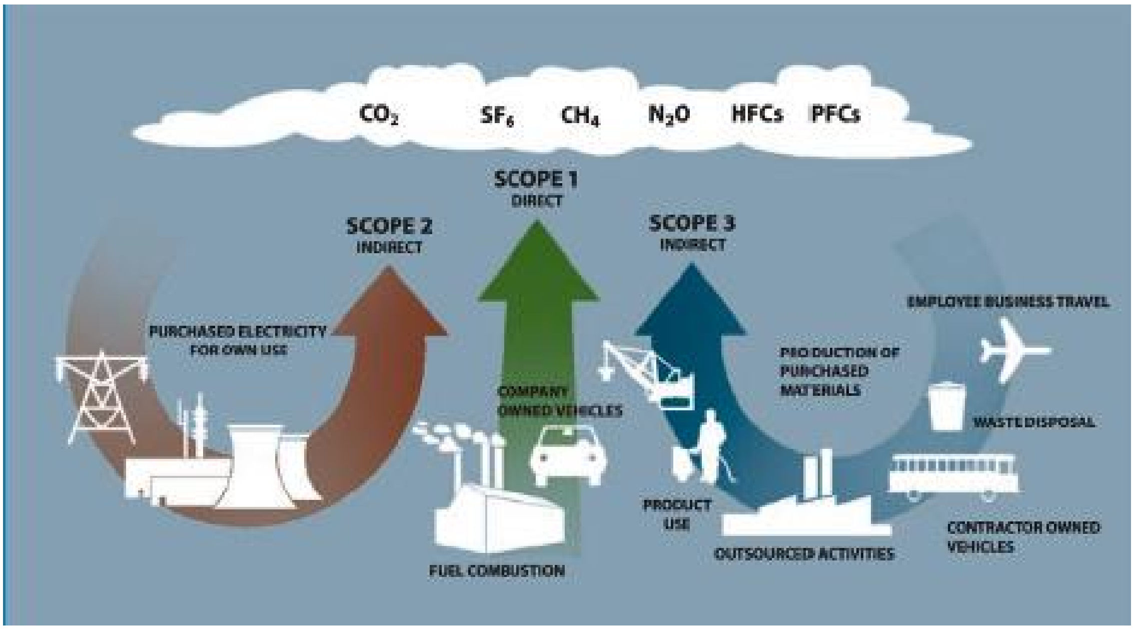
GHG emissions are categorised into three different scopes (either scope 1, 2 or 3) in accordance with the Intergovernmental Panel on Climate Change (IPCC) and Australian Government GHG accounting/classification systems. The GHG emission scopes are illustrated in Figure 1.

Scope 1 emissions, also called “direct emissions” are emissions which are generated directly by the project, e.g. emissions generated by the use of diesel fuel by construction plant/equipment.

Scope 2 emissions, also referred to as “indirect emissions” are emissions which are generated outside of the project’s boundaries to provide energy to the project, e.g. the use of purchased electricity from the grid.

Scope 3 emissions, also referred to as “upstream, indirect emissions”, are upstream emissions due to third party supply chains that are in direct relation to the project, e.g. extraction, production and transport of purchased materials and waste disposal offsite.

Figure 1 Greenhouse Gas Emission Scopes



Source: WBCSD & WRI, 2004

2.0 Scope

This GHG Inventory has been undertaken for the anthropogenic Scope 1, 2 and 3 emissions associated with the construction and operation of the project.

The GHG's which have been included in this inventory (also known as the Kyoto GHG's) are:

- Carbon Dioxide (CO_2)
- Sulphur Hexafluoride (SF_6)
- Methane (CH_4)
- Nitrous Oxide (N_2O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)

GHG emission sources which have been included in this inventory are listed under each scope in the following Table.

Table 2 Emission Scopes

Scope 1 – Direct Emissions	Scope 2 – Indirect Emissions	Scope 3 – Upstream Indirect Emissions
• The onsite use of fuel by construction plant/equipment • The vegetation permanently cleared • Landfill gas (methane) emissions	• The onsite use of electricity purchased from the grid	• The onsite use of fuel by construction plant/equipment • The use of fuel for the transportation of construction materials and staff to/from the site • The onsite use of electricity purchased from the grid • The use of construction materials

3.0 Methodology

This GHG inventory was undertaken in accordance with a methodology based on the general principles outlined in:

- National Greenhouse Accounts (NGA) Factors, Australian Government Department of Climate Change (DCC), June 2009
- The National Greenhouse and Energy Reporting System Measurement, Technical Guidelines for the estimation of greenhouse gas emissions by facilities in Australia, DCC, June 2009
- Life Cycle Assessment Australian and New Zealand Standards (ISO 14040 series)
- Australian Standard (AS ISO 14064.1 – 2006) Greenhouse Gases Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals.
- The Greenhouse Gas Protocol, World Business Council for Sustainable Development (WBCSD) and World Resources Institute (WRI), 2004

To calculate the GHG emissions associated with the construction of the project, the following steps were undertaken:

1) The assumptions and data to be used in the assessment were determined (e.g. the source of construction materials and density of materials).
2) The total quantity of the vegetation cleared, materials, electricity and fuel consumed was estimated.
3) The quantity of GHG emissions were estimated:
    - Scope 3 construction material GHG emissions were calculated using the SimaPro Life Cycle Analysis software (version SimaPro 7.1)
    - GHG emissions for fuel and electricity were calculated using the NGA Factors methods (DCC, June 2009)
    - GHG emissions (methane) released from the landfill were calculated using the methodology, equations and factors contained within the National Greenhouse and Energy Reporting System Measurement Technical Guidelines (Part 5.2, DCC, 2009)
    - GHG emissions for permanently cleared vegetation were calculated using recently published scientific data on the average amount of carbon stored in vegetation (Green Carbon: The role of natural forests in carbon storage, Part 1. A green carbon account of Australia's south-eastern Eucalypt forests, and policy implications, Mackey, B.G., Keith, H., Berry, S.L. and Lindenmayer, D.B., The Fenner School of Environment & Society, The Australian National University, 2008)
    -

The assumptions used to complete this inventory and exclusions are described in Appendix A.

3.1 Data Sources

A fixed quantity of 15,000 t of waste will be landfilled each year. The construction material, fuel consumption, electricity use and vegetation clearing quantities were estimated based on the concept design information. Refer to Appendix B for a summary of the quantity data used in this inventory.

3.2 GHG Emissions Calculation Methodology

3.2.1 Diesel Fuel

To calculate the Scope 1 GHG emissions from the consumption of diesel the following formula was used:

$$\textbf{GHG emissions (t } CO_2\textbf{-e) = Q x ECF x (}EF_{CO2} + EF_{CH4} + EF_{N2O}\textbf{) / 1000}$$

Where: Q = quantity of fuel (in kL)

ECF = relevant energy content factor (in GJ/kL)

EF_{CO2} = relevant CO_2 emission factor (in kg CO_{2}-e/GJ)

EF_{CH4} is the relevant CH_4 emission factor (in kg CO_2-e/GJ)

EF_{N2O} is the relevant N_2O emission factor (in kg CO_2-e/GJ)

To calculate the Scope 3 GHG emissions from the consumption of diesel the following formula was used:

GHG emissions (t CO_2-e) = Q x ECF x $EF_{scope\ 3}$ / 1000

Where: Q = quantity of fuel (in kL)

ECF = relevant energy content factor (in GJ/kL)

$EF_{scope\ 3}$ = relevant emission factor (in kg CO_2-e/GJ)

3.2.2 Landfill Gases

Methane will be generated as organic waste within the landfill decomposes. The volumetric composition of the gas produced by the mostly anaerobic decomposition that occurs in landfills is approximately 50% methane, 38% carbon dioxide, and 12% other gases[1]. The anaerobic conditions are created by human activity because the waste is buried and thus contained in an unnaturally low oxygen environment. The natural aerobic decomposition that occurs when waste is not buried does not produce methane, therefore methane produced in landfill decomposition is considered to be anthropogenic.

The amount of landfill gas which will be generated will be dependent upon the fraction of putrescible materials within the waste stream. The landfill will be classed as a General Solid Waste (putrescibles) landfill. It is Council's longer term objective, however, to begin operating the landfill, as soon as possible in the future (and then until final closure) only as a General Solid Waste (non-putrescible) facility, when appropriate additional off-site sorting and/or treatment technologies are able to be procured and successfully employed. To account for this, the following waste stream scenarios have been modelled:

- Scenario 1: General Solid Waste (putrescibles) landfill operating for 50 years
- Scenario 2: General Solid Waste (putrescibles) landfill operating from years 1-10, General Solid Waste (non-putrescible) landfill operating from years 11-50

Scenario 2 assumes that from year 11 onwards the waste landfilled will be pre-treated at an alternative waste treatment facility and that this facility will successfully remove 85% of the following materials from the waste stream:

- Food
- Paper and paper board
- Garden and park
- Wood and wood waste
- Nappies

To calculate the Scope 1 GHG emissions released from the decomposition of the organic material fraction of the waste disposed of in the landfill, the following formula was used:

GHG emissions emitted each year (t CO_2-e/yr) = [CH_4* $-\ \gamma$ (Q_{cap} + Q_{flared} + Q_{tr})] x (1-OF)

Where: CH_4* is the estimated quantity of methane in landfill gas generated by the landfill during the year as determined under the conditions below (measured in t CO_2-e)

γ is the factor 6.784 x 10^{-4} x 21 converting cubic meters of methane at standard conditions to CO_2-e tonnes

---

[1] 'Potential for Greenhouse Gas Abatement from Waste Management and Resource Recovery in Australia' (Draft), Warnken ISE March 2007.

Q_{cap} is the quantity of methane in landfill gas captured for combustion from the landfill during the year in cubic metres

Q_{flared} is the quantity of methane in landfill gas flared from the landfill during the year and measured in cubic metres

Q_{tr} is the quantity of methane in landfill gas transferred out of the landfill during the year and measured in cubic metres

OF is the oxidation factor for near surface methane in the landfill; default value 0.1

If: (Qcap / CH4 gen) ≤ 0.75, then $CH_4^* = CH_{4gen}$

Where: CH_{4gen} is the quantity of methane in landfill gas generation released from the landfill during the year estimated

If: $(Q_{cap} / CH_{4\ gen}) > 0.75$, then $CH_4^* = Q_{cap} \times (1/0.75)$

It is assumed that no landfill gas collection or flaring is carried out at the proposed landfill.

3.2.3 Land Use Change

Approximately 12.7ha of Stringybark Woodland will be permanently cleared for the construction of the project. This area will no longer have the potential to store carbon in vegetation biomass. The amount of carbon stored in the 12.7ha of Stringybark Woodland has been estimated and added to the scope 1 GHG emissions estimate of the project.

The quantity of Scope 1 GHG emissions associated with the permanent clearing of vegetation was calculated based on the following simplified formula:

GHG emissions (t CO_2-e) = A * S

Where: A = Area of vegetation permanently cleared (in ha)

S = Mass of carbon stored in vegetation (in t CO_2-e/ha)

The existing carbon store (S) has been estimated as approximately 360 t CO_2-e/ha (Green Carbon: The role of natural forests in carbon storage, Part 1. A green carbon account of Australia's south-eastern Eucalypt forests, and policy implications, Mackey, B.G., Keith, H., Berry, S.L. and Lindenmayer, D.B., The Fenner School of Environment & Society, The Australian National University, 2008). This estimate is based on vegetation biomass only (soil carbon excluded) and Eucalypt forests of South-Eastern Australia tree species group.

3.2.4 Electricity

To calculate the Scope 2 indirect GHG emissions from the consumption of purchased electricity from the grid the following formula was used:

GHG emissions (t CO_2-e) = $Q \times EF_{scope\ 2}$ / 1000

Where: Q = quantity of purchased electricity (in kWh)

$EF_{scope\ 2}$ = Scope 2 emissions factor for NSW (in kg CO_2-e/kWh)

To calculate the Scope 3 GHG emissions from the consumption of purchased electricity from the grid the following formula was used:

GHG emissions (t CO_2-e) = $Q \times EF_{scope\ 3}$ / 1000

Where: Q = quantity of purchased electricity (in kWh)

$EF_{\text{scope 3}}$ = Scope 3 emissions factor for NSW (in kg CO_2-e/kWh)

The emissions factors used to calculate the GHG emissions associated with diesel and electricity use were sourced from the NGA Factors (June 2009) workbook.

3.2.5 Construction Materials

The quantity of Scope 3 GHG emissions associated with the use of materials (embodied emissions) was calculated based on the following simplified formula:

GHG emissions (t CO_2-e) = Q x EF

Where: Q = quantity of material (in tonnes, kL, or m^3)

EF = relevant Emission Factor (in t CO_2-e/t of material)

The emission factors for the materials were sourced from the EcoInvent database (contained within the SimaPro 7.1 software). SimaPro is a Life Cycle Analysis software that draws on a large in-built database of materials and processes.

Scope 3 material embodied energy emissions sources that were not expected to contribute ‘significantly’ to total GHG emissions were excluded from the inventory to simplify the estimation process. The exclusion of insignificant emissions sources is consistent with ISO 14064 and the principles of relevance and consistency. Emissions sources that were estimated to cumulatively change the total estimate by less than 0.5% were defined as being insignificant and excluded from the assessment.

4.0 Results

4.1 Total GHG Emissions

The construction and 50 year operation of the project will generate approximately 693,871 tCO_2-e for Scenario 1 (i.e. if the putrescible materials and recyclables are not removed from the general waste prior to landfilling). The construction and 50 year operation of the project will generate approximately 279,381 tCO_2-e for Scenario 2 (i.e. if the putrescible materials and recyclables are removed from the general waste prior to landfilling from years 11 onwards). The breakdown of GHG emissions from the project are shown in the following Table.

Table 3 Estimated Total Greenhouse Gas Emissions (50 year period)

Emissions Source	**Quantity**	**Units**	**GHG Emissions (t CO_2-e)**			**Total GHG Emissions (t CO_2-e)**
			Scope 1	**Scope 2**	**Scope 3**	
Diesel Fuel Use						
Transport of Construction Materials	1,999	kL	5,394		409	5,804
Construction Equipment Onsite	11,856	kL	31,989		2,426	34,415
Transport of Waste to Landfill	1,452	kL	3,917		297	4,214
Landfill Gases						
Landfill Gas Emissions – Scenario 1*	750,000	t of waste	641, 622			641, 622
Landfill Gas Emissions – Scenario 2*	750,000	t of waste	227,132			227,132
Land Use Change						
Cleared vegetation	12.7	ha	4,572			4,572
Electricity Use						
Purchased Electricity	680,940	kWh		606	123	729
Use of Construction Materials						
Clay	338,831	t			678	678
Gravel	128,472	t			899	899
HDPE (liner)	167	t			363	363
Soil	308,459	t			463	463
Cover Material	75,960	t			114	114
Total – Scenario 1	**na**		**687,494**	**606**	**5,771**	**693,871**
Total – Scenario 2	**na**		**273,004**	**606**	**5,771**	**279,381**

Note:* refer to the scenario descriptions in section 3.2.2 of this report.

The total estimated quantities of fuel, waste disposed, vegetation removed, electricity and construction materials used during the 50 year operation of the project are shown in column 2 of the Table above.

The results show that the majority of GHG emissions are associated with Scope 1direct emissions, specifically the methane generated as the waste decomposes in the landfill.

The breakdown of the annual Scope 1 and Scope 2 GHG emissions associated with the project are provided in the following section.

4.2 Annual Scope 1 and Scope 2 Emissions

For Scenario 1 the project will generate approximately 13,658 t of Scope 1 CO_2-e per annum. For Scenario 2 the project will generate approximately 5,369 t of Scope 1 CO_2-e per annum.

For Scenarios 1 and 2, the project will generate approximately 12 t of Scope 2 CO_2-e per annum. The breakdown of annual Scope 1 and 2 GHG emissions from the project are shown in the following Table.

Table 4 **Annual Scope 1 and Scope 2 GHG Emissions**

Emissions Source	**Quantity**	**Units**	**GHG Emissions (t CO_2–e per annum)**		**Total GHG Emissions (t CO_2–e per annum)**
			Scope 1	**Scope 2**	
Fuel Use					
Construction Equipment Onsite	40	kL	108	0	108
Transport of Construction Materials	237	kL	640	0	640
Transport of Waste to Landfill	29	kL	78	0	78
Landfill Gases					
Landfill Gas Emissions – Scenario 1	15,000	t of waste	12,832	0	12,832
Landfill Gas Emissions – Scenario 2*	15,000	t of waste	4,543		4,543
Electricity Use					
Purchased Electricity	13,619	kWh	0	12	12
Total – Scenario 1	**na**	**na**	**13,658**	**12**	**13,671**
Total – Scenario 2	**na**	**na**	**5,369**	**12**	**5,381**

Note:* refer to the scenario descriptions in section 3.2.2 of this report.

The detailed GHG emissions calculations for each of the material types, electricity and fuel use sources, and land use change are presented in the detailed results tables in Appendix B. The detailed landfill gas emission calculations for each of the two landfilling scenarios (Scenario 1 and Scenario 2) are presented in Appendix C.

5.0 Discussion

5.1 Regulatory Requirements

The proposed landfill is to be assessed in accordance with the requirements of the *Environmental Planning and Assessment Act 1979* (the EP&A Act) and the *Environmental Planning and Assessment Regulation 2000* (EP&A Regulation).

The EP&A Act contains a general requirement to address environmentally sustainable principles. Recent precedents in environmental approvals suggest that a plan to address the negative external costs of GHG emissions is required to address sustainable development principles.

GHG emissions are specifically addressed in the EPA's 'Landfill Guidelines Benchmark Technique Number 11 – Extraction and Disposal of Landfill Gas', which states the following:

- *'A gas extraction system should be used to extract and, where possible, combust landfill gases. This system should reduce the risk of explosion and fire, reduce the contribution to greenhouse gases (methane is 20 to 30 times more potent than carbon dioxide), and lower the level of toxic organic compounds emitted from landfills. In conformance with the EPA's commitment to using landfill as a resource, applicants should evaluate generation of electricity as an option when designing the extraction system.'*

And:

- *Energy should be recovered from the landfill gas where possible, either by directly using the gas or by generating electricity for export.*

This report addresses these regulatory requirements by:

- Providing an assessment of potential GHG emissions from the project using a standard method that is internationally and locally recognised; and
- Identifying abatement measures.

The landfill may trigger National Greenhouse and Energy Reporting (NGERs) and Carbon Pollution Reduction Scheme (CPRS) obligations, depending on its proximity to other large landfills.CPRS obligations will be triggered by individual facilities if their emissions equal or exceed 25 kilo tonnes (kt) of CO_2-e per year. In addition, CPRS obligations apply to some landfill facilities that are near a large landfill that accepts similar waste, where the facility's emissions are at least 10kt CO_2-e a year.

The distance between landfills that triggers the lower threshold will be set in regulations. Businesses will be able to work out whether the lower threshold applies to them from a list of large landfills and their locations that will be published by the Australian Climate Change Regulatory Authority.

The nearest landfill to the proposed landfill is the Armidale Long Swamp Road Waste depot which is approximately 10km from the proposed landfill site which will be completely filled and capped potentially in the next few years.

Only Scope 1 (i.e. direct) emissions as determined by the NGERS Act are used to calculate the threshold. This includes direct emissions from processes such as methane as well as emissions from fuel combusted on site (e.g. vehicles used on site).

5.2 Comparison with NSW's Emissions

NSW's annual GHG emissions are approximately 162.7 million tCO_2-e, of which 5.3 million tCO_2-e of emissions in NSW are associated with the waste sector. (DCC, May 2009, Australia's National Greenhouse Accounts: State and Territory Greenhouse Gas Inventories 2007). Thus, the estimated annual scope 1 and 2 emissions from the project would contribute to approximately 0.25% and 0.10% of the state's annual waste sector emissions for Scenarios 1 and 2 respectively.

6.0 Proposed GHG Reduction Measures

The following hierarchy was used to develop proposed measures to reduce GHG emissions from the Landfill:

- Avoid
- Reduce
- Abate
- Offset

The above hierarchy is derived from generally accepted principles for sustainable resource management.

The following opportunities will be undertaken to reduce/offset GHG emissions associated with the project:

Fuel:

- Assess the fuel efficiency of the construction plant/equipment prior to selection and, where practical, use equipment with the highest fuel efficiency or equipment which uses lower GHG intensive fuel such as biofuels (e.g. biodiesel, ethanol)
- Consider the distance of construction material suppliers prior to procurement to reduce transport-related emissions

Equipment:

- Ensure construction equipment and transport vehicles are maintained to reduce energy efficiency losses associated with damaged/unmaintained equipment
- Ensure electrically efficient equipment is purchased

Materials:

- Plan construction works to avoid double handling of materials

Vegetation Sequestration:

The trees planted and maintained within the proposed Biodiversity Offset Area have the potential to sequester and store carbon. The trees within the Biodiversity Offset area have the potential to sequester and store (in the vegetation biomass only) an average of 360 t CO_2-e/ha.

Reduce areas of land clearing. Reductions in land clearing are 24-50 times more effective than replanting vegetation (NSW Energy and Greenhouse Guidelines for Environmental Impact Assessment, 2002)

Additional GHG reduction opportunities which will be considered during the design stage of the project include:

- Purchasing Green Power
- Purchasing emissions credits through a program such as 'Greenfleet'.
- Maximising the energy efficiency of the buildings
- Reducing landfill methane emissions.

Maximising energy efficiency

During the detailed design stage additional and more specific energy efficiency and energy reduction measures to be implemented at the landfill facility will be determined, which may include:

- Using purchasing policies that favour electrically efficient equipment
- Enhancing the energy efficiency of the buildings by using:
  - Energy efficient lighting systems with low energy lights, wide-panel skylights, task lighting, timers, and motion sensors
  - Natural ventilation

  - Energy efficient heating and air conditioning systems, for example systems that incorporate ceiling fans with central air conditioning and heating plant or evaporative air conditioning
  - A well insulated building envelope
- Using a renewable form of energy. For example, combusting the available landfill gas and generating energy for use on site, or installing a solar photovoltaic array to produce electricity from the sun.

Reducing landfill methane emissions

The amount of landfill gas which will be generated will be dependent upon the fraction of putrescible materials within the waste stream. Reducing the amount of putrescible waste landfilled at the proposed facility will have the greatest impact on reducing the landfill's GHG emissions. It is Council's longer term objective, to begin operating the landfill, as soon as possible in the future (and then until final closure) only as a General Solid Waste (non-putrescible) facility, when appropriate additional off-site sorting and/or treatment technologies are able to be procured and successfully employed.

Additional methods which can be implemented to reduce the generation of landfill gas GHG emissions are discussed in the following. The measures to be implemented will be determined once the landfill has commenced operating and the quantity of emissions generated is determined. During the initial operational phase of the proposed development, the landfill's performance with respect to landfill gas production and other associated matters would be assessed and the results discussed with both the DECCW and DoP. Once the filling of Cell 1 is complete, landfill gas monitoring (perimeter well testing) would be conducted to determine if the amount of gas produced requires the installation of a gas extraction/control system.

Three suitable options to manage landfill gas at the landfill include:

- The application of a methane oxidation cap
- Passive venting and using a filter (e.g. activated carbon or the like) to reduce emissions
- Actively collecting the landfill gasses with a landfill gas collection system and flaring the methane (combustion conversion to CO_2)

The methane oxidation cap is a “biological' cap (sometimes called a phyto-remediation cap) that is used in preference to the standard compacted clay type of cap. It relies on a biomass that oxidises CH_4 as the landfill gas permeates through the soil media that constitutes the cap. Extensive research into this type of capping demonstrates a reduction in methane emissions from landfills of up to 10 times over a standard compacted clay cap. Currently research is being undertaken in Australia as part of the Australian Alternative Capping Assessment Program that is trying to loosen up the capping requirements nationally so that smaller landfills have an alternative to the prescriptive expensive caps that are typically required.

Landfill methane can be combusted by open flaring, burning to generate heat, or burning in an internal combustion engine to generate electricity. When anthropogenic methane is burned in air to produce carbon dioxide and water, the carbon dioxide produced is equal to the amount that would have been produced by natural decomposition, and is not considered anthropogenic GHG emissions.

Flaring is generally most effective and economically viable where smaller or unreliable quantities of methane are generated. Generation of heat or electricity has an additional benefit of offsetting electricity consumption, which further offsets total GHG emissions. However, these methods are only economically feasible where sufficient quantities of methane can be reliably collected over a long time.

In general, most commercially viable landfill gas to energy operations rely on consistent (i.e. 80% operational time) generation of 1MW for a period of 5-7 years. In order to achieve this, a landfill gas (LFG) flow of about 600m^3/hr is required with a 50% CH_4, composition. To achieve this flow, a landfill will need to have approximately 1million tonnes of waste in place after about 10 years. Armidale Regional Landfill will have approximately 150,000 tonnes of waste after approximately 10 years of operation, hence generation of electricity from landfill methane is not likely to be commercially viable.

The amount of methane generated after the Landfill is operating will be monitored and assessed to determine whether the amount of methane produced is sufficient for either small scale self generation or commercial scale electricity generation and export.

7.0 Emissions Monitoring and Reporting

7.1 Proposed Monitoring Program

It is recommended that the Armidale Regional Landfill quantitatively measures, records and reports annual GHG emissions. Strategies to monitor and report emissions are as follows:

1. Transfer Station weighbridge. The Transfer Station weighbridge can be used to service commercial and reporting needs. Records of the waste types and weights are then maintained in order to improve the estimates of the waste being disposed of.
2. Gas measurements. If a landfill gas collection system is installed at the landfill the quantity of gas flared or captured can be measured by the inclusion of a gas meter in the collection circuit.

Emissions reported may be subject to a non-compulsory audit by the Australian Climate Change Regulatory Authority[2] (ACCRA) . Depending on the landfill's proximity to other landfills, it may trigger CPRS obligations i.e.>10,000 t CO_2-e for facilities within a prescribed distance of designated large landfill facility and >25,000 t CO_2-e for other facilities. As the distance that specifies the applicable threshold for CPRS obligations hasn't yet been specified and considering that the nearest landfill which is 10km from the proposed landfill will be closed in a few years (but will still emit GHG after closure), and the next closest large landfill will be in Tamworth or Coffs Harbour, approximately at a distance of 115km. It is therefore assumed that the 10,000 t CO_2-e threshold applies to the proposed landfill.

Registering for NGERS (if required) provides access to the Online System for Challenge Activity Reporting, or 'OSCAR', which can be used to record emissions data, and estimate emissions.

OSCAR enables participants to input and update their energy, waste and materials consumption data online by creating a database structure that represents the entity relationships within their organisation, and adding information to the emissions information to the database over time.

OSCAR stores all the necessary conversion factors to automatically convert energy, fuel, waste and materials consumption data into GHG emissions in quantities of CO_2-e.

Greenhouse performance can be tracked over time against specific business measures, and GHG abatement activities can be reported.

---

[2] Note: If passed, the Carbon Pollution Reduction Scheme Bill 2009 and Australian Climate Change Regulatory Authority Bill 2009 will establish the independent ACCRA

References

Australian and New Zealand Standards (ISO 14040 series) Life Cycle Assessment.

Australian Standard (AS ISO 14064.1 – 2006) Greenhouse Gases Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals.

Department of Climate Change (DCC), May 2009, Australia's National Greenhouse Accounts: State and Territory Greenhouse Gas Inventories 2007.
http://www.climatechange.gov.au/inventory/2007/pubs/state_territory_inventoryv.pdf

DCC, June 2008, Australia's National Greenhouse Accounts: National Greenhouse Gas Inventory 2006 - Accounting for the Kyoto Target. http://www.climatechange.gov.au/inventory/2006/pubs/inventory2006.pdf

DCC, June 2008, Australia's National Greenhouse Accounts: State and Territory Greenhouse Gas Inventories 2006. http://www.climatechange.gov.au/inventory/stateinv/pubs/states2006.pdf

DCC, November 2008, National Greenhouse Accounts (NGA) Factors.

DCC, October 2005, the National Carbon Accounting Toolbox (NCAT).

DCC, June 2009The National Greenhouse and Energy Reporting System Measurement, Technical Guidelines for the estimation of greenhouse gas emissions by facilities in Australia.

Mackey, B.G., Keith, H., Berry, S.L. and Lindenmayer, D.B., The Fenner School of Environment & Society, The Australian National University, 2008, Green Carbon: The role of natural forests in carbon storage, Part 1. A green carbon account of Australia's south-eastern Eucalypt forests, and policy implications.

World Business Council for Sustainable Development (WBCSD) and World Resources Institute (WRI), 2004, The Greenhouse Gas Protocol.

WRI &WBCSD, 2004, The Greenhouse Gas Protocol A Corporate Accounting and Reporting Standard, Revised Edition.

WRI &WBCSD, November 2005, The Greenhouse Gas Protocol for Project Accounting.

Appendix A

Assumptions and Exclusions

Appendix A Assumptions and Exclusions

Assumptions

The following assumptions have been used in the preparation of this inventory:

- Fuel used for all construction vehicles and by all vehicles to transport materials is diesel oil
- The energy content factor for diesel oil is 38.6 GJ/kL (DCC, NGA Factors, June 2009. Table 4)
- The Scope 1 emission factors for the combustion of diesel oil are:
    - EFCO2: 69.2 kg CO2-e/GJ
    - EFCH4: 0.2 kg CO2-e/GJ
    - EFN2O: 0.5 kg CO2-e/GJ (DCC, NGA Factors, June 2009. Table 4)
- The Scope 3 emission factor for diesel oil is 5.3 kg CO2-e/GJ (DCC, NGA Factors, June 2009. Table 38)
- Transport of materials to/from site is by road only
- Fuel used for transport of materials to/from site is diesel (general transport), with a fuel consumption rate of 0.542L/km
- Fuel used for transport of staff is gasoline, with a fuel consumption rate of 0.107L/km
- The Scope 2 emission factor for consumption of purchased electricity from the grid in NSW is 0.89 kg CO2-e/kWh (DCC, NGA Factors, June 2009. Table 5)
- The Scope 3 emission factor for consumption of purchased electricity from the grid in NSW is 0.18 kg CO2-e/kWh (DCC, NGA Factors, June 2009. Table 39)
- All construction materials will be delivered by the supplier, therefore the Scope 1 and Scope 3 emissions associated with the transport of construction materials will be categorised as a scope 3 emissions for the project.
- Fuel used during transportation of materials is calculated based on round trips
- 15,000 tonnes of waste per annum will be landfilled
- The existing waste transfer station is proposed to be used during the operation of the Armidale Regional Landfill.
- The landfill management will be responsible for the transport of waste and cover material to the landfill site.
- The landfill will operate for 6 days a week, 52 weeks a year.
- Vegetation *temporarily* cleared will be revegetated as part of the construction works. Whilst removal of vegetation within the development footprint would be *permanent*, clearing for access and compound areas would be temporary as these areas would be rehabilitated post-construction.
- 12.7 ha of vegetation will be permanently cleared.

Materials

Bulk Densities

- Clay Density – 2.82 t/m3
- Fill/Cover Material Density – 2.0 t/m3
- HDPE Density – 0.97 t/m3
- Gravel Density – 1.522 t/m3
- Soil Density – 1.800 t/m3

Waste

It was assumed that the waste landfilled will be transported from the existing waste transfer facility on Long Swamp Road to the proposed landfill site. Three trucks per day will deliver the waste to the landfill.

The landfill will be classed as a General Solid Waste (putrescibles) landfill. It is Council's longer term objective, however, to begin operating the landfill, as soon as possible in the future (and then until final closure) only as a General Solid Waste (non-putrescible) facility, when appropriate additional off-site sorting and/or treatment technologies are able to be procured and successfully employed.

Exclusions

This assessment excludes GHG emissions associated with:

- The end of life (demolition, decommissioning, etc) of the project's infrastructure (site sheds, road, etc)
- The use of materials and construction equipment for maintenance purposes
- The mixed waste generated by construction and operational staff
- The removal of any existing infrastructure
- The operation, maintenance and sorting of waste at the waste transfer station
- Fugitive emissions of refrigerants from refrigeration and air conditioning systems
- Support services for the facility

Appendix B

Input Data and Resource Consumption Calculations

Appendix B Input Data and Resource Consumption Calculations

Typical Excavation Dimensions	**Per Cell**
Width (m)	80
Length (m)	275
Depth (m)	14
Area (m2)	22,000
Volume (m3)	308,000

Material requirements for landfill and pond lining	**Quantity**
Landfill cell area (m2)	22,000
Number of Cells	5
Total landfill area (m2)	110,000
Leachate pond base area (m2)	4,900
Total area of landfill and leachate pond which will be lined (m2)	114,900
Thickness of clay lining (m)	0.3
Clay required (for landfill and leachate pond lining) (m3)	***34,470***
HDPE thickness for lining (m)	0.0015
HDPE required (for landfill and leachate pond lining) (m3)	***172.35***
Thickness of gravel for leachate drainage layer (m)	0.3
Gravel required for leachate drainage layer (m3)	***33,000***

Material requirements for landfill cap	**Quantity**
Surface area of landfill cap (m2)	171,366
Thickness of revegetation layer (Soil) (m)	1
Volume of soil required (m3)	***171,366***
Thickness of gravel drainage layer (m)	0.3
Volume of gravel required (m3)	**51,410**
Thickness of clay capping (m)	0.5
Volume of clay required (m3)	**85,683**
Volume of Waste and Cover (m3)	211,000
Percentage of cover	20%
Cover material required (m3)	**42,200**

Note: The above estimate of the construction materials which will be used in the project's construction is based on the preliminary concept design.

Use of Construction Materials - Scope 3 GHG Emissions

Emission Source	Quantity (m3	Density (t/	Quantity (t)	Scope 3 Emis	Source	Total Scop	Haulage Capacity (t)	Movements	Distance (km)	Total Km Travelled	Fuel Efficiency (L/km)	Fuel Used (kL)
Clay	120 153	2.82	338,831	0.002	Ecoinvent Database	678	25	27,107	55	1,490,858	0.542	808,045
Gravel	64 410	1.022	128,472	0.007	Ecoinvent Database	899	25	10,278	55	565,278	0.542	306,379
HDPE	172.35	0.97	167	2.171	Ecoinvent Database	363	15	22	100	2,229	0.542	1,208
Soil	171 366	1.8	308,459	0.0015	Ecoinvent Database	463	25	24,677	50	1,233,835	0.542	668,709
Cover Material	42 200	1.8	75,960	0.0015	Ecoinvent Database	114	10	15,192	50	759,300	0.233	214,967
TOTAL						2,517					Total fuel use	1,999,330

Use of Fuel to Transport Construction Materials - Scope 1 & 3 GHG Emissions

Purpose	Vehicle Type	Fuel Type	Fuel Efficiency (L/km)	Fuel Used (kL)	Energy Content Factor (GJ/kL)	Scope 1 Emission factor (EF) kg/CO2-			Total Scope 1 GHG Emissions	Scope 3 Emission Factor (EF) kg/CO2-e/GJ	Scope 3 GHG Emission	Total GHG Emissions (t CO2-e)
						CO2	CH4	N2O	(tCO2e)		(tCO2e)	
Construction Materials Transport	Heavy	Diesel	0.542	1,999	38.6	69.2	0.2	0.5	5,394	5.3	409	5,804

Use of Fuel By Construction Equipment Onsite - Scope 1 & 3 GHG Emissions

										ANNUAL				TOTAL - 50 YRS		
Equipment	Diesel Consumption (L/hr)	Daily Work Duration (hr/day)	Total Work Duration (hr/yr)	Annual Diesel Consumption (kL/yr)	Total Diesel Consumption (kL/50yrs)	Energy Content Factor (GJ/kL)	Scope 1 Emission factor (EF)			Total Scope 1 GHG Emissions (tCO2e)	Scope 3 Emission Factor (EF) kg/CO2-e/GJ	Scope 3 GHG Emission (tCO2e)	Total GHG Emissions (t CO2-e)	Total Scope 1 GHG Emissions (tCO2e)	Scope 3 GHG Emission (tCO2e)	Total GHG Emissions (t CO2-e)
							CO2	CH4	N2O							
Excavator	30	2	624	18.72	936	38.6	69.2	0.2	0.5	51	5.3	4	54	2,525	191	2,717
Water Cart	15	8	2496	37.44	1,872	38.6	69.2	0.2	0.5	101	5.3	8	109	5,051	383	5,434
Dozer	30	6	1872	56.16	2,808	38.6	69.2	0.2	0.5	152	5.3	11	163	7,576	574	8,151
Compactor	20	8	2496	49.92	2,496	38.6	69.2	0.2	0.5	135	5.3	10	145	6,735	511	7,245
Grader	25	2	624	15.6	780	38.6	69.2	0.2	0.5	42	5.3	3	45	2,105	160	2,264
Tipper truck	20	6	1872	37.44	1,872	38.6	69.2	0.2	0.5	101	5.3	8	109	5,051	383	5,434
Truck	15	2	624	9.36	468	38.6	69.2	0.2	0.5	25	5.3	2	27	1,263	96	1,358
Scrapper	20	2	624	12.48	624	38.6	69.2	0.2	0.5	34	5.3	3	36	1,684	128	1,811
TOTAL					11,856				Total	640		49	688	31,990	2,426	34,415

Use to Transport Waste to Landfill - Scope 1 & 3 GHG Emissions

Purpose	Vehicle Type	Fuel Type	Fuel Efficiency (l/km)	Daily Trip Frequency	Distance (km)	Annual Distance Travelled (km)	Annual Consumption (kL)	Energy Content Factor (GJ/kL)	Scope 1 Emission factor (EF) kg/CO2-			Total Annual Scope 1 GHG Emission	Total 50 yr Operational Scope 1 GHG	Scope 3 Emission Factor (EF)	Annual Scope 3 GHG Emission	Operational 50yr Scope 3 GHG Emission	Total Annual GHG Emissions
									CO2	CH4	N2O	(tCO2e)	(tCO2e)	kg/CO2-e/GJ	(tCO2e)	(tCO2e)	(t CO2-e)
Waste Transport	MRV	Diesel	0.233	3	54.8	102,586	29	38.6	69.2	0.2	0.5	78	3,917	5.3	6	297	84
							1,452 Total Fuel Consumption for 50yrs										

The waste transport fuel use is based on 3 trucks per day travelling between the transfer station & the landfill

Electricity Use Onsite

Equipment	Power (W)	No of Units	Operating hours/day (hr)	Annual Energy Consumption (kWh)
Mult Functional Device (printer's	450	1	8	1123.2
Microwave	1120	1	0.5	174.72
Toaster	1500	1	0.5	234
Kettle	2400	1	0.5	374.4
Sandwich maker	1000	1	0.5	156
Fridge two door	160	1	24	1198.08
Computer	150	5	8	1872
Airconditioning	1000	2	10	6240
Lighting	60	15	8	2246.4
Total				13,619

Use of Electricity Onsite - Scope 2 & 3 GHG Emissions

Annual Energy Consumption (kWh)	Years operating	Scope 2 Emission factor (EF) kg/CO2-e/kWh	Annual Scope 2 GHG Emissions (tCO2e)	Total 50 yr Scope 2 GHG Emissions (tCO2e)	Scope 3 Emission factor (EF) kg/CO2-e/kWh	Annual Scope 3 GHG Emissions (tCO2e)	Total 50 yr Scope 3 GHG Emissions (tCO2e)	Total Annual GHG Emissions (t CO2-e)	Total Operational 50yr GHG Emissions (t CO2-
13,619	50	0.89	12	606	0.18	2	123	15	729

Vegetation Clearing Onsite

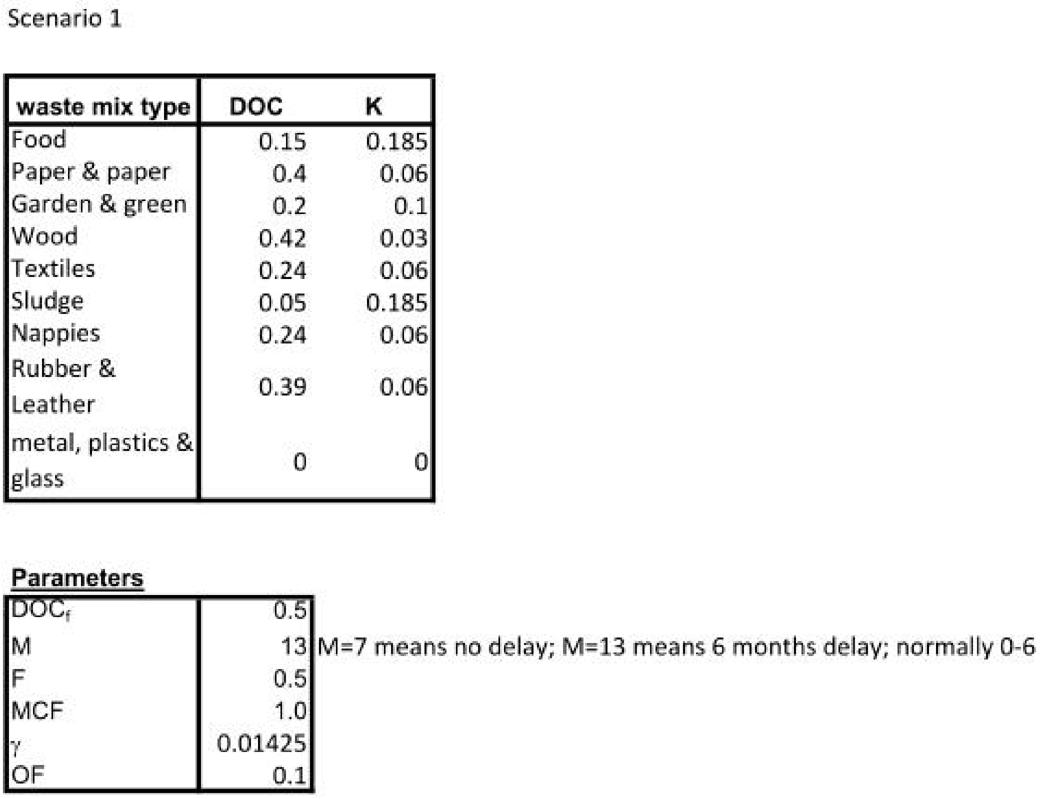
Area (ha)	Carbon St	Total Carbon Stock Loss (tCO2e)
12.7	360	4672

380,940 Total Energy Consumption for 50yrs

Appendix C

Landfill Greenhouse Gas Emissions Calculation Results

Appendix C Landfill Greenhouse Gas Emissions Calculation Results

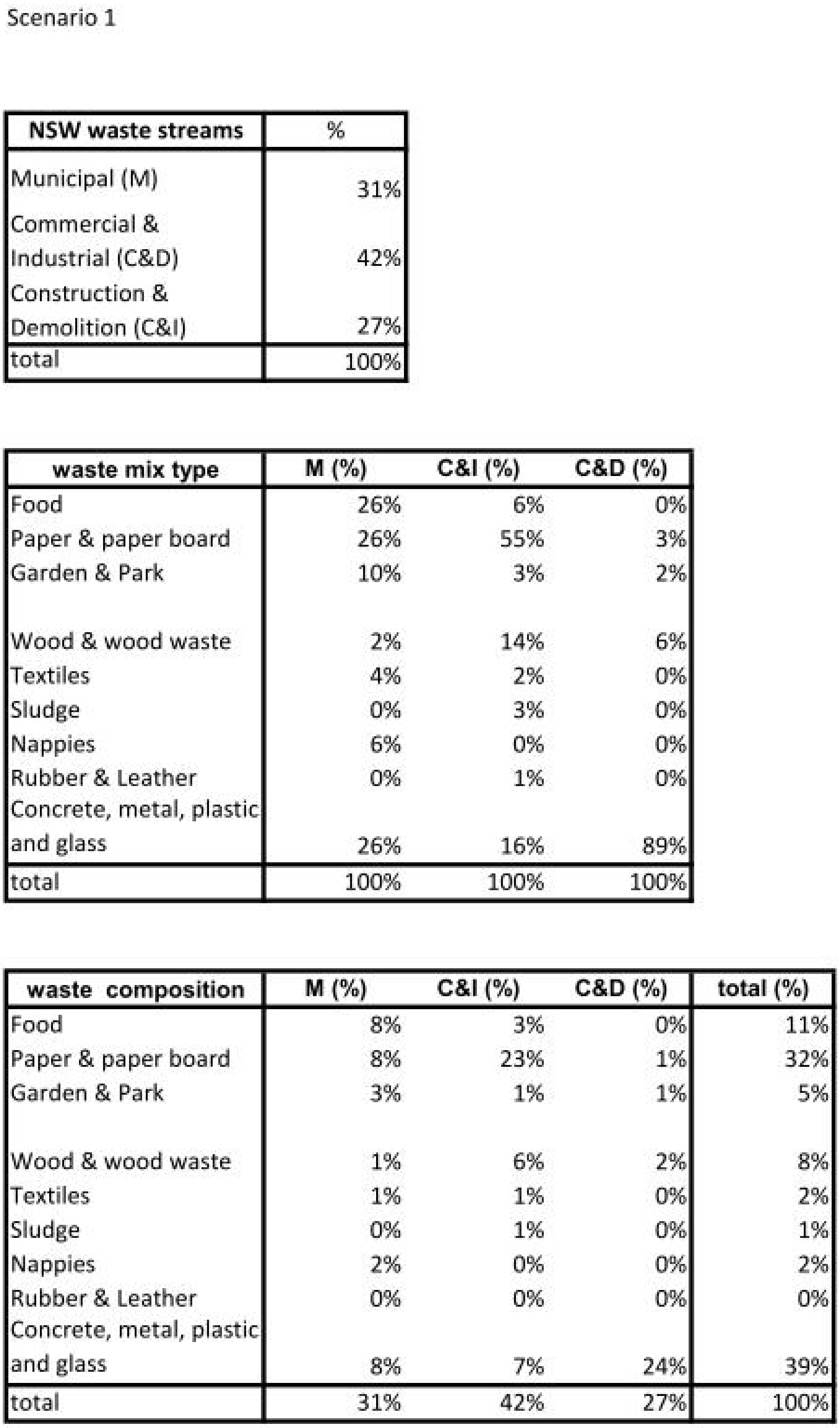


Scenario 1

waste mix type	DOC	K
Food	0.15	0.185
Paper & paper	0.4	0.06
Garden & green	0.2	0.1
Wood	0.42	0.03
Textiles	0.24	0.06
Sludge	0.05	0.185
Nappies	0.24	0.06
Rubber & Leather	0.39	0.06
metal, plastics & glass	0	0

Parameters

DOC_f	0.5	
M	13	M=7 means no delay; M=13 means 6 months delay; normally 0-6
F	0.5	
MCF	1.0	
γ	0.01425	
OF	0.1	



Scenario 1

NSW waste streams	%
Municipal (M)	31%
Commercial & Industrial (C&D)	42%
Construction & Demolition (C&I)	27%
total	100%

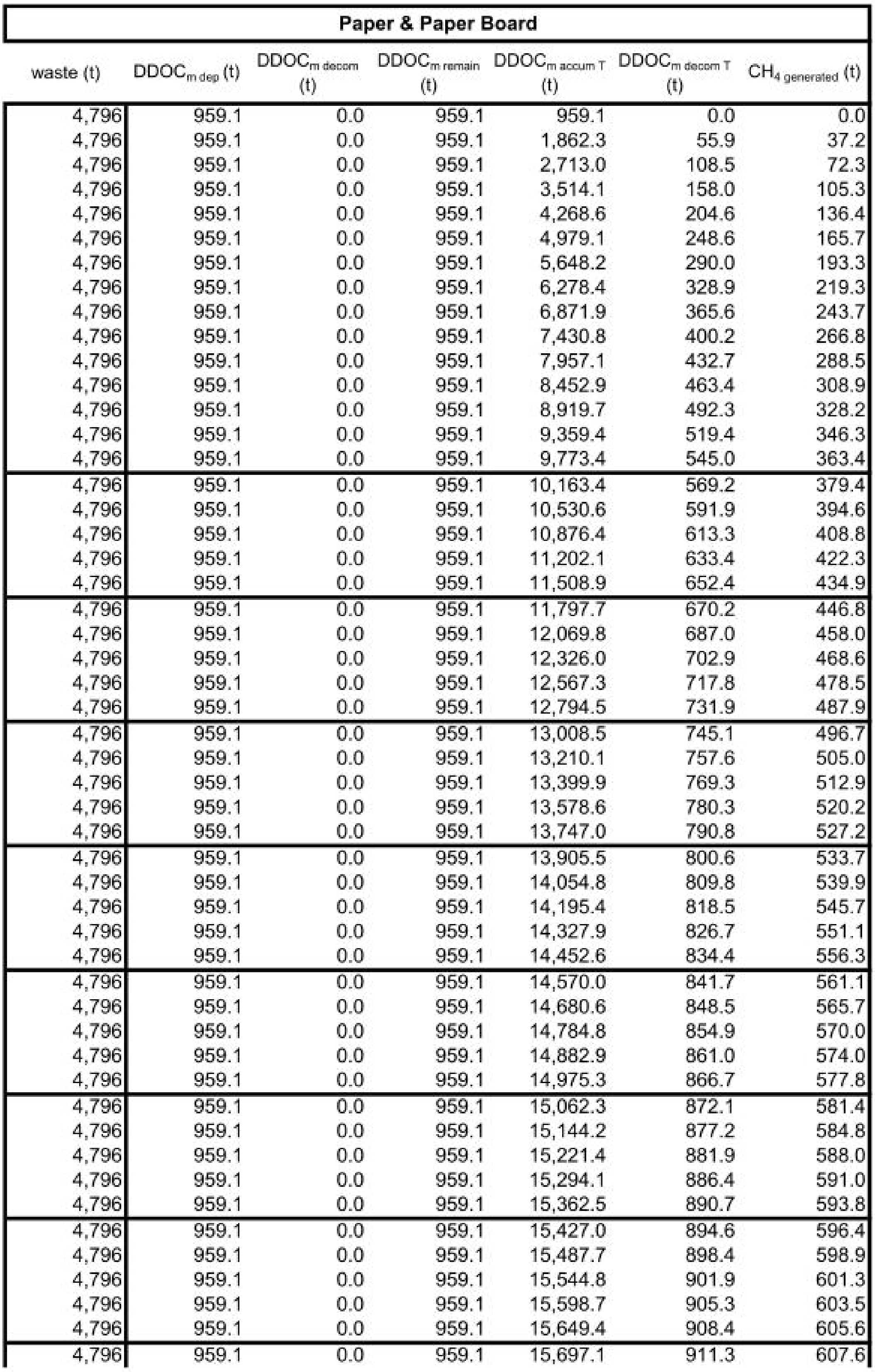
waste mix type	M (%)	C&I (%)	C&D (%)
Food	26%	6%	0%
Paper & paper board	26%	55%	3%
Garden & Park	10%	3%	2%
Wood & wood waste	2%	14%	6%
Textiles	4%	2%	0%
Sludge	0%	3%	0%
Nappies	6%	0%	0%
Rubber & Leather	0%	1%	0%
Concrete, metal, plastic and glass	26%	16%	89%
total	100%	100%	100%

waste composition	M (%)	C&I (%)	C&D (%)	total (%)
Food	8%	3%	0%	11%
Paper & paper board	8%	23%	1%	32%
Garden & Park	3%	1%	1%	5%
Wood & wood waste	1%	6%	2%	8%
Textiles	1%	1%	0%	2%
Sludge	0%	1%	0%	1%
Nappies	2%	0%	0%	2%
Rubber & Leather	0%	0%	0%	0%
Concrete, metal, plastic and glass	8%	7%	24%	39%
total	31%	42%	27%	100%

Scenario 1

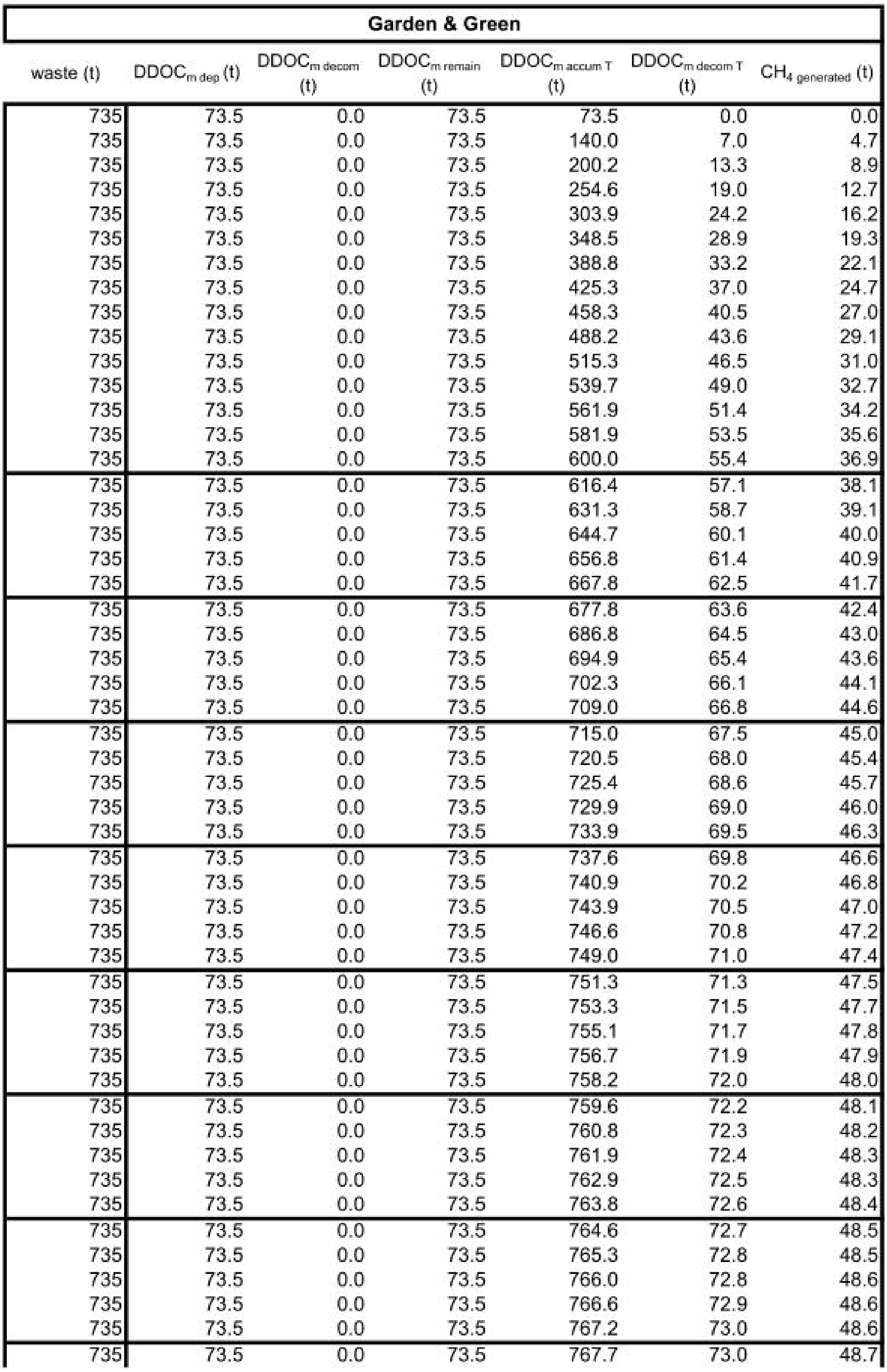
Year	Food						
	waste (t)	$DDOC_{m\ dep}$ (t)	$DDOC_{m\ decom}$ (t)	$DDOC_{m\ remain}$ (t)	$DDOC_{m\ accum\ T}$ (t)	$DDOC_{m\ decom\ T}$ (t)	$CH_{4\ generated}$ (t)
1	1,587	119.0	0.0	119.0	119.0	0.0	0.0
2	1,587	119.0	0.0	119.0	217.9	20.1	13.4
3	1,587	119.0	0.0	119.0	300.2	36.8	24.5
4	1,587	119.0	0.0	119.0	368.5	50.7	33.8
5	1,587	119.0	0.0	119.0	425.3	62.2	41.5
6	1,587	119.0	0.0	119.0	472.5	71.8	47.9
7	1,587	119.0	0.0	119.0	511.7	79.8	53.2
8	1,587	119.0	0.0	119.0	544.3	86.4	57.6
9	1,587	119.0	0.0	119.0	571.4	91.9	61.3
10	1,587	119.0	0.0	119.0	593.9	96.5	64.3
11	1,587	119.0	0.0	119.0	612.6	100.3	66.9
12	1,587	119.0	0.0	119.0	628.2	103.5	69.0
13	1,587	119.0	0.0	119.0	641.1	106.1	70.7
14	1,587	119.0	0.0	119.0	651.9	108.3	72.2
15	1,587	119.0	0.0	119.0	660.8	110.1	73.4
16	1,587	119.0	0.0	119.0	668.2	111.6	74.4
17	1,587	119.0	0.0	119.0	674.4	112.9	75.2
18	1,587	119.0	0.0	119.0	679.5	113.9	75.9
19	1,587	119.0	0.0	119.0	683.8	114.8	76.5
20	1,587	119.0	0.0	119.0	687.3	115.5	77.0
21	1,587	119.0	0.0	119.0	690.2	116.1	77.4
22	1,587	119.0	0.0	119.0	692.7	116.6	77.7
23	1,587	119.0	0.0	119.0	694.7	117.0	78.0
24	1,587	119.0	0.0	119.0	696.4	117.3	78.2
25	1,587	119.0	0.0	119.0	697.8	117.6	78.4
26	1,587	119.0	0.0	119.0	699.0	117.9	78.6
27	1,587	119.0	0.0	119.0	700.0	118.1	78.7
28	1,587	119.0	0.0	119.0	700.8	118.2	78.8
29	1,587	119.0	0.0	119.0	701.4	118.4	78.9
30	1,587	119.0	0.0	119.0	702.0	118.5	79.0
31	1,587	119.0	0.0	119.0	702.4	118.6	79.0
32	1,587	119.0	0.0	119.0	702.8	118.6	79.1
33	1,587	119.0	0.0	119.0	703.2	118.7	79.1
34	1,587	119.0	0.0	119.0	703.4	118.8	79.2
35	1,587	119.0	0.0	119.0	703.6	118.8	79.2
36	1,587	119.0	0.0	119.0	703.8	118.8	79.2
37	1,587	119.0	0.0	119.0	704.0	118.9	79.2
38	1,587	119.0	0.0	119.0	704.1	118.9	79.3
39	1,587	119.0	0.0	119.0	704.2	118.9	79.3
40	1,587	119.0	0.0	119.0	704.3	118.9	79.3
41	1,587	119.0	0.0	119.0	704.4	119.0	79.3
42	1,587	119.0	0.0	119.0	704.4	119.0	79.3
43	1,587	119.0	0.0	119.0	704.5	119.0	79.3
44	1,587	119.0	0.0	119.0	704.5	119.0	79.3
45	1,587	119.0	0.0	119.0	704.6	119.0	79.3
46	1,587	119.0	0.0	119.0	704.6	119.0	79.3
47	1,587	119.0	0.0	119.0	704.6	119.0	79.3
48	1,587	119.0	0.0	119.0	704.6	119.0	79.3
49	1,587	119.0	0.0	119.0	704.6	119.0	79.3
50	1,587	119.0	0.0	119.0	704.7	119.0	79.3
51	1,587	119.0	0.0	119.0	704.7	119.0	79.3

Scenario 1



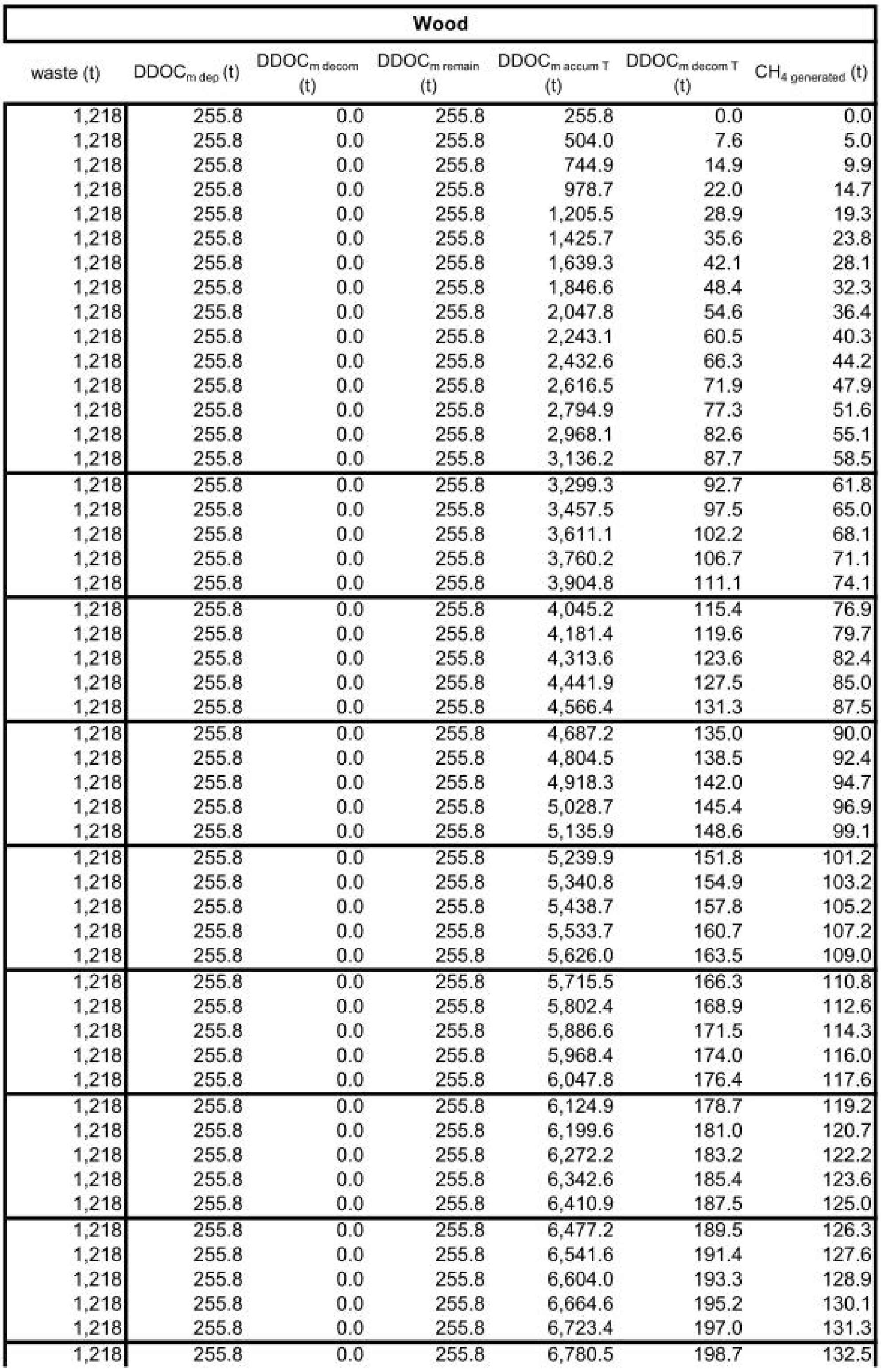
Paper & Paper Board						
waste (t)	DDOC$_{m\ dep}$ (t)	DDOC$_{m\ decom}$ (t)	DDOC$_{m\ remain}$ (t)	DDOC$_{m\ accum\ T}$ (t)	DDOC$_{m\ decom\ T}$ (t)	CH$_{4\ generated}$ (t)
4,796	959.1	0.0	959.1	959.1	0.0	0.0
4,796	959.1	0.0	959.1	1,862.3	55.9	37.2
4,796	959.1	0.0	959.1	2,713.0	108.5	72.3
4,796	959.1	0.0	959.1	3,514.1	158.0	105.3
4,796	959.1	0.0	959.1	4,268.6	204.6	136.4
4,796	959.1	0.0	959.1	4,979.1	248.6	165.7
4,796	959.1	0.0	959.1	5,648.2	290.0	193.3
4,796	959.1	0.0	959.1	6,278.4	328.9	219.3
4,796	959.1	0.0	959.1	6,871.9	365.6	243.7
4,796	959.1	0.0	959.1	7,430.8	400.2	266.8
4,796	959.1	0.0	959.1	7,957.1	432.7	288.5
4,796	959.1	0.0	959.1	8,452.9	463.4	308.9
4,796	959.1	0.0	959.1	8,919.7	492.3	328.2
4,796	959.1	0.0	959.1	9,359.4	519.4	346.3
4,796	959.1	0.0	959.1	9,773.4	545.0	363.4
4,796	959.1	0.0	959.1	10,163.4	569.2	379.4
4,796	959.1	0.0	959.1	10,530.6	591.9	394.6
4,796	959.1	0.0	959.1	10,876.4	613.3	408.8
4,796	959.1	0.0	959.1	11,202.1	633.4	422.3
4,796	959.1	0.0	959.1	11,508.9	652.4	434.9
4,796	959.1	0.0	959.1	11,797.7	670.2	446.8
4,796	959.1	0.0	959.1	12,069.8	687.0	458.0
4,796	959.1	0.0	959.1	12,326.0	702.9	468.6
4,796	959.1	0.0	959.1	12,567.3	717.8	478.5
4,796	959.1	0.0	959.1	12,794.5	731.9	487.9
4,796	959.1	0.0	959.1	13,008.5	745.1	496.7
4,796	959.1	0.0	959.1	13,210.1	757.6	505.0
4,796	959.1	0.0	959.1	13,399.9	769.3	512.9
4,796	959.1	0.0	959.1	13,578.6	780.3	520.2
4,796	959.1	0.0	959.1	13,747.0	790.8	527.2
4,796	959.1	0.0	959.1	13,905.5	800.6	533.7
4,796	959.1	0.0	959.1	14,054.8	809.8	539.9
4,796	959.1	0.0	959.1	14,195.4	818.5	545.7
4,796	959.1	0.0	959.1	14,327.9	826.7	551.1
4,796	959.1	0.0	959.1	14,452.6	834.4	556.3
4,796	959.1	0.0	959.1	14,570.0	841.7	561.1
4,796	959.1	0.0	959.1	14,680.6	848.5	565.7
4,796	959.1	0.0	959.1	14,784.8	854.9	570.0
4,796	959.1	0.0	959.1	14,882.9	861.0	574.0
4,796	959.1	0.0	959.1	14,975.3	866.7	577.8
4,796	959.1	0.0	959.1	15,062.3	872.1	581.4
4,796	959.1	0.0	959.1	15,144.2	877.2	584.8
4,796	959.1	0.0	959.1	15,221.4	881.9	588.0
4,796	959.1	0.0	959.1	15,294.1	886.4	591.0
4,796	959.1	0.0	959.1	15,362.5	890.7	593.8
4,796	959.1	0.0	959.1	15,427.0	894.6	596.4
4,796	959.1	0.0	959.1	15,487.7	898.4	598.9
4,796	959.1	0.0	959.1	15,544.8	901.9	601.3
4,796	959.1	0.0	959.1	15,598.7	905.3	603.5
4,796	959.1	0.0	959.1	15,649.4	908.4	605.6
4,796	959.1	0.0	959.1	15,697.1	911.3	607.6

Scenario 1



Garden & Green						
waste (t)	$DDOC_{m\ dep}$ (t)	$DDOC_{m\ decom}$ (t)	$DDOC_{m\ remain}$ (t)	$DDOC_{m\ accum\ T}$ (t)	$DDOC_{m\ decom\ T}$ (t)	$CH_{4\ generated}$ (t)
735	73.5	0.0	73.5	73.5	0.0	0.0
735	73.5	0.0	73.5	140.0	7.0	4.7
735	73.5	0.0	73.5	200.2	13.3	8.9
735	73.5	0.0	73.5	254.6	19.0	12.7
735	73.5	0.0	73.5	303.9	24.2	16.2
735	73.5	0.0	73.5	348.5	28.9	19.3
735	73.5	0.0	73.5	388.8	33.2	22.1
735	73.5	0.0	73.5	425.3	37.0	24.7
735	73.5	0.0	73.5	458.3	40.5	27.0
735	73.5	0.0	73.5	488.2	43.6	29.1
735	73.5	0.0	73.5	515.3	46.5	31.0
735	73.5	0.0	73.5	539.7	49.0	32.7
735	73.5	0.0	73.5	561.9	51.4	34.2
735	73.5	0.0	73.5	581.9	53.5	35.6
735	73.5	0.0	73.5	600.0	55.4	36.9
735	73.5	0.0	73.5	616.4	57.1	38.1
735	73.5	0.0	73.5	631.3	58.7	39.1
735	73.5	0.0	73.5	644.7	60.1	40.0
735	73.5	0.0	73.5	656.8	61.4	40.9
735	73.5	0.0	73.5	667.8	62.5	41.7
735	73.5	0.0	73.5	677.8	63.6	42.4
735	73.5	0.0	73.5	686.8	64.5	43.0
735	73.5	0.0	73.5	694.9	65.4	43.6
735	73.5	0.0	73.5	702.3	66.1	44.1
735	73.5	0.0	73.5	709.0	66.8	44.6
735	73.5	0.0	73.5	715.0	67.5	45.0
735	73.5	0.0	73.5	720.5	68.0	45.4
735	73.5	0.0	73.5	725.4	68.6	45.7
735	73.5	0.0	73.5	729.9	69.0	46.0
735	73.5	0.0	73.5	733.9	69.5	46.3
735	73.5	0.0	73.5	737.6	69.8	46.6
735	73.5	0.0	73.5	740.9	70.2	46.8
735	73.5	0.0	73.5	743.9	70.5	47.0
735	73.5	0.0	73.5	746.6	70.8	47.2
735	73.5	0.0	73.5	749.0	71.0	47.4
735	73.5	0.0	73.5	751.3	71.3	47.5
735	73.5	0.0	73.5	753.3	71.5	47.7
735	73.5	0.0	73.5	755.1	71.7	47.8
735	73.5	0.0	73.5	756.7	71.9	47.9
735	73.5	0.0	73.5	758.2	72.0	48.0
735	73.5	0.0	73.5	759.6	72.2	48.1
735	73.5	0.0	73.5	760.8	72.3	48.2
735	73.5	0.0	73.5	761.9	72.4	48.3
735	73.5	0.0	73.5	762.9	72.5	48.3
735	73.5	0.0	73.5	763.8	72.6	48.4
735	73.5	0.0	73.5	764.6	72.7	48.5
735	73.5	0.0	73.5	765.3	72.8	48.5
735	73.5	0.0	73.5	766.0	72.8	48.6
735	73.5	0.0	73.5	766.6	72.9	48.6
735	73.5	0.0	73.5	767.2	73.0	48.6
735	73.5	0.0	73.5	767.7	73.0	48.7

Scenario 1



Wood						
waste (t)	$DDOC_{m\ dep}$ (t)	$DDOC_{m\ decom}$ (t)	$DDOC_{m\ remain}$ (t)	$DDOC_{m\ accum\ T}$ (t)	$DDOC_{m\ decom\ T}$ (t)	$CH_{4\ generated}$ (t)
1,218	255.8	0.0	255.8	255.8	0.0	0.0
1,218	255.8	0.0	255.8	504.0	7.6	5.0
1,218	255.8	0.0	255.8	744.9	14.9	9.9
1,218	255.8	0.0	255.8	978.7	22.0	14.7
1,218	255.8	0.0	255.8	1,205.5	28.9	19.3
1,218	255.8	0.0	255.8	1,425.7	35.6	23.8
1,218	255.8	0.0	255.8	1,639.3	42.1	28.1
1,218	255.8	0.0	255.8	1,846.6	48.4	32.3
1,218	255.8	0.0	255.8	2,047.8	54.6	36.4
1,218	255.8	0.0	255.8	2,243.1	60.5	40.3
1,218	255.8	0.0	255.8	2,432.6	66.3	44.2
1,218	255.8	0.0	255.8	2,616.5	71.9	47.9
1,218	255.8	0.0	255.8	2,794.9	77.3	51.6
1,218	255.8	0.0	255.8	2,968.1	82.6	55.1
1,218	255.8	0.0	255.8	3,136.2	87.7	58.5
1,218	255.8	0.0	255.8	3,299.3	92.7	61.8
1,218	255.8	0.0	255.8	3,457.5	97.5	65.0
1,218	255.8	0.0	255.8	3,611.1	102.2	68.1
1,218	255.8	0.0	255.8	3,760.2	106.7	71.1
1,218	255.8	0.0	255.8	3,904.8	111.1	74.1
1,218	255.8	0.0	255.8	4,045.2	115.4	76.9
1,218	255.8	0.0	255.8	4,181.4	119.6	79.7
1,218	255.8	0.0	255.8	4,313.6	123.6	82.4
1,218	255.8	0.0	255.8	4,441.9	127.5	85.0
1,218	255.8	0.0	255.8	4,566.4	131.3	87.5
1,218	255.8	0.0	255.8	4,687.2	135.0	90.0
1,218	255.8	0.0	255.8	4,804.5	138.5	92.4
1,218	255.8	0.0	255.8	4,918.3	142.0	94.7
1,218	255.8	0.0	255.8	5,028.7	145.4	96.9
1,218	255.8	0.0	255.8	5,135.9	148.6	99.1
1,218	255.8	0.0	255.8	5,239.9	151.8	101.2
1,218	255.8	0.0	255.8	5,340.8	154.9	103.2
1,218	255.8	0.0	255.8	5,438.7	157.8	105.2
1,218	255.8	0.0	255.8	5,533.7	160.7	107.2
1,218	255.8	0.0	255.8	5,626.0	163.5	109.0
1,218	255.8	0.0	255.8	5,715.5	166.3	110.8
1,218	255.8	0.0	255.8	5,802.4	168.9	112.6
1,218	255.8	0.0	255.8	5,886.6	171.5	114.3
1,218	255.8	0.0	255.8	5,968.4	174.0	116.0
1,218	255.8	0.0	255.8	6,047.8	176.4	117.6
1,218	255.8	0.0	255.8	6,124.9	178.7	119.2
1,218	255.8	0.0	255.8	6,199.6	181.0	120.7
1,218	255.8	0.0	255.8	6,272.2	183.2	122.2
1,218	255.8	0.0	255.8	6,342.6	185.4	123.6
1,218	255.8	0.0	255.8	6,410.9	187.5	125.0
1,218	255.8	0.0	255.8	6,477.2	189.5	126.3
1,218	255.8	0.0	255.8	6,541.6	191.4	127.6
1,218	255.8	0.0	255.8	6,604.0	193.3	128.9
1,218	255.8	0.0	255.8	6,664.6	195.2	130.1
1,218	255.8	0.0	255.8	6,723.4	197.0	131.3
1,218	255.8	0.0	255.8	6,780.5	198.7	132.5

Scenario 1

Textiles						
waste (t)	$DDOC_{m\ dep}$ (t)	$DDOC_{m\ decom}$ (t)	$DDOC_{m\ remain}$ (t)	$DDOC_{m\ accum\ T}$ (t)	$DDOC_{m\ decom\ T}$ (t)	$CH_{4\ generated}$ (t)
312	37.4	0.0	37.4	37.4	0.0	0.0
312	37.4	0.0	37.4	72.7	2.2	1.5
312	37.4	0.0	37.4	105.9	4.2	2.8
312	37.4	0.0	37.4	137.2	6.2	4.1
312	37.4	0.0	37.4	166.6	8.0	5.3
312	37.4	0.0	37.4	194.4	9.7	6.5
312	37.4	0.0	37.4	220.5	11.3	7.5
312	37.4	0.0	37.4	245.1	12.8	8.6
312	37.4	0.0	37.4	268.3	14.3	9.5
312	37.4	0.0	37.4	290.1	15.6	10.4
312	37.4	0.0	37.4	310.6	16.9	11.3
312	37.4	0.0	37.4	330.0	18.1	12.1
312	37.4	0.0	37.4	348.2	19.2	12.8
312	37.4	0.0	37.4	365.4	20.3	13.5
312	37.4	0.0	37.4	381.5	21.3	14.2
312	37.4	0.0	37.4	396.7	22.2	14.8
312	37.4	0.0	37.4	411.1	23.1	15.4
312	37.4	0.0	37.4	424.6	23.9	16.0
312	37.4	0.0	37.4	437.3	24.7	16.5
312	37.4	0.0	37.4	449.3	25.5	17.0
312	37.4	0.0	37.4	460.5	26.2	17.4
312	37.4	0.0	37.4	471.2	26.8	17.9
312	37.4	0.0	37.4	481.2	27.4	18.3
312	37.4	0.0	37.4	490.6	28.0	18.7
312	37.4	0.0	37.4	499.5	28.6	19.0
312	37.4	0.0	37.4	507.8	29.1	19.4
312	37.4	0.0	37.4	515.7	29.6	19.7
312	37.4	0.0	37.4	523.1	30.0	20.0
312	37.4	0.0	37.4	530.1	30.5	20.3
312	37.4	0.0	37.4	536.6	30.9	20.6
312	37.4	0.0	37.4	542.8	31.3	20.8
312	37.4	0.0	37.4	548.7	31.6	21.1
312	37.4	0.0	37.4	554.1	32.0	21.3
312	37.4	0.0	37.4	559.3	32.3	21.5
312	37.4	0.0	37.4	564.2	32.6	21.7
312	37.4	0.0	37.4	568.8	32.9	21.9
312	37.4	0.0	37.4	573.1	33.1	22.1
312	37.4	0.0	37.4	577.1	33.4	22.2
312	37.4	0.0	37.4	581.0	33.6	22.4
312	37.4	0.0	37.4	584.6	33.8	22.6
312	37.4	0.0	37.4	588.0	34.0	22.7
312	37.4	0.0	37.4	591.2	34.2	22.8
312	37.4	0.0	37.4	594.2	34.4	23.0
312	37.4	0.0	37.4	597.0	34.6	23.1
312	37.4	0.0	37.4	599.7	34.8	23.2
312	37.4	0.0	37.4	602.2	34.9	23.3
312	37.4	0.0	37.4	604.6	35.1	23.4
312	37.4	0.0	37.4	606.8	35.2	23.5
312	37.4	0.0	37.4	608.9	35.3	23.6
312	37.4	0.0	37.4	610.9	35.5	23.6
312	37.4	0.0	37.4	612.8	35.6	23.7

Scenario 1

Sludges						
waste (t)	$DDOC_{m\ dep}$ (t)	$DDOC_{m\ decom}$ (t)	$DDOC_{m\ remain}$ (t)	$DDOC_{m\ accum\ T}$ (t)	$DDOC_{m\ decom\ T}$ (t)	$CH_{4\ generated}$ (t)
189	4.7	0.0	4.7	4.7	0.0	0.0
189	4.7	0.0	4.7	8.7	0.8	0.5
189	4.7	0.0	4.7	11.9	1.5	1.0
189	4.7	0.0	4.7	14.6	2.0	1.3
189	4.7	0.0	4.7	16.9	2.5	1.6
189	4.7	0.0	4.7	18.8	2.9	1.9
189	4.7	0.0	4.7	20.3	3.2	2.1
189	4.7	0.0	4.7	21.6	3.4	2.3
189	4.7	0.0	4.7	22.7	3.6	2.4
189	4.7	0.0	4.7	23.6	3.8	2.6
189	4.7	0.0	4.7	24.3	4.0	2.7
189	4.7	0.0	4.7	24.9	4.1	2.7
189	4.7	0.0	4.7	25.5	4.2	2.8
189	4.7	0.0	4.7	25.9	4.3	2.9
189	4.7	0.0	4.7	26.2	4.4	2.9
189	4.7	0.0	4.7	26.5	4.4	3.0
189	4.7	0.0	4.7	26.8	4.5	3.0
189	4.7	0.0	4.7	27.0	4.5	3.0
189	4.7	0.0	4.7	27.1	4.6	3.0
189	4.7	0.0	4.7	27.3	4.6	3.1
189	4.7	0.0	4.7	27.4	4.6	3.1
189	4.7	0.0	4.7	27.5	4.6	3.1
189	4.7	0.0	4.7	27.6	4.6	3.1
189	4.7	0.0	4.7	27.6	4.7	3.1
189	4.7	0.0	4.7	27.7	4.7	3.1
189	4.7	0.0	4.7	27.7	4.7	3.1
189	4.7	0.0	4.7	27.8	4.7	3.1
189	4.7	0.0	4.7	27.8	4.7	3.1
189	4.7	0.0	4.7	27.8	4.7	3.1
189	4.7	0.0	4.7	27.9	4.7	3.1
189	4.7	0.0	4.7	27.9	4.7	3.1
189	4.7	0.0	4.7	27.9	4.7	3.1
189	4.7	0.0	4.7	27.9	4.7	3.1
189	4.7	0.0	4.7	27.9	4.7	3.1
189	4.7	0.0	4.7	27.9	4.7	3.1
189	4.7	0.0	4.7	27.9	4.7	3.1
189	4.7	0.0	4.7	27.9	4.7	3.1
189	4.7	0.0	4.7	28.0	4.7	3.1
189	4.7	0.0	4.7	28.0	4.7	3.1
189	4.7	0.0	4.7	28.0	4.7	3.1
189	4.7	0.0	4.7	28.0	4.7	3.1
189	4.7	0.0	4.7	28.0	4.7	3.1
189	4.7	0.0	4.7	28.0	4.7	3.1
189	4.7	0.0	4.7	28.0	4.7	3.1
189	4.7	0.0	4.7	28.0	4.7	3.1
189	4.7	0.0	4.7	28.0	4.7	3.1
189	4.7	0.0	4.7	28.0	4.7	3.1
189	4.7	0.0	4.7	28.0	4.7	3.1
189	4.7	0.0	4.7	28.0	4.7	3.1
189	4.7	0.0	4.7	28.0	4.7	3.1
189	4.7	0.0	4.7	28.0	4.7	3.1

Scenario 1

Nappies						
waste (t)	$DDOC_{m\ dep}$ (t)	$DDOC_{m\ decom}$ (t)	$DDOC_{m\ remain}$ (t)	$DDOC_{m\ accum\ T}$ (t)	$DDOC_{m\ decom\ T}$ (t)	$CH_{4\ generated}$ (t)
279	33.5	0.0	33.5	33.5	0.0	0.0
279	33.5	0.0	33.5	65.0	1.9	1.3
279	33.5	0.0	33.5	94.7	3.8	2.5
279	33.5	0.0	33.5	122.7	5.5	3.7
279	33.5	0.0	33.5	149.0	7.1	4.8
279	33.5	0.0	33.5	173.8	8.7	5.8
279	33.5	0.0	33.5	197.2	10.1	6.7
279	33.5	0.0	33.5	219.2	11.5	7.7
279	33.5	0.0	33.5	239.9	12.8	8.5
279	33.5	0.0	33.5	259.4	14.0	9.3
279	33.5	0.0	33.5	277.8	15.1	10.1
279	33.5	0.0	33.5	295.1	16.2	10.8
279	33.5	0.0	33.5	311.4	17.2	11.5
279	33.5	0.0	33.5	326.7	18.1	12.1
279	33.5	0.0	33.5	341.2	19.0	12.7
279	33.5	0.0	33.5	354.8	19.9	13.2
279	33.5	0.0	33.5	367.6	20.7	13.8
279	33.5	0.0	33.5	379.7	21.4	14.3
279	33.5	0.0	33.5	391.0	22.1	14.7
279	33.5	0.0	33.5	401.7	22.8	15.2
279	33.5	0.0	33.5	411.8	23.4	15.6
279	33.5	0.0	33.5	421.3	24.0	16.0
279	33.5	0.0	33.5	430.3	24.5	16.4
279	33.5	0.0	33.5	438.7	25.1	16.7
279	33.5	0.0	33.5	446.6	25.5	17.0
279	33.5	0.0	33.5	454.1	26.0	17.3
279	33.5	0.0	33.5	461.1	26.4	17.6
279	33.5	0.0	33.5	467.8	26.9	17.9
279	33.5	0.0	33.5	474.0	27.2	18.2
279	33.5	0.0	33.5	479.9	27.6	18.4
279	33.5	0.0	33.5	485.4	27.9	18.6
279	33.5	0.0	33.5	490.6	28.3	18.8
279	33.5	0.0	33.5	495.5	28.6	19.0
279	33.5	0.0	33.5	500.2	28.9	19.2
279	33.5	0.0	33.5	504.5	29.1	19.4
279	33.5	0.0	33.5	508.6	29.4	19.6
279	33.5	0.0	33.5	512.5	29.6	19.7
279	33.5	0.0	33.5	516.1	29.8	19.9
279	33.5	0.0	33.5	519.5	30.1	20.0
279	33.5	0.0	33.5	522.8	30.3	20.2
279	33.5	0.0	33.5	525.8	30.4	20.3
279	33.5	0.0	33.5	528.7	30.6	20.4
279	33.5	0.0	33.5	531.3	30.8	20.5
279	33.5	0.0	33.5	533.9	30.9	20.6
279	33.5	0.0	33.5	536.3	31.1	20.7
279	33.5	0.0	33.5	538.5	31.2	20.8
279	33.5	0.0	33.5	540.6	31.4	20.9
279	33.5	0.0	33.5	542.6	31.5	21.0
279	33.5	0.0	33.5	544.5	31.6	21.1
279	33.5	0.0	33.5	546.3	31.7	21.1
279	33.5	0.0	33.5	548.0	31.8	21.2

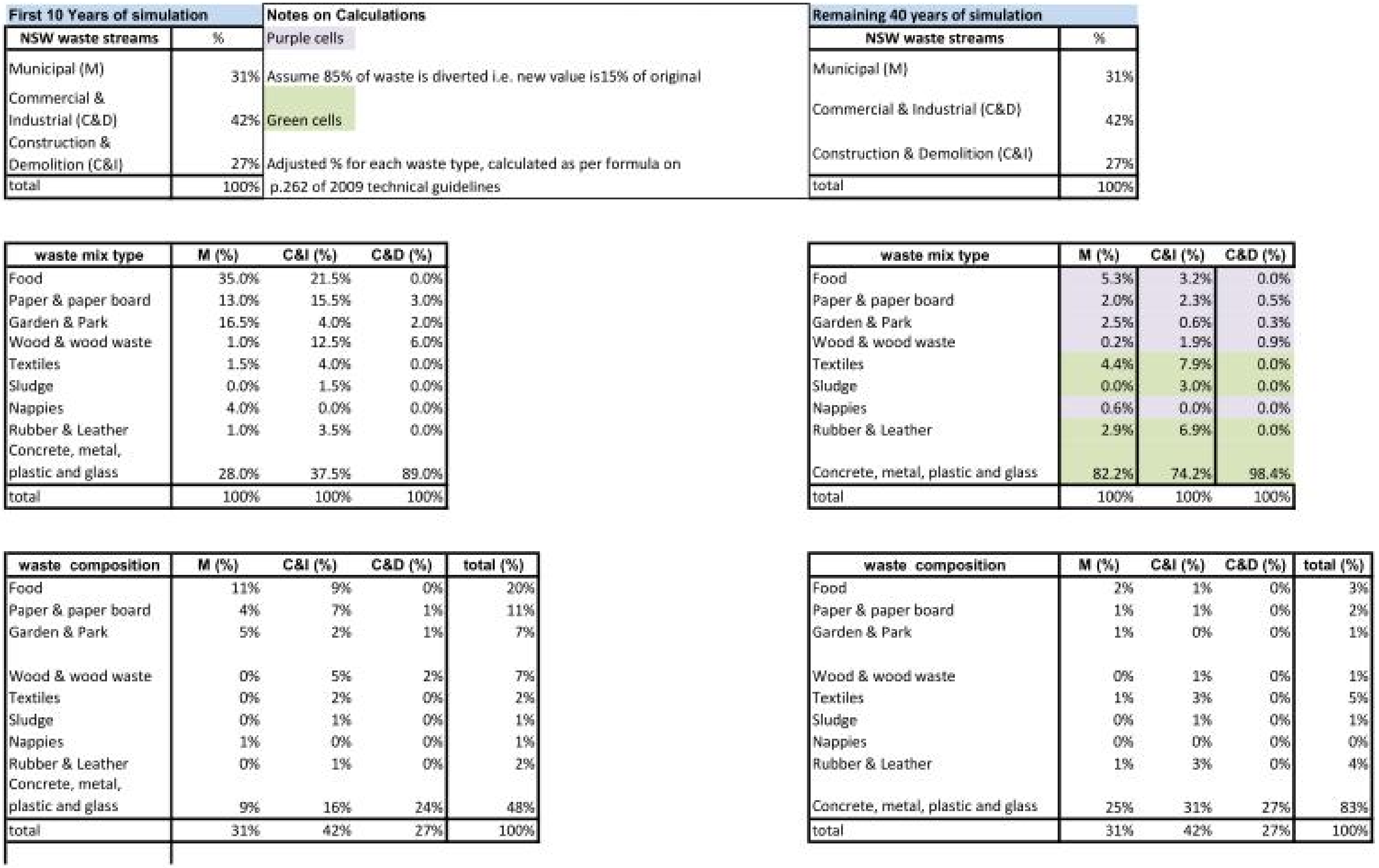
Scenario 1

Rubber						
waste (kt)	$DDOC_{m\ dep}$ (t)	$DDOC_{m\ decom}$ (t)	$DDOC_{m\ remain}$ (t)	$DDOC_{m\ accum\ T}$ (t)	$DDOC_{m\ decom\ T}$ (t)	$CH_{4\ generated}$ (t)
63	12.3	0.0	12.3	12.3	0.0	0.0
63	12.3	0.0	12.3	23.9	0.7	0.5
63	12.3	0.0	12.3	34.8	1.4	0.9
63	12.3	0.0	12.3	45.0	2.0	1.3
63	12.3	0.0	12.3	54.7	2.6	1.7
63	12.3	0.0	12.3	63.8	3.2	2.1
63	12.3	0.0	12.3	72.3	3.7	2.5
63	12.3	0.0	12.3	80.4	4.2	2.8
63	12.3	0.0	12.3	88.0	4.7	3.1
63	12.3	0.0	12.3	95.2	5.1	3.4
63	12.3	0.0	12.3	101.9	5.5	3.7
63	12.3	0.0	12.3	108.3	5.9	4.0
63	12.3	0.0	12.3	114.3	6.3	4.2
63	12.3	0.0	12.3	119.9	6.7	4.4
63	12.3	0.0	12.3	125.2	7.0	4.7
63	12.3	0.0	12.3	130.2	7.3	4.9
63	12.3	0.0	12.3	134.9	7.6	5.1
63	12.3	0.0	12.3	139.3	7.9	5.2
63	12.3	0.0	12.3	143.5	8.1	5.4
63	12.3	0.0	12.3	147.4	8.4	5.6
63	12.3	0.0	12.3	151.1	8.6	5.7
63	12.3	0.0	12.3	154.6	8.8	5.9
63	12.3	0.0	12.3	157.9	9.0	6.0
63	12.3	0.0	12.3	161.0	9.2	6.1
63	12.3	0.0	12.3	163.9	9.4	6.2
63	12.3	0.0	12.3	166.6	9.5	6.4
63	12.3	0.0	12.3	169.2	9.7	6.5
63	12.3	0.0	12.3	171.6	9.9	6.6
63	12.3	0.0	12.3	173.9	10.0	6.7
63	12.3	0.0	12.3	176.1	10.1	6.8
63	12.3	0.0	12.3	178.1	10.3	6.8
63	12.3	0.0	12.3	180.0	10.4	6.9
63	12.3	0.0	12.3	181.8	10.5	7.0
63	12.3	0.0	12.3	183.5	10.6	7.1
63	12.3	0.0	12.3	185.1	10.7	7.1
63	12.3	0.0	12.3	186.6	10.8	7.2
63	12.3	0.0	12.3	188.0	10.9	7.2
63	12.3	0.0	12.3	189.4	11.0	7.3
63	12.3	0.0	12.3	190.6	11.0	7.4
63	12.3	0.0	12.3	191.8	11.1	7.4
63	12.3	0.0	12.3	192.9	11.2	7.4
63	12.3	0.0	12.3	194.0	11.2	7.5
63	12.3	0.0	12.3	195.0	11.3	7.5
63	12.3	0.0	12.3	195.9	11.4	7.6
63	12.3	0.0	12.3	196.8	11.4	7.6
63	12.3	0.0	12.3	197.6	11.5	7.6
63	12.3	0.0	12.3	198.4	11.5	7.7
63	12.3	0.0	12.3	199.1	11.6	7.7
63	12.3	0.0	12.3	199.8	11.6	7.7
63	12.3	0.0	12.3	200.5	11.6	7.8
63	12.3	0.0	12.3	201.1	11.7	7.8

Scenario 1

Total CH_4 Generated (t)	**Methan recovered**			CH_4* (t)	E_j	Ej (t CO_2-e)
	Q_{cap} (m^3)	Q_{flared} (m^3)	Q_{tr} (m^3)			
0.0	0	0	0	0.0	0.0	0.0
64.1	0	0	0	64.1	57.7	1211.5
122.9	0	0	0	122.9	110.6	2322.9
177.0	0	0	0	177.0	159.3	3344.9
226.8	0	0	0	226.8	204.2	4287.3
272.9	0	0	0	272.9	245.6	5158.1
315.6	0	0	0	315.6	284.0	5964.6
355.2	0	0	0	355.2	319.7	6712.9
392.0	0	0	0	392.0	352.8	7408.5
426.3	0	0	0	426.3	383.6	8056.2
458.2	0	0	0	458.2	412.4	8660.3
488.1	0	0	0	488.1	439.3	9224.4
516.0	0	0	0	516.0	464.4	9751.9
542.1	0	0	0	542.1	487.9	10245.8
566.6	0	0	0	566.6	509.9	10708.7
589.6	0	0	0	589.6	530.6	11142.9
611.1	0	0	0	611.1	550.0	11550.7
631.4	0	0	0	631.4	568.3	11933.9
650.5	0	0	0	650.5	585.4	12294.3
668.4	0	0	0	668.4	601.6	12633.5
685.3	0	0	0	685.3	616.8	12953.0
701.3	0	0	0	701.3	631.1	13254.1
716.3	0	0	0	716.3	644.7	13538.0
730.5	0	0	0	730.5	657.4	13805.8
743.8	0	0	0	743.8	669.5	14058.5
756.5	0	0	0	756.5	680.8	14297.2
768.4	0	0	0	768.4	691.6	14522.6
779.7	0	0	0	779.7	701.7	14735.7
790.3	0	0	0	790.3	711.3	14937.1
800.4	0	0	0	800.4	720.4	15127.6
809.9	0	0	0	809.9	728.9	15307.9
819.0	0	0	0	819.0	737.1	15478.4
827.5	0	0	0	827.5	744.8	15639.9
835.6	0	0	0	835.6	752.0	15792.8
843.3	0	0	0	843.3	758.9	15937.6
850.5	0	0	0	850.5	765.5	16074.8
857.4	0	0	0	857.4	771.7	16204.9
863.9	0	0	0	863.9	777.5	16328.2
870.1	0	0	0	870.1	783.1	16445.1
876.0	0	0	0	876.0	788.4	16556.0
881.5	0	0	0	881.5	793.4	16661.2
886.8	0	0	0	886.8	798.1	16761.1
891.8	0	0	0	891.8	802.7	16855.8
896.6	0	0	0	896.6	806.9	16945.8
901.1	0	0	0	901.1	811.0	17031.3
905.4	0	0	0	905.4	814.9	17112.5
909.5	0	0	0	909.5	818.6	17189.6
913.4	0	0	0	913.4	822.0	17262.9
917.1	0	0	0	917.1	825.4	17332.6
920.6	0	0	0	920.6	828.5	17398.8
923.9	0	0	0	923.9	831.5	17461.9
						641,622 Total

Scenario 2



First 10 Years of simulation

NSW waste streams	%	Notes on Calculations
		Purple cells
Municipal (M)	31%	Assume 85% of waste is diverted i.e. new value is15% of original
Commercial & Industrial (C&D)	42%	Green cells
Construction & Demolition (C&I)	27%	Adjusted % for each waste type, calculated as per formula on
total	100%	p.262 of 2009 technical guidelines

waste mix type	M (%)	C&I (%)	C&D (%)
Food	35.0%	21.5%	0.0%
Paper & paper board	13.0%	15.5%	3.0%
Garden & Park	16.5%	4.0%	2.0%
Wood & wood waste	1.0%	12.5%	6.0%
Textiles	1.5%	4.0%	0.0%
Sludge	0.0%	1.5%	0.0%
Nappies	4.0%	0.0%	0.0%
Rubber & Leather	1.0%	3.5%	0.0%
Concrete, metal, plastic and glass	28.0%	37.5%	89.0%
total	100%	100%	100%

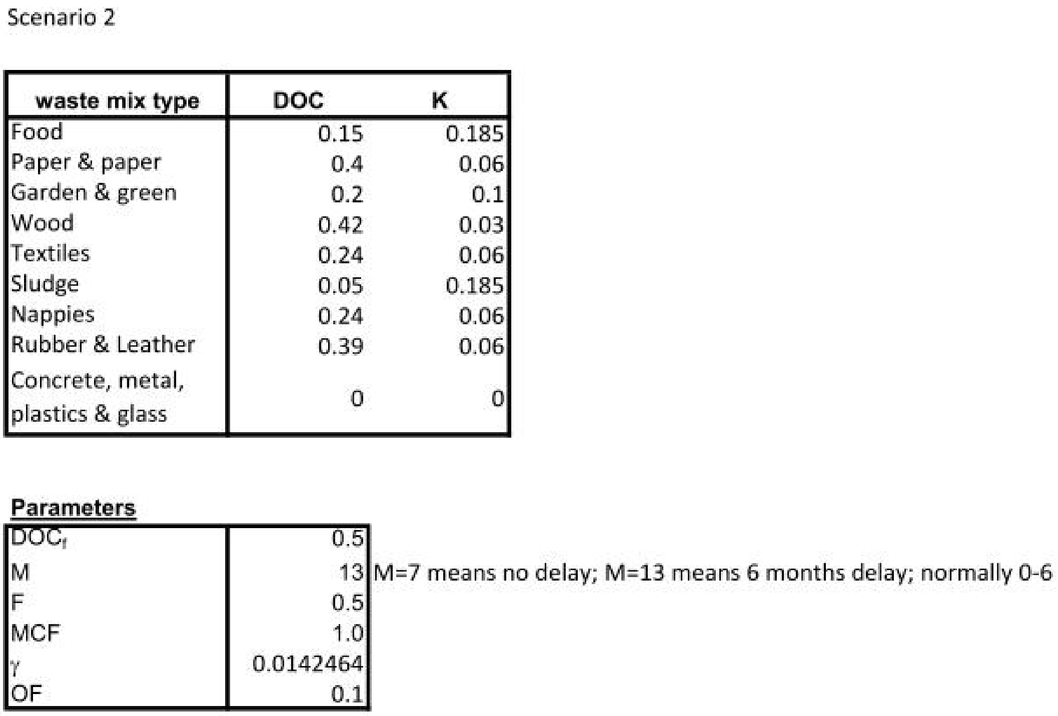
waste composition	M (%)	C&I (%)	C&D (%)	total (%)
Food	11%	9%	0%	20%
Paper & paper board	4%	7%	1%	11%
Garden & Park	5%	2%	1%	7%
Wood & wood waste	0%	5%	2%	7%
Textiles	0%	2%	0%	2%
Sludge	0%	1%	0%	1%
Nappies	1%	0%	0%	1%
Rubber & Leather	0%	1%	0%	2%
Concrete, metal, plastic and glass	9%	16%	24%	48%
total	31%	42%	27%	100%

Remaining 40 years of simulation

NSW waste streams	%
Municipal (M)	31%
Commercial & Industrial (C&D)	42%
Construction & Demolition (C&I)	27%
total	100%

waste mix type	M (%)	C&I (%)	C&D (%)
Food	5.3%	3.2%	0.0%
Paper & paper board	2.0%	2.3%	0.5%
Garden & Park	2.5%	0.6%	0.3%
Wood & wood waste	0.2%	1.9%	0.9%
Textiles	4.4%	7.9%	0.0%
Sludge	0.0%	3.0%	0.0%
Nappies	0.6%	0.0%	0.0%
Rubber & Leather	2.9%	6.9%	0.0%
Concrete, metal, plastic and glass	82.2%	74.2%	98.4%
total	100%	100%	100%

waste composition	M (%)	C&I (%)	C&D (%)	total (%)
Food	2%	1%	0%	3%
Paper & paper board	1%	1%	0%	2%
Garden & Park	1%	0%	0%	1%
Wood & wood waste	0%	1%	0%	1%
Textiles	1%	3%	0%	5%
Sludge	0%	1%	0%	1%
Nappies	0%	0%	0%	0%
Rubber & Leather	1%	3%	0%	4%
Concrete, metal, plastic and glass	25%	31%	27%	83%
total	31%	42%	27%	100%



Scenario 2

waste mix type	DOC	K
Food	0.15	0.185
Paper & paper	0.4	0.06
Garden & green	0.2	0.1
Wood	0.42	0.03
Textiles	0.24	0.06
Sludge	0.05	0.185
Nappies	0.24	0.06
Rubber & Leather	0.39	0.06
Concrete, metal, plastics & glass	0	0

Parameters

DOC_f	0.5	
M	13	M=7 means no delay; M=13 means 6 months delay; normally 0-6
F	0.5	
MCF	1.0	
γ	0.0142464	
OF	0.1	

Scenario 2

	Food						
Year	waste (t)	$DDOC_{m\ dep}$ (t)	$DDOC_{m\ decom}$ (t)	$DDOC_{m\ remain}$ (t)	$DDOC_{m\ accum\ T}$ (t)	$DDOC_{m\ decom\ T}$ (t)	$CH_{4\ generated}$ (t)
1	2,982	223.7	0.0	223.7	223.7	0.0	0.0
2	2,982	223.7	0.0	223.7	409.5	37.8	25.2
3	2,982	223.7	0.0	223.7	564.0	69.2	46.1
4	2,982	223.7	0.0	223.7	692.4	95.3	63.5
5	2,982	223.7	0.0	223.7	799.1	116.9	78.0
6	2,982	223.7	0.0	223.7	887.8	135.0	90.0
7	2,982	223.7	0.0	223.7	961.5	149.9	100.0
8	2,982	223.7	0.0	223.7	1,022.8	162.4	108.3
9	2,982	223.7	0.0	223.7	1,073.7	172.7	115.2
10	2,982	223.7	0.0	223.7	1,116.0	181.3	120.9
11	447	33.5	0.0	33.5	961.0	188.5	125.7
12	447	33.5	0.0	33.5	832.3	162.3	108.2
13	447	33.5	0.0	33.5	725.3	140.6	93.7
14	447	33.5	0.0	33.5	636.3	122.5	81.7
15	447	33.5	0.0	33.5	562.4	107.5	71.6
16	447	33.5	0.0	33.5	500.9	95.0	63.3
17	447	33.5	0.0	33.5	449.9	84.6	56.4
18	447	33.5	0.0	33.5	407.5	76.0	50.7
19	447	33.5	0.0	33.5	372.2	68.8	45.9
20	447	33.5	0.0	33.5	342.9	62.9	41.9
21	447	33.5	0.0	33.5	318.5	57.9	38.6
22	447	33.5	0.0	33.5	298.3	53.8	35.9
23	447	33.5	0.0	33.5	281.4	50.4	33.6
24	447	33.5	0.0	33.5	267.4	47.5	31.7
25	447	33.5	0.0	33.5	255.8	45.2	30.1
26	447	33.5	0.0	33.5	246.2	43.2	28.8
27	447	33.5	0.0	33.5	238.1	41.6	27.7
28	447	33.5	0.0	33.5	231.5	40.2	26.8
29	447	33.5	0.0	33.5	225.9	39.1	26.1
30	447	33.5	0.0	33.5	221.3	38.2	25.4
31	447	33.5	0.0	33.5	217.5	37.4	24.9
32	447	33.5	0.0	33.5	214.3	36.7	24.5
33	447	33.5	0.0	33.5	211.6	36.2	24.1
34	447	33.5	0.0	33.5	209.4	35.7	23.8
35	447	33.5	0.0	33.5	207.6	35.4	23.6
36	447	33.5	0.0	33.5	206.1	35.1	23.4
37	447	33.5	0.0	33.5	204.8	34.8	23.2
38	447	33.5	0.0	33.5	203.8	34.6	23.1
39	447	33.5	0.0	33.5	202.9	34.4	22.9
40	447	33.5	0.0	33.5	202.2	34.3	22.8
41	447	33.5	0.0	33.5	201.6	34.1	22.8
42	447	33.5	0.0	33.5	201.1	34.0	22.7
43	447	33.5	0.0	33.5	200.7	34.0	22.6
44	447	33.5	0.0	33.5	200.3	33.9	22.6
45	447	33.5	0.0	33.5	200.0	33.8	22.6
46	447	33.5	0.0	33.5	199.8	33.8	22.5
47	447	33.5	0.0	33.5	199.6	33.7	22.5
48	447	33.5	0.0	33.5	199.4	33.7	22.5
49	447	33.5	0.0	33.5	199.3	33.7	22.5
50	447	33.5	0.0	33.5	199.2	33.7	22.4
51	447	33.5	0.0	33.5	199.1	33.6	22.4

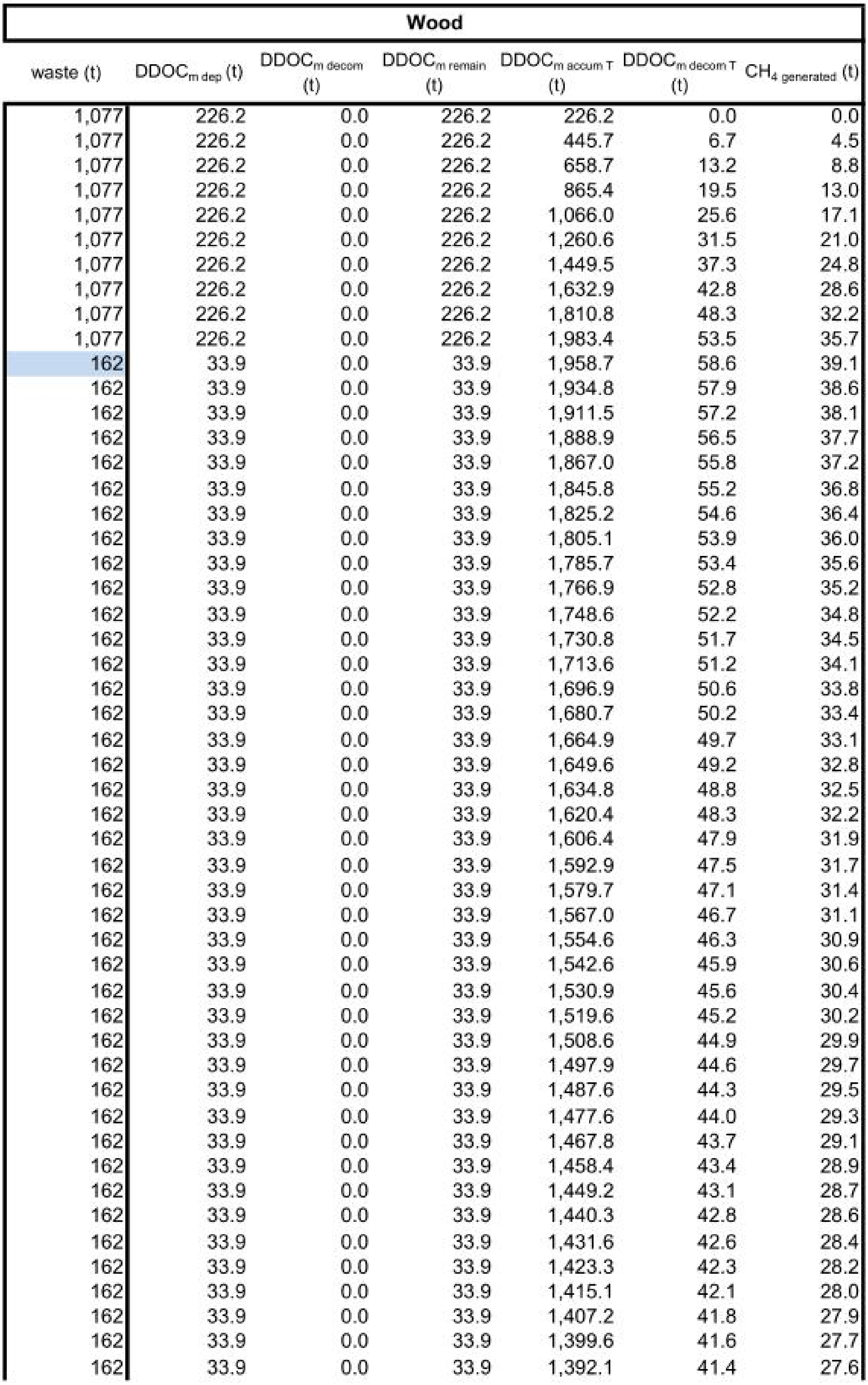
Scenario 2

Paper & Paper Board						
waste (t)	$DDOC_{m\ dep}$ (t)	$DDOC_{m\ decom}$ (t)	$DDOC_{m\ remain}$ (t)	$DDOC_{m\ accum\ T}$ (t)	$DDOC_{m\ decom\ T}$ (t)	$CH_{4\ generated}$ (t)
1,703	340.5	0.0	340.5	340.5	0.0	0.0
1,703	340.5	0.0	340.5	661.2	19.8	13.2
1,703	340.5	0.0	340.5	963.2	38.5	25.7
1,703	340.5	0.0	340.5	1,247.6	56.1	37.4
1,703	340.5	0.0	340.5	1,515.4	72.7	48.4
1,703	340.5	0.0	340.5	1,767.7	88.3	58.8
1,703	340.5	0.0	340.5	2,005.2	102.9	68.6
1,703	340.5	0.0	340.5	2,229.0	116.8	77.9
1,703	340.5	0.0	340.5	2,439.7	129.8	86.5
1,703	340.5	0.0	340.5	2,638.1	142.1	94.7
255	51.1	0.0	51.1	2,535.5	153.6	102.4
255	51.1	0.0	51.1	2,438.9	147.7	98.4
255	51.1	0.0	51.1	2,348.0	142.0	94.7
255	51.1	0.0	51.1	2,262.3	136.7	91.2
255	51.1	0.0	51.1	2,181.6	131.7	87.8
255	51.1	0.0	51.1	2,105.7	127.0	84.7
255	51.1	0.0	51.1	2,034.1	122.6	81.7
255	51.1	0.0	51.1	1,966.7	118.5	79.0
255	51.1	0.0	51.1	1,903.3	114.5	76.4
255	51.1	0.0	51.1	1,843.5	110.8	73.9
255	51.1	0.0	51.1	1,787.2	107.4	71.6
255	51.1	0.0	51.1	1,734.2	104.1	69.4
255	51.1	0.0	51.1	1,684.3	101.0	67.3
255	51.1	0.0	51.1	1,637.3	98.1	65.4
255	51.1	0.0	51.1	1,593.0	95.3	63.6
255	51.1	0.0	51.1	1,551.3	92.8	61.8
255	51.1	0.0	51.1	1,512.1	90.3	60.2
255	51.1	0.0	51.1	1,475.1	88.1	58.7
255	51.1	0.0	51.1	1,440.3	85.9	57.3
255	51.1	0.0	51.1	1,407.5	83.9	55.9
255	51.1	0.0	51.1	1,376.6	82.0	54.6
255	51.1	0.0	51.1	1,347.5	80.2	53.4
255	51.1	0.0	51.1	1,320.1	78.5	52.3
255	51.1	0.0	51.1	1,294.3	76.9	51.3
255	51.1	0.0	51.1	1,270.0	75.4	50.2
255	51.1	0.0	51.1	1,247.1	74.0	49.3
255	51.1	0.0	51.1	1,225.5	72.6	48.4
255	51.1	0.0	51.1	1,205.3	71.4	47.6
255	51.1	0.0	51.1	1,186.1	70.2	46.8
255	51.1	0.0	51.1	1,168.1	69.1	46.1
255	51.1	0.0	51.1	1,151.2	68.0	45.4
255	51.1	0.0	51.1	1,135.2	67.0	44.7
255	51.1	0.0	51.1	1,120.2	66.1	44.1
255	51.1	0.0	51.1	1,106.0	65.2	43.5
255	51.1	0.0	51.1	1,092.7	64.4	42.9
255	51.1	0.0	51.1	1,080.1	63.6	42.4
255	51.1	0.0	51.1	1,068.3	62.9	41.9
255	51.1	0.0	51.1	1,057.2	62.2	41.5
255	51.1	0.0	51.1	1,046.7	61.6	41.0
255	51.1	0.0	51.1	1,036.8	61.0	40.6
255	51.1	0.0	51.1	1,027.5	60.4	40.3

Scenario 2

Garden & Green						
waste (t)	$DDOC_{m\ dep}$ (t)	$DDOC_{m\ decom}$ (t)	$DDOC_{m\ remain}$ (t)	$DDOC_{m\ accum\ T}$ (t)	$DDOC_{m\ decom\ T}$ (t)	$CH_{4\ generated}$ (t)
1,100	110.0	0.0	110.0	110.0	0.0	0.0
1,100	110.0	0.0	110.0	209.6	10.5	7.0
1,100	110.0	0.0	110.0	299.7	19.9	13.3
1,100	110.0	0.0	110.0	381.2	28.5	19.0
1,100	110.0	0.0	110.0	454.9	36.3	24.2
1,100	110.0	0.0	110.0	521.7	43.3	28.9
1,100	110.0	0.0	110.0	582.0	49.6	33.1
1,100	110.0	0.0	110.0	636.7	55.4	36.9
1,100	110.0	0.0	110.0	686.1	60.6	40.4
1,100	110.0	0.0	110.0	730.8	65.3	43.5
165	16.5	0.0	16.5	677.8	69.5	46.4
165	16.5	0.0	16.5	629.8	64.5	43.0
165	16.5	0.0	16.5	586.4	59.9	40.0
165	16.5	0.0	16.5	547.1	55.8	37.2
165	16.5	0.0	16.5	511.5	52.1	34.7
165	16.5	0.0	16.5	479.3	48.7	32.5
165	16.5	0.0	16.5	450.2	45.6	30.4
165	16.5	0.0	16.5	423.9	42.8	28.6
165	16.5	0.0	16.5	400.1	40.3	26.9
165	16.5	0.0	16.5	378.5	38.1	25.4
165	16.5	0.0	16.5	359.0	36.0	24.0
165	16.5	0.0	16.5	341.3	34.2	22.8
165	16.5	0.0	16.5	325.3	32.5	21.7
165	16.5	0.0	16.5	310.9	31.0	20.6
165	16.5	0.0	16.5	297.8	29.6	19.7
165	16.5	0.0	16.5	286.0	28.3	18.9
165	16.5	0.0	16.5	275.3	27.2	18.1
165	16.5	0.0	16.5	265.6	26.2	17.5
165	16.5	0.0	16.5	256.8	25.3	16.8
165	16.5	0.0	16.5	248.9	24.4	16.3
165	16.5	0.0	16.5	241.7	23.7	15.8
165	16.5	0.0	16.5	235.2	23.0	15.3
165	16.5	0.0	16.5	229.3	22.4	14.9
165	16.5	0.0	16.5	224.0	21.8	14.5
165	16.5	0.0	16.5	219.2	21.3	14.2
165	16.5	0.0	16.5	214.8	20.9	13.9
165	16.5	0.0	16.5	210.9	20.4	13.6
165	16.5	0.0	16.5	207.3	20.1	13.4
165	16.5	0.0	16.5	204.1	19.7	13.2
165	16.5	0.0	16.5	201.2	19.4	12.9
165	16.5	0.0	16.5	198.5	19.1	12.8
165	16.5	0.0	16.5	196.1	18.9	12.6
165	16.5	0.0	16.5	194.0	18.7	12.4
165	16.5	0.0	16.5	192.0	18.5	12.3
165	16.5	0.0	16.5	190.3	18.3	12.2
165	16.5	0.0	16.5	188.7	18.1	12.1
165	16.5	0.0	16.5	187.2	18.0	12.0
165	16.5	0.0	16.5	185.9	17.8	11.9
165	16.5	0.0	16.5	184.7	17.7	11.8
165	16.5	0.0	16.5	183.6	17.6	11.7
165	16.5	0.0	16.5	182.7	17.5	11.7

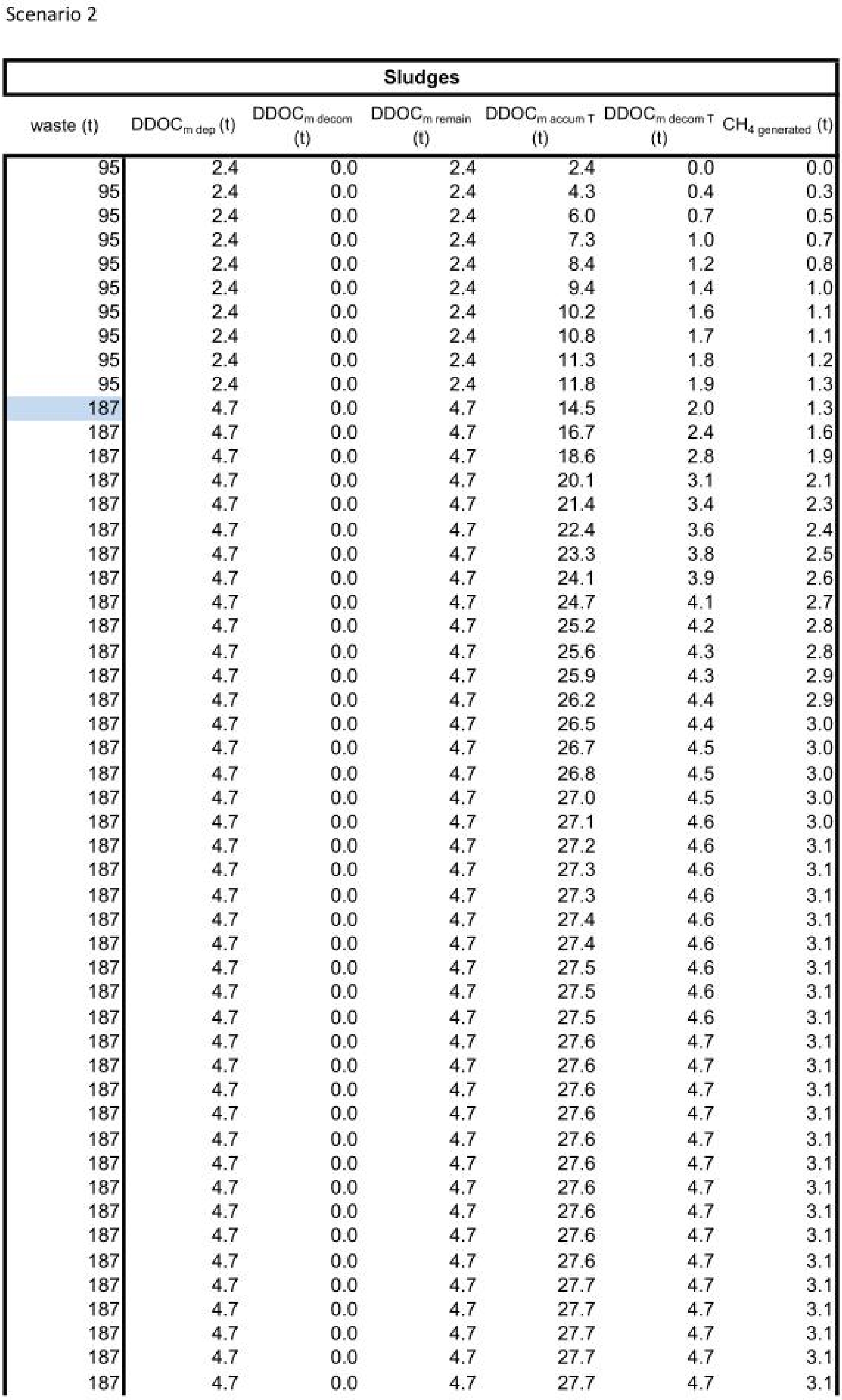
Scenario 2



Wood						
waste (t)	$DDOC_{m\ dep}$ (t)	$DDOC_{m\ decom}$ (t)	$DDOC_{m\ remain}$ (t)	$DDOC_{m\ accum\ T}$ (t)	$DDOC_{m\ decom\ T}$ (t)	$CH_{4\ generated}$ (t)
1,077	226.2	0.0	226.2	226.2	0.0	0.0
1,077	226.2	0.0	226.2	445.7	6.7	4.5
1,077	226.2	0.0	226.2	658.7	13.2	8.8
1,077	226.2	0.0	226.2	865.4	19.5	13.0
1,077	226.2	0.0	226.2	1,066.0	25.6	17.1
1,077	226.2	0.0	226.2	1,260.6	31.5	21.0
1,077	226.2	0.0	226.2	1,449.5	37.3	24.8
1,077	226.2	0.0	226.2	1,632.9	42.8	28.6
1,077	226.2	0.0	226.2	1,810.8	48.3	32.2
1,077	226.2	0.0	226.2	1,983.4	53.5	35.7
162	33.9	0.0	33.9	1,958.7	58.6	39.1
162	33.9	0.0	33.9	1,934.8	57.9	38.6
162	33.9	0.0	33.9	1,911.5	57.2	38.1
162	33.9	0.0	33.9	1,888.9	56.5	37.7
162	33.9	0.0	33.9	1,867.0	55.8	37.2
162	33.9	0.0	33.9	1,845.8	55.2	36.8
162	33.9	0.0	33.9	1,825.2	54.6	36.4
162	33.9	0.0	33.9	1,805.1	53.9	36.0
162	33.9	0.0	33.9	1,785.7	53.4	35.6
162	33.9	0.0	33.9	1,766.9	52.8	35.2
162	33.9	0.0	33.9	1,748.6	52.2	34.8
162	33.9	0.0	33.9	1,730.8	51.7	34.5
162	33.9	0.0	33.9	1,713.6	51.2	34.1
162	33.9	0.0	33.9	1,696.9	50.6	33.8
162	33.9	0.0	33.9	1,680.7	50.2	33.4
162	33.9	0.0	33.9	1,664.9	49.7	33.1
162	33.9	0.0	33.9	1,649.6	49.2	32.8
162	33.9	0.0	33.9	1,634.8	48.8	32.5
162	33.9	0.0	33.9	1,620.4	48.3	32.2
162	33.9	0.0	33.9	1,606.4	47.9	31.9
162	33.9	0.0	33.9	1,592.9	47.5	31.7
162	33.9	0.0	33.9	1,579.7	47.1	31.4
162	33.9	0.0	33.9	1,567.0	46.7	31.1
162	33.9	0.0	33.9	1,554.6	46.3	30.9
162	33.9	0.0	33.9	1,542.6	45.9	30.6
162	33.9	0.0	33.9	1,530.9	45.6	30.4
162	33.9	0.0	33.9	1,519.6	45.2	30.2
162	33.9	0.0	33.9	1,508.6	44.9	29.9
162	33.9	0.0	33.9	1,497.9	44.6	29.7
162	33.9	0.0	33.9	1,487.6	44.3	29.5
162	33.9	0.0	33.9	1,477.6	44.0	29.3
162	33.9	0.0	33.9	1,467.8	43.7	29.1
162	33.9	0.0	33.9	1,458.4	43.4	28.9
162	33.9	0.0	33.9	1,449.2	43.1	28.7
162	33.9	0.0	33.9	1,440.3	42.8	28.6
162	33.9	0.0	33.9	1,431.6	42.6	28.4
162	33.9	0.0	33.9	1,423.3	42.3	28.2
162	33.9	0.0	33.9	1,415.1	42.1	28.0
162	33.9	0.0	33.9	1,407.2	41.8	27.9
162	33.9	0.0	33.9	1,399.6	41.6	27.7
162	33.9	0.0	33.9	1,392.1	41.4	27.6

Scenario 2

Textiles						
waste (t)	$DDOC_{m\ dep}$ (t)	$DDOC_{m\ decom}$ (t)	$DDOC_{m\ remain}$ (t)	$DDOC_{m\ accum\ T}$ (t)	$DDOC_{m\ decom\ T}$ (t)	$CH_{4\ generated}$ (t)
322	38.6	0.0	38.6	38.6	0.0	0.0
322	38.6	0.0	38.6	75.0	2.2	1.5
322	38.6	0.0	38.6	109.2	4.4	2.9
322	38.6	0.0	38.6	141.5	6.4	4.2
322	38.6	0.0	38.6	171.8	8.2	5.5
322	38.6	0.0	38.6	200.4	10.0	6.7
322	38.6	0.0	38.6	227.4	11.7	7.8
322	38.6	0.0	38.6	252.7	13.2	8.8
322	38.6	0.0	38.6	276.6	14.7	9.8
322	38.6	0.0	38.6	299.1	16.1	10.7
703	84.4	0.0	84.4	366.1	17.4	11.6
703	84.4	0.0	84.4	429.2	21.3	14.2
703	84.4	0.0	84.4	488.6	25.0	16.7
703	84.4	0.0	84.4	544.5	28.5	19.0
703	84.4	0.0	84.4	597.2	31.7	21.1
703	84.4	0.0	84.4	646.8	34.8	23.2
703	84.4	0.0	84.4	693.6	37.7	25.1
703	84.4	0.0	84.4	737.6	40.4	26.9
703	84.4	0.0	84.4	779.0	43.0	28.6
703	84.4	0.0	84.4	818.0	45.4	30.2
703	84.4	0.0	84.4	854.8	47.6	31.8
703	84.4	0.0	84.4	889.4	49.8	33.2
703	84.4	0.0	84.4	922.0	51.8	34.5
703	84.4	0.0	84.4	952.7	53.7	35.8
703	84.4	0.0	84.4	981.6	55.5	37.0
703	84.4	0.0	84.4	1,008.9	57.2	38.1
703	84.4	0.0	84.4	1,034.5	58.8	39.2
703	84.4	0.0	84.4	1,058.6	60.2	40.2
703	84.4	0.0	84.4	1,081.4	61.7	41.1
703	84.4	0.0	84.4	1,102.8	63.0	42.0
703	84.4	0.0	84.4	1,123.0	64.2	42.8
703	84.4	0.0	84.4	1,142.0	65.4	43.6
703	84.4	0.0	84.4	1,159.9	66.5	44.3
703	84.4	0.0	84.4	1,176.7	67.5	45.0
703	84.4	0.0	84.4	1,192.6	68.5	45.7
703	84.4	0.0	84.4	1,207.5	69.5	46.3
703	84.4	0.0	84.4	1,221.6	70.3	46.9
703	84.4	0.0	84.4	1,234.9	71.1	47.4
703	84.4	0.0	84.4	1,247.3	71.9	47.9
703	84.4	0.0	84.4	1,259.1	72.6	48.4
703	84.4	0.0	84.4	1,270.2	73.3	48.9
703	84.4	0.0	84.4	1,280.6	74.0	49.3
703	84.4	0.0	84.4	1,290.4	74.6	49.7
703	84.4	0.0	84.4	1,299.7	75.1	50.1
703	84.4	0.0	84.4	1,308.4	75.7	50.5
703	84.4	0.0	84.4	1,316.6	76.2	50.8
703	84.4	0.0	84.4	1,324.3	76.7	51.1
703	84.4	0.0	84.4	1,331.6	77.1	51.4
703	84.4	0.0	84.4	1,338.4	77.5	51.7
703	84.4	0.0	84.4	1,344.9	77.9	52.0
703	84.4	0.0	84.4	1,350.9	78.3	52.2



Scenario 2

Sludges						
waste (t)	DDOC$_{m\ dep}$ (t)	DDOC$_{m\ decom}$ (t)	DDOC$_{m\ remain}$ (t)	DDOC$_{m\ accum\ T}$ (t)	DDOC$_{m\ decom\ T}$ (t)	CH$_{4\ generated}$ (t)
95	2.4	0.0	2.4	2.4	0.0	0.0
95	2.4	0.0	2.4	4.3	0.4	0.3
95	2.4	0.0	2.4	6.0	0.7	0.5
95	2.4	0.0	2.4	7.3	1.0	0.7
95	2.4	0.0	2.4	8.4	1.2	0.8
95	2.4	0.0	2.4	9.4	1.4	1.0
95	2.4	0.0	2.4	10.2	1.6	1.1
95	2.4	0.0	2.4	10.8	1.7	1.1
95	2.4	0.0	2.4	11.3	1.8	1.2
95	2.4	0.0	2.4	11.8	1.9	1.3
187	4.7	0.0	4.7	14.5	2.0	1.3
187	4.7	0.0	4.7	16.7	2.4	1.6
187	4.7	0.0	4.7	18.6	2.8	1.9
187	4.7	0.0	4.7	20.1	3.1	2.1
187	4.7	0.0	4.7	21.4	3.4	2.3
187	4.7	0.0	4.7	22.4	3.6	2.4
187	4.7	0.0	4.7	23.3	3.8	2.5
187	4.7	0.0	4.7	24.1	3.9	2.6
187	4.7	0.0	4.7	24.7	4.1	2.7
187	4.7	0.0	4.7	25.2	4.2	2.8
187	4.7	0.0	4.7	25.6	4.3	2.8
187	4.7	0.0	4.7	25.9	4.3	2.9
187	4.7	0.0	4.7	26.2	4.4	2.9
187	4.7	0.0	4.7	26.5	4.4	3.0
187	4.7	0.0	4.7	26.7	4.5	3.0
187	4.7	0.0	4.7	26.8	4.5	3.0
187	4.7	0.0	4.7	27.0	4.5	3.0
187	4.7	0.0	4.7	27.1	4.6	3.0
187	4.7	0.0	4.7	27.2	4.6	3.1
187	4.7	0.0	4.7	27.3	4.6	3.1
187	4.7	0.0	4.7	27.3	4.6	3.1
187	4.7	0.0	4.7	27.4	4.6	3.1
187	4.7	0.0	4.7	27.4	4.6	3.1
187	4.7	0.0	4.7	27.5	4.6	3.1
187	4.7	0.0	4.7	27.5	4.6	3.1
187	4.7	0.0	4.7	27.5	4.6	3.1
187	4.7	0.0	4.7	27.6	4.7	3.1
187	4.7	0.0	4.7	27.6	4.7	3.1
187	4.7	0.0	4.7	27.6	4.7	3.1
187	4.7	0.0	4.7	27.6	4.7	3.1
187	4.7	0.0	4.7	27.6	4.7	3.1
187	4.7	0.0	4.7	27.6	4.7	3.1
187	4.7	0.0	4.7	27.6	4.7	3.1
187	4.7	0.0	4.7	27.6	4.7	3.1
187	4.7	0.0	4.7	27.6	4.7	3.1
187	4.7	0.0	4.7	27.6	4.7	3.1
187	4.7	0.0	4.7	27.7	4.7	3.1
187	4.7	0.0	4.7	27.7	4.7	3.1
187	4.7	0.0	4.7	27.7	4.7	3.1
187	4.7	0.0	4.7	27.7	4.7	3.1
187	4.7	0.0	4.7	27.7	4.7	3.1

Scenario 2

Nappies						
waste (t)	$DDOC_{m\ dep}$ (t)	$DDOC_{m\ decom}$ (t)	$DDOC_{m\ remain}$ (t)	$DDOC_{m\ accum\ T}$ (t)	$DDOC_{m\ decom\ T}$ (t)	$CH_{4\ generated}$ (t)
186	22.3	0.0	22.3	22.3	0.0	0.0
186	22.3	0.0	22.3	43.3	1.3	0.9
186	22.3	0.0	22.3	63.1	2.5	1.7
186	22.3	0.0	22.3	81.8	3.7	2.5
186	22.3	0.0	22.3	99.3	4.8	3.2
186	22.3	0.0	22.3	115.9	5.8	3.9
186	22.3	0.0	22.3	131.4	6.7	4.5
186	22.3	0.0	22.3	146.1	7.7	5.1
186	22.3	0.0	22.3	159.9	8.5	5.7
186	22.3	0.0	22.3	172.9	9.3	6.2
28	3.3	0.0	3.3	166.2	10.1	6.7
28	3.3	0.0	3.3	159.9	9.7	6.5
28	3.3	0.0	3.3	153.9	9.3	6.2
28	3.3	0.0	3.3	148.3	9.0	6.0
28	3.3	0.0	3.3	143.0	8.6	5.8
28	3.3	0.0	3.3	138.0	8.3	5.6
28	3.3	0.0	3.3	133.3	8.0	5.4
28	3.3	0.0	3.3	128.9	7.8	5.2
28	3.3	0.0	3.3	124.8	7.5	5.0
28	3.3	0.0	3.3	120.8	7.3	4.8
28	3.3	0.0	3.3	117.2	7.0	4.7
28	3.3	0.0	3.3	113.7	6.8	4.5
28	3.3	0.0	3.3	110.4	6.6	4.4
28	3.3	0.0	3.3	107.3	6.4	4.3
28	3.3	0.0	3.3	104.4	6.3	4.2
28	3.3	0.0	3.3	101.7	6.1	4.1
28	3.3	0.0	3.3	99.1	5.9	3.9
28	3.3	0.0	3.3	96.7	5.8	3.8
28	3.3	0.0	3.3	94.4	5.6	3.8
28	3.3	0.0	3.3	92.3	5.5	3.7
28	3.3	0.0	3.3	90.2	5.4	3.6
28	3.3	0.0	3.3	88.3	5.3	3.5
28	3.3	0.0	3.3	86.5	5.1	3.4
28	3.3	0.0	3.3	84.8	5.0	3.4
28	3.3	0.0	3.3	83.2	4.9	3.3
28	3.3	0.0	3.3	81.7	4.8	3.2
28	3.3	0.0	3.3	80.3	4.8	3.2
28	3.3	0.0	3.3	79.0	4.7	3.1
28	3.3	0.0	3.3	77.8	4.6	3.1
28	3.3	0.0	3.3	76.6	4.5	3.0
28	3.3	0.0	3.3	75.5	4.5	3.0
28	3.3	0.0	3.3	74.4	4.4	2.9
28	3.3	0.0	3.3	73.4	4.3	2.9
28	3.3	0.0	3.3	72.5	4.3	2.9
28	3.3	0.0	3.3	71.6	4.2	2.8
28	3.3	0.0	3.3	70.8	4.2	2.8
28	3.3	0.0	3.3	70.0	4.1	2.7
28	3.3	0.0	3.3	69.3	4.1	2.7
28	3.3	0.0	3.3	68.6	4.0	2.7
28	3.3	0.0	3.3	68.0	4.0	2.7
28	3.3	0.0	3.3	67.4	4.0	2.6

Scenario 2

Rubber						
waste (kt)	$DDOC_{m\ dep}$ (t)	$DDOC_{m\ decom}$ (t)	$DDOC_{m\ remain}$ (t)	$DDOC_{m\ accum\ T}$ (t)	$DDOC_{m\ decom\ T}$ (t)	$CH_{4\ generated}$ (t)
267	52.1	0.0	52.1	52.1	0.0	0.0
267	52.1	0.0	52.1	101.1	3.0	2.0
267	52.1	0.0	52.1	147.3	5.9	3.9
267	52.1	0.0	52.1	190.8	8.6	5.7
267	52.1	0.0	52.1	231.7	11.1	7.4
267	52.1	0.0	52.1	270.3	13.5	9.0
267	52.1	0.0	52.1	306.6	15.7	10.5
267	52.1	0.0	52.1	340.8	17.9	11.9
267	52.1	0.0	52.1	373.0	19.8	13.2
267	52.1	0.0	52.1	403.4	21.7	14.5
573	111.7	0.0	111.7	491.6	23.5	15.7
573	111.7	0.0	111.7	574.6	28.6	19.1
573	111.7	0.0	111.7	652.8	33.5	22.3
573	111.7	0.0	111.7	726.5	38.0	25.3
573	111.7	0.0	111.7	795.9	42.3	28.2
573	111.7	0.0	111.7	861.2	46.3	30.9
573	111.7	0.0	111.7	922.7	50.2	33.4
573	111.7	0.0	111.7	980.7	53.7	35.8
573	111.7	0.0	111.7	1,035.2	57.1	38.1
573	111.7	0.0	111.7	1,086.6	60.3	40.2
573	111.7	0.0	111.7	1,135.0	63.3	42.2
573	111.7	0.0	111.7	1,180.6	66.1	44.1
573	111.7	0.0	111.7	1,223.5	68.8	45.8
573	111.7	0.0	111.7	1,263.9	71.3	47.5
573	111.7	0.0	111.7	1,302.0	73.6	49.1
573	111.7	0.0	111.7	1,337.9	75.8	50.5
573	111.7	0.0	111.7	1,371.6	77.9	51.9
573	111.7	0.0	111.7	1,403.4	79.9	53.3
573	111.7	0.0	111.7	1,433.4	81.7	54.5
573	111.7	0.0	111.7	1,461.6	83.5	55.6
573	111.7	0.0	111.7	1,488.1	85.1	56.7
573	111.7	0.0	111.7	1,513.2	86.7	57.8
573	111.7	0.0	111.7	1,536.7	88.1	58.7
573	111.7	0.0	111.7	1,558.9	89.5	59.7
573	111.7	0.0	111.7	1,579.8	90.8	60.5
573	111.7	0.0	111.7	1,599.5	92.0	61.3
573	111.7	0.0	111.7	1,618.0	93.1	62.1
573	111.7	0.0	111.7	1,635.5	94.2	62.8
573	111.7	0.0	111.7	1,651.9	95.2	63.5
573	111.7	0.0	111.7	1,667.4	96.2	64.1
573	111.7	0.0	111.7	1,682.0	97.1	64.7
573	111.7	0.0	111.7	1,695.7	97.9	65.3
573	111.7	0.0	111.7	1,708.6	98.7	65.8
573	111.7	0.0	111.7	1,720.8	99.5	66.3
573	111.7	0.0	111.7	1,732.3	100.2	66.8
573	111.7	0.0	111.7	1,743.0	100.9	67.3
573	111.7	0.0	111.7	1,753.2	101.5	67.7
573	111.7	0.0	111.7	1,762.8	102.1	68.1
573	111.7	0.0	111.7	1,771.8	102.7	68.4
573	111.7	0.0	111.7	1,780.3	103.2	68.8
573	111.7	0.0	111.7	1,788.3	103.7	69.1

Scenario 2

Total CH_4 Generated (t)	Methan recovered			CH_4* (t)	E_j	Ej (t CO_2-e)
	Q_{cap} (m^3)	Q_{flared} (m^3)	Q_{tr} (m^3)			
0.0	0	0	0	0.0	0.0	0.0
54.5	0	0	0	54.5	49.0	1029.9
102.9	0	0	0	102.9	92.6	1944.1
146.0	0	0	0	146.0	131.4	2758.8
184.5	0	0	0	184.5	166.1	3487.6
219.1	0	0	0	219.1	197.2	4141.9
250.4	0	0	0	250.4	225.3	4731.7
278.6	0	0	0	278.6	250.7	5265.1
304.2	0	0	0	304.2	273.8	5749.2
327.5	0	0	0	327.5	294.8	6190.2
348.8	0	0	0	348.8	314.0	6593.0
329.6	0	0	0	329.6	296.7	6229.9
313.5	0	0	0	313.5	282.2	5925.8
300.1	0	0	0	300.1	270.1	5671.1
288.8	0	0	0	288.8	259.9	5457.7
279.3	0	0	0	279.3	251.4	5278.8
271.4	0	0	0	271.4	244.2	5128.8
264.7	0	0	0	264.7	238.2	5002.9
259.1	0	0	0	259.1	233.2	4897.3
254.4	0	0	0	254.4	229.0	4808.5
250.5	0	0	0	250.5	225.4	4734.0
247.2	0	0	0	247.2	222.4	4671.3
244.4	0	0	0	244.4	219.9	4618.6
242.0	0	0	0	242.0	217.8	4574.2
240.0	0	0	0	240.0	216.0	4536.8
238.4	0	0	0	238.4	214.5	4505.3
237.0	0	0	0	237.0	213.3	4478.7
235.8	0	0	0	235.8	212.2	4456.3
234.8	0	0	0	234.8	211.3	4437.4
233.9	0	0	0	233.9	210.5	4421.3
233.2	0	0	0	233.2	209.9	4407.7
232.6	0	0	0	232.6	209.3	4396.2
232.1	0	0	0	232.1	208.9	4386.4
231.6	0	0	0	231.6	208.5	4378.1
231.3	0	0	0	231.3	208.1	4371.0
230.9	0	0	0	230.9	207.9	4364.9
230.7	0	0	0	230.7	207.6	4359.6
230.4	0	0	0	230.4	207.4	4355.1
230.2	0	0	0	230.2	207.2	4351.2
230.0	0	0	0	230.0	207.0	4347.9
229.9	0	0	0	229.9	206.9	4344.9
229.8	0	0	0	229.8	206.8	4342.3
229.6	0	0	0	229.6	206.7	4340.0
229.5	0	0	0	229.5	206.6	4338.0
229.4	0	0	0	229.4	206.5	4336.1
229.3	0	0	0	229.3	206.4	4334.5
229.3	0	0	0	229.3	206.3	4332.9
229.2	0	0	0	229.2	206.3	4331.5
229.1	0	0	0	229.1	206.2	4330.3
229.1	0	0	0	229.1	206.1	4329.0
229.0	0	0	0	229.0	206.1	4327.9
						227,132 Total

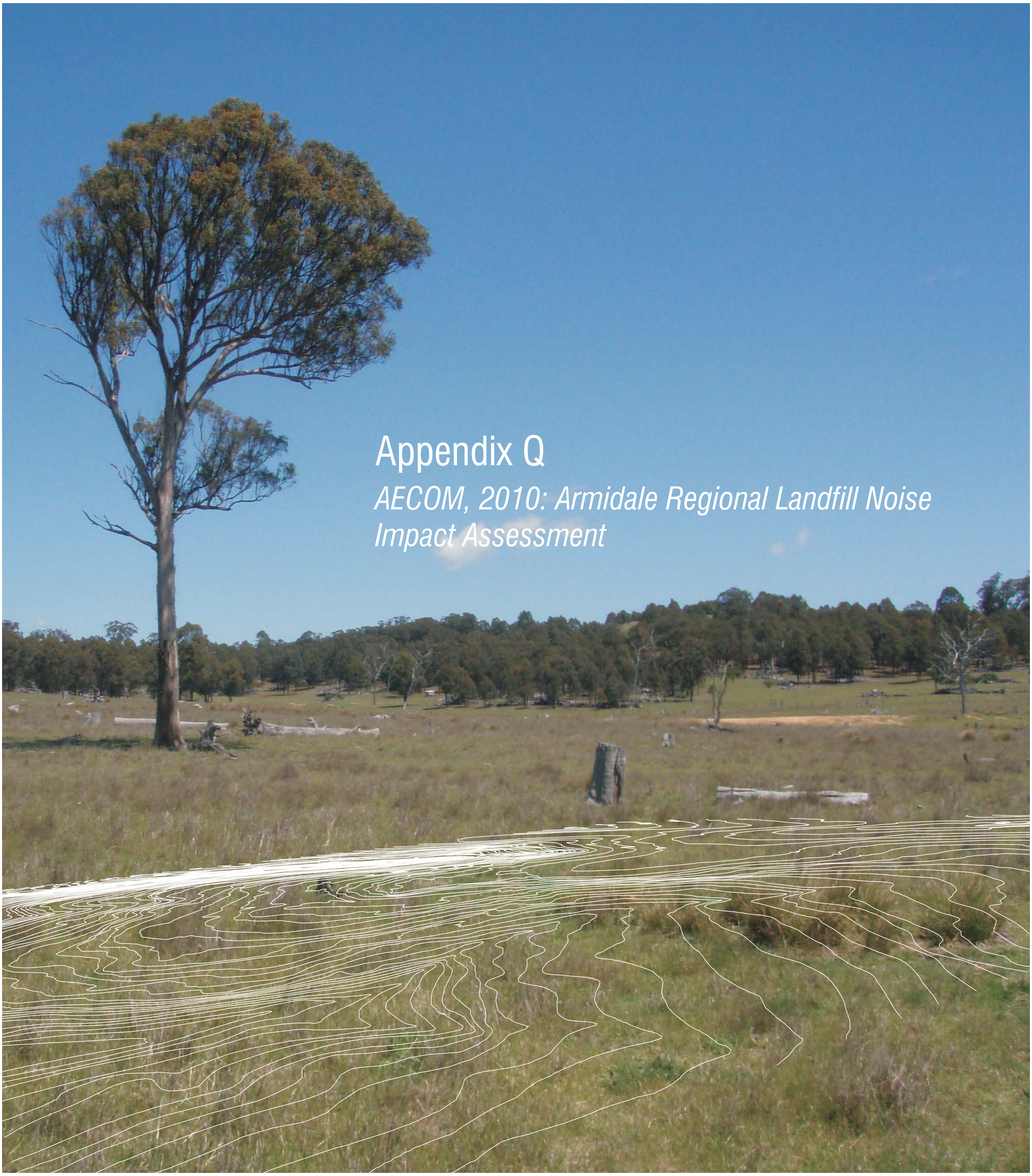
Worldwide Locations

Australia	+61-2-8484-8999
Azerbaijan	+994 12 4975881
Belgium	+32-3-540-95-86
Bolivia	+591-3-354-8564
Brazil	+55-21-3526-8160
China	+86-20-8130-3737
England	+44 1928-726006
France	+33(0)1 48 42 59 53
Germany	+49-631-341-13-62
Ireland	+353 1631 9356
Italy	+39-02-3180 77 1
Japan	+813-3541 5926
Malaysia	+603-7725-0380
Netherlands	+31 10 2120 744
Philippines	+632 910 6226
Scotland	+44 (0) 1224-624624
Singapore	+65 6295 5752
Thailand	+662 642 6161
Turkey	+90-312-428-3667
United States	+1 978-589-3200
Venezuela	+58-212-762-63 39

Australian Locations

Adelaide
Brisbane
Canberra
Darwin
Melbourne
Newcastle
Perth
Sydney
Singleton

www.aecom.com

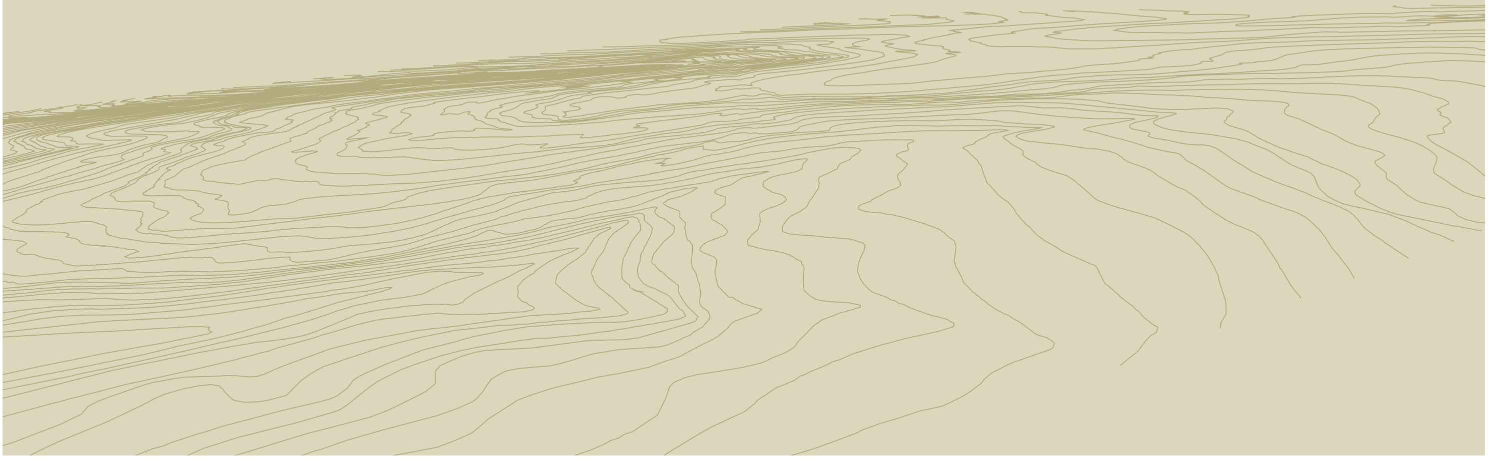


Appendix Q

AECOM, 2010: Armidale Regional Landfill Noise Impact Assessment

ARMIDALE REGIONAL LANDFILL

Environmental Assessment



Armidale Regional Landfill
Armidale Dumeresq Council
18 February 2010

Armidale Regional Landfill

Noise Impact Assessment

Armidale Regional Landfill

Noise Impact Assessment

Prepared for

Armidale Dumeresq Council

Prepared by

AECOM Australia Pty Ltd
Level 5, 828 Pacific Highway, Gordon NSW 2072
T +61 2 8484 8999 F +61 2 8484 8989 www.aecom.com
ABN 20 093 846 925

18 February 2010

Quality Information

Document	**Armidale Regional Landfill**
Ref	\\ausyd1fp002\Projects\20017605.00 ARMLANDFIL\Eng-Plan\Environment\EA Document\Post Adequacy Review EA 2009\revised reports\Appendix P Noise Assessment\Revised NoiseRpt_18Feb10
Date	18 February 2010
Prepared by	Evan Mudge/Andrew Matchell Author Signature
Reviewed by	Peter Sanderson Technical Peer Reviewer Signature

Revision History

Revision	**Revision Date**	**Details**	**Authorised**	
			Name/Position	**Signature**
A	01-Sep-2006	Draft – For Comment	Evan Mudge Acoustic Engineer	
B	17-Sep-2006	Draft – For Approval	Evan Mudge Acoustic Engineer	
0	21-Dec-2009	Issue incorporating comments from Department of Planning	Peter Sanderson Senior Engineer - Acoustic	
Revision 1	09-Feb-2010	Issue Incorporating comments from Department of Planning	Peter Sanderson Senior Engineer - Acoustic	

This page has been left blank intentionally

Contents

List of Tables

Body Report

List of Figures

Body Report

List of Appendices

Executive Summary

Armidale Dumeresq Council is proposing to construct a new landfill facility to replace the existing facility on Long Swamp Rd, which is close to capacity. The proposed site is located approximately 12km east of Armidale, NSW and would be accessed from Waterfall Way. Waste would be processed at the existing landfill and transfer station on Long Swamp Road and would be transported between the transfer station and the site by truck.

The noise emission from the proposed landfill development off Waterfall Way has been assessed against the criteria contained in the DEC *Industrial Noise Policy* determine the impact at the nearest receivers throughout the life of the landfill.

Due to the low existing background noise levels, the noise emission from the site operations would need to be controlled to ensure compliance with the INP criteria. The required mitigation measures would include the use of silencers and engine enclosures on permanent site equipment to achieve a reduction in noise levels of 5-10 dB(A).

With these and the additional mitigation measures discussed in Section 5.2.2 implemented, it is expected that the noise levels at the nearest receivers would generally comply with the INP criteria for the typical operational scenarios that have been analysed.

The expected increase in traffic noise resulting from traffic generated by the development was calculated and was found to be less than 2 dB(A). Therefore the development would be expected to comply with the criteria outlined in the DEC *Environmental Criteria for Road Traffic Noise*.

As the proposed development would be reliant on engineered noise control treatment, the ongoing maintenance of equipment will be critical to ensure the continuing compliance with the noise criteria. For this reason it is recommended that an annual compliance monitoring program be undertaken to confirm that the site noise emissions remain acceptable over the life of the landfill.

1.0 Introduction

Armidale Dumeresq Council is proposing to construct a new landfill facility to replace the existing facility on Long Swamp Rd, which is close to capacity. The proposed site for the new landfill facility (the site) is located approximately 12km east of Armidale, NSW and would be accessed from Waterfall Way. Waste would be processed at the existing landfill and transfer station on Long Swamp Road and would be transported between the transfer station and the site by truck. No public access to the proposed site would be provided.

The proposed development would involve minor excavation associated with the construction of the landfill cells, the construction of a sealed access road between Waterfall Way and the landfill site and the construction of unsealed maintenance roads around the perimeter of the site. Landfill operations would originate at the south of the site and would generally move north over the 50 year design life of the facility.

AECOM was commissioned to provide a noise impact assessment of the proposed landfill development site during construction and operation of the facility.

This report assesses the noise impact of the proposed landfill facility at the most affected residential receivers located around the proposed landfill site. The environmental noise impact has been assessed against the relevant criteria presented in the Department of Environment and Conservation's (DEC) Industrial Noise Policy (INP) and recommendations have been made to minimise the impact of the proposed development on the existing noise environment of the area throughout the life of the development.

2.0 Description of the Proposed Development

2.1 Proposed Site

The site of the proposed landfill facility is located approximately 12km east of Armidale with access to the site from Waterfall Way as shown in Figure 1 below. The site is located in a rural area, with the proposed site and surrounding area predominantly open grassland and paddocks.

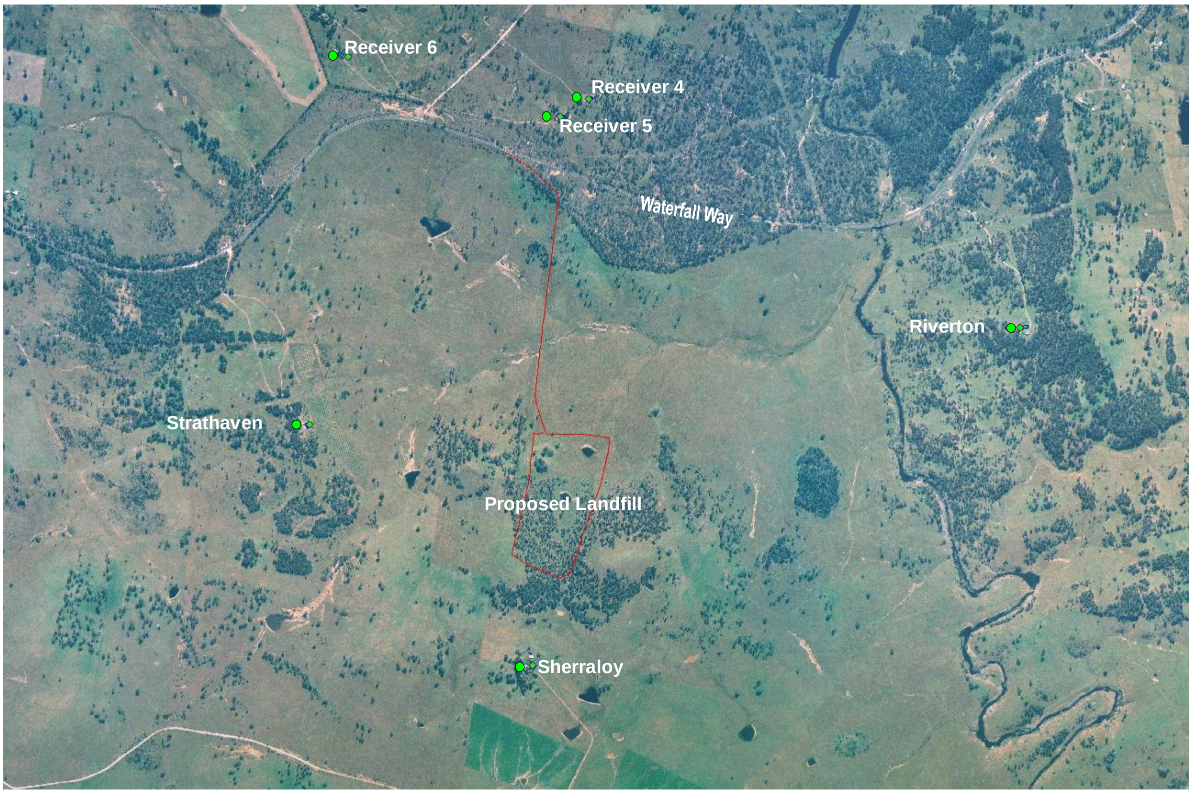


Figure 1 – Site Locality

Typical rural residences are distributed around the site with the most-affected residences located approximately 350m from the Southern boundary of the proposed site, approximately 900m from the Western boundary of the proposed site and approximately 250m north of the proposed Waterfall Way site access.

Additional residences located at greater distances to the East and the North West of the site have also been included in the assessment but would be less affected by the proposed development.

2.2 Proposed Operations

Waste would be processed at the existing landfill and transfer station on Long Swamp Road and would be transported between the transfer station and the site by truck. No direct public access to the proposed site would be provided.

The proposed landfill facility would operate seven days per week with the proposed operating hours from 7:00am to 5:30pm Monday to Friday and 8:00am to 6:30pm on Saturday, Sunday and Public Holidays.

The main activities on the site would be associated with the unloading, distribution and compaction of waste materials in the landfill cells and the loading, distribution and compaction of cover material. For the purpose of this report the operations occurring on the site are as summarised below:

- Three waste vehicles per day arrive from the Long Swamp Rd transfer station via Waterfall Way and the proposed site access road.

- The trucks proceed along the perimeter maintenance road to the landfill cell in use, where they unload the waste.
- The empty trucks exit the site along the perimeter maintenance road and the sealed access road to Waterfall Way.
- The waste material is distributed in the landfill cell using a dozer and compactor throughout the operating hours of the facility.
- Cover material is loaded from an adjacent cell using an excavator and transported using a bogie type truck. One truck per day would bring additional cover material to the site.
- The cover material is spread using the dozer or excavator and is then compacted. Covering operations would generally occur in the afternoon and would be expected to be approximately 4 hours in duration.
- Two passenger vehicles per day would be associated with the transport of employees to and from the site.

3.0 Environmental Noise Measurements

3.1 Ambient Noise Level Measurements

Two ARL EL-215 noise loggers were used to continuously measure ambient noise levels approximately 30m from residences (Strathaven and Sherraloy) in close proximity to the site for a period of 1 week. The locations of the loggers are shown in Figure 2 below.

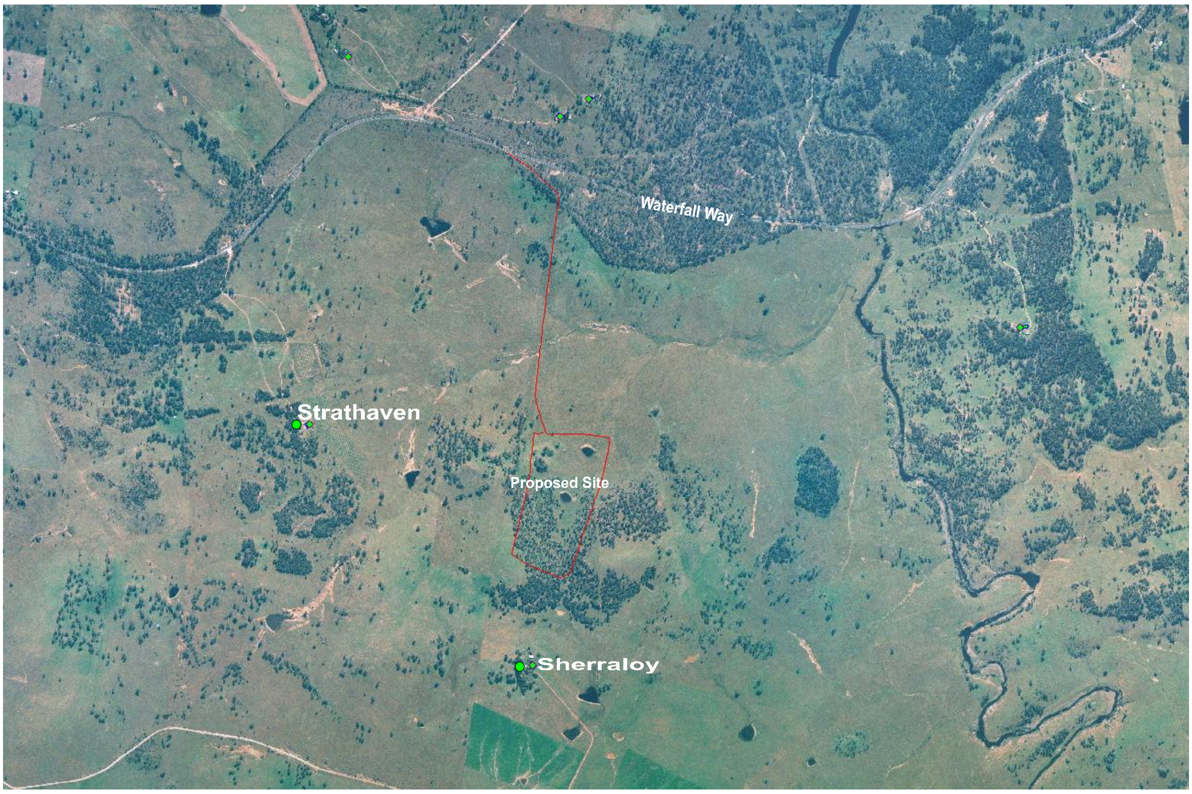


Figure 2 – Noise Logging Locations at (1) Strathhaven and (2) Sherraloy

The existing noise environment at the receivers is typical of rural areas, with ambient noise levels during the day dominated by rural human activity, animals and intermittent traffic. Natural sounds such as wind in trees and grass and small contributions of industrial noise from distant water pumps were also audible at times during the assessment. The loggers were set for a sample period of 15 minutes and continuously logged from Friday 2nd June until Friday 9th June 2006.

A noise logger measures the noise level over the sample period and then determines L_{A1}, L_{A10}, L_{A90}, L_{Amax} and L_{Aeq} levels of the noise environment. The L_{A1}, L_{A10} and L_{A90} levels are the levels exceeded for 1%, 10% and 90% of the sample period respectively. The $L_{A,max}$ is indicative of maximum noise levels due to individual noise events such as the pass by of a heavy vehicle. The $L_{A,90}$ is taken as the background noise level. The L_{Aeq} level is the equivalent continuous sound level and has the same sound energy over the sample period as the actual noise environment with fluctuating sound levels.

The background noise level is defined by the DEC as “the underlying level of noise present in ambient noise when all unusual extraneous noise is removed”. It can include sounds that are normal features of a location and may include birds, traffic, insects etc. The background noise level is represented by the LA90,15 min descriptor. Existing background and ambient noise levels are presented in **Table 1 and Table 2**.

The measured noise levels were analysed to determine a single assessment background level (ABL) for each day, evening and night period, in accordance with the INP. The ABL is established by determining the lowest ten-percentile level of the L_{A90} noise data acquired over each period of interest. The background noise level or rating background level (RBL) representing the day, evening and night-time assessment periods is based on the median of individual ABLs determined over the entire monitoring period.

Table 3 presents the RBL's determined for each receiver and assessment period and an overall representative L_{Aeq} noise level determined by logarithmically averaging each assessment period for the entire monitoring period. Graphical representations of the logged noise levels are included in **Appendix A**. It is noted that the where the noise levels are measured to be 25 dB(A), the measurements are affected by the noise floor of the instrumentation and the actual noise levels may be significantly lower. However, in situations where the RBL is assessed to be less than 30 dB(A), the INP criteria limits the RBL to 30 dB(A).

Table 1– Existing Background (L_{A90}) and Ambient (L_{Aeq}) Noise Levels – Strathaven

Day	**L_{A90} Background Noise Levels**			**L_{Aeq} Ambient Noise Levels**		
	Day	**Evening**	**Night**	**Day**	**Evening**	**Night**
Friday 02 June, 2006	34	30	30	48	39	41
Saturday 03 June, 2006	31	26	25	41	30	29
Sunday 04 June, 2006	27	25	25	38	30	32
Monday 05 June, 2006	27	27	26	38	62	48
Tuesday 06 June, 2006	27	25	26	40	31	29
Wednesday 07 June, 2006	27	26	26	42	32	32
Thursday 08 June, 2006	28	26	26	40	33	35
Friday 09 June, 2006	28	-	-	36	-	-
RBL / Log Average	27	26	26	42	54	41

Table 2– Existing Background (L_{A90}) and Ambient (L_{Aeq}) Noise Levels – Sherraloy

Day	**L_{A90} Background Noise Levels**			**L_{Aeq} Ambient Noise Levels**		
	Day	**Evening**	**Night**	**Day**	**Evening**	**Night**
Friday 02 June, 2006	31	29	29	40	35	37
Saturday 03 June, 2006	29	25	25	47	49	38
Sunday 04 June, 2006	26	26	26	53	27	28
Monday 05 June, 2006	26	27	27	34	56	43
Tuesday 06 June, 2006	26	25	26	35	29	29
Wednesday 07 June, 2006	27	27	27	37	30	31
Thursday 08 June, 2006	26	26	27	35	29	30
Friday 09 June, 2006	29	-	-	35	-	-
RBL / Log Average	27	26	27	45	49	37

Table 3– Assessed Rating Background Level and Ambient Noise Level

	RBL and Ambient Noise Levels					
	Day		**Evening**		**Night**	
Location	RBL	L_{Aeq}	RBL	L_{Aeq}	RBL	L_{Aeq}
1. Strathaven	30*	42	30*	34	30*	35
2. Sherraloy	30*	45	30*	41	30*	34

Notes:

1. Day is defined as 7:00am to 6:00pm, Monday to Saturday and 8:00am to 6:00pm Sundays & Public Holidays.
2. Evening is defined as 6:00pm to 10:00pm, Monday to Sunday & Public Holidays.
3. Night is defined as 10:00pm to 7:00am, Monday to Saturday and 10:00pm to 8:00am Sundays & Public Holidays

*Where the RBL is found to be less than 30 dB(A), then it is set to 30 dB(A) in accordance with DEC recommendations.

4.0 Noise Criteria

4.1 Operational Noise

The NSW Department of Environment and Conservation (DEC) provides guidelines for external noise emissions from developments provided in the New South Wales Industrial Noise Policy (INP). In accordance with the Director General's requirements the noise emission from the site has been assessed against the INP criteria which will apply to the mobile plant and equipment operated on the site.

The assessment procedure for industrial noise sources has two components:

1. Controlling intrusive noise impacts in the short term for residences.
2. Maintaining noise level amenity for particular land uses for residences and other land uses.

4.1.1 Intrusive Noise Impacts

The INP states that the noise from any single source should not intrude greatly above the prevailing background noise level. Industrial noises are generally considered acceptable if the equivalent continuous (energy-average) A-weighted level of noise from the source (L_{Aeq}), measured over a 15 minute period, does not exceed the background noise level measured in the absence of the source by more than 5 dB. This is often termed the Intrusiveness Criterion.

The 'Rating Background Level' (RBL) is the background noise level to be used for assessment purposes and is determined by the methods given in Section 3.1 of the INP. Using the rating background noise level approach results in the intrusiveness criterion being met for 90% of the time. Adjustments are to be applied to the level of noise produced by the source that is received at the assessment point where the noise source contains annoying characteristics such as tonality or impulsiveness.

As operation of the proposed facility is only intended for the day time period, and no fixed equipment will be left operating overnight, the daytime RBL will be the controlling period. Since the RBL in the area has been assessed to be 30 dB(A) for all periods, the applicable intrusiveness criterion is 35dB(A).

4.1.2 Protecting Noise Amenity

To limit continuing increases in noise levels, the maximum ambient noise level within an area from industrial noise sources should not normally exceed the acceptable noise levels specified in Table 2.1 of the INP. That is, the background noise level should not exceed the level appropriate for the particular locality and land use. This is often termed the "Background Creep" or Amenity criterion.

For a residential receiver in a rural area, the recommended amenity criteria are shown in Table 4.

Table 4– Recommended L_{Aeq} noise levels from Industrial Noise Sources

Type of receiver	Indicative Noise Amenity Area	Time of Day	Recommended L_{Aeq} Noise Level dB(A)	
			Acceptable Noise Level (ANL)	Recommended Maximum
Residence	Rural	Day	50	55
		Evening	45	50
		Night	40	45

4.1.3 Resultant Environmental Noise Criteria

A summary of the intrusive and amenity criteria is given in Table 5. The final criteria are formulated to satisfy the lowest of the amenity or intrusiveness criteria for each time period. Note that the night and evening period criteria have been shown for completeness only, and are not applicable to this assessment since no operations will take place outside of the daytime period.

Table 5– Resultant Environmental Noise Criteria

Period	RBL (L_{A90})	Intrusive Criterion = RBL + 5	Ambient L_{Aeq}	Amenity Criteria	Final Criteria
Receiver 1 – Strathaven					
Day	30	35	42	50	35
Evening *	30	35	34	45	35
Night *	30	35	35	40	35
Receiver 2 – Sherraloy					
Day	30	35	45	50	35
Evening *	30	35	41	45	35
Night *	30	35	34	40	35

* Night and evening criteria not applicable to this assessment as no operations will take place outside of the daytime period

As the criteria are identical at both receivers and equal to the minimum criteria to be used for all assessment periods, the existing noise levels and criteria at the northern and western receivers are also expected to be similar. This was confirmed by attended measurements of the background noise level at the Northern boundary of the site.

These criteria apply to environmental noise emissions from mechanical equipment and vehicle noise emissions from the site.

It is noted that the situation where the RBL is identical for the day and night assessment periods is acknowledged in section 2.1 of the INP where it is stated:

"In some rural situations, the rating background level may be the same for the day and night. In these cases it is recognised that excursions of noise above the intrusiveness criterion during the day would not usually have the same impact as they would at night. This is due to the more sensitive nature of activities likely to be disturbed at night (for example, sleep and relaxation)"

Therefore, AECOM considers that small exceedances of the environmental criteria of less than 5 dB(A) for parts of the day would not be expected to cause an adverse impact on the receivers.

4.2 Traffic Noise

4.2.1 Environmental Criteria for Road Traffic Noise

In accordance with the Director General's requirements, the DEC's *Environmental Criteria for Road Traffic Noise* (ECRTN) has been used for the assessment of noise from traffic visiting the subject development.

Waste vehicles bound for the proposed landfill facility from the Long Swamp Road transfer station would use Long Swamp Road and Canambe Street and would then turn right onto Grafton Road and proceed along Waterfall Way to the proposed site. Grafton Road and Waterfall Way would be classified as collector roads according to the DEC guidelines and Long Swamp Road and Canambe Street would be classified as local roads.

Table 6 presents the road traffic noise criteria from the ECRTN for land use developments with potential to create additional traffic on existing collector and local roads. The external noise criteria are applied at 1 metre from the affected external building façade.

Table 6 – Road Traffic Noise Criteria

Period	Parameter	Criterion
Collector Roads		
Day (7.00 am – 10.00pm)	$L_{Aeq, 1hr}$	60
Night (10.00 pm – 7.00am)	$L_{Aeq, 1hr}$	55
Local Roads		
Day (7.00 am – 10.00pm)	$L_{Aeq, 1hr}$	55
Night (10.00 pm – 7.00am)	$L_{Aeq, 1hr}$	50

In cases where noise from an existing road already exceeds the above criteria, the DEC recommends that, where feasible, existing noise levels should be mitigated to meet the noise criteria. Examples of applicable strategies include appropriate location of private access roads; regulating times of use; using clustering; using 'quiet' vehicles; and using barriers and acoustic treatments.

For traffic generating developments the criteria stipulates that traffic arising from the development should not lead to an increase in existing noise levels of more than 2 dB(A) for all road types.

4.2.2 Sleep Arousal

The DEC ECRTN recommends that an assessment of sleep arousal due to the pass-bys of heavy vehicles during the night period be conducted.

A detailed discussion of the issues involved in sleep arousal can be found in the ECTRN. The following summary of sleep arousal issues gives recommendations for noise criteria to control maximum internal noise levels. The intent of a sleep arousal criterion is to ensure that the amenity of sleeping areas is protected and sleep arousal, beyond reasonable limits is avoided.

The following characteristics of a noise signal are identified as being strongly related to sleep disturbance.

- The peak level of the noise events, described by L_{Amax}
- The emergence of noise events above the general ambient noise level, described by measures such as (L_{Amax} – L_{Aeq}) or (L_{Amax} – L_{A90})
- The number of such noise events occurring during the sleeping period

A comparison of the existing research on sleep arousal results in the following conclusions:

- Maximum internal noise levels below 55 dB(A) are unlikely to cause awakening reactions
- One or two noise events per night, with maximum internal noise levels of 70 dB(A), are not likely to affect health and well being significantly.

As no night time operations have been proposed, the development would not be expected to generate heavy vehicle traffic during the night time assessment period.

4.3 Construction Noise

In July 2009 the NSW Department of Environment, Climate Change and Water (DECCW) published their *Interim Construction Noise Guidelines (ICNG)* for use in construction noise assessment. This document supersedes their previous publication the *Environmental Noise Control Manual (ENCM)* and is used as the basis for establishing construction noise criteria.

Under the existing DECCW policy, a construction noise management plan is required to be compiled by the Contractor, prior to construction commencing. Noise level objectives must be set for the daytime and evening periods, and must be complied with where reasonably practicable. Work that is proposed outside of standard working hours, as defined in the *ICNG*, generally requires strong justification.

The noise management plan should detail the "best practice" construction methods to be used, presenting a reasonable and feasible approach. The plan should identify the extent of the residential area affected and assess the impact on residents. The plan should detail any community relation programs that are planned e.g. prior notification for particularly noisy activities, letter box drop regarding out of hours construction work to be undertaken and a 24 hour contact phone number for residents to call should they have any complaints or questions.

The *ICNG* defines what is considered to be feasible and reasonable as follows:

> *Feasible*
>
> > *A work practice or abatement measure is feasible if it is capable of being put into practice or of being engineered and is practical to build given project constraints such as safety and maintenance requirements.*
>
> *Reasonable*
>
> > *Selecting reasonable measures from those that are feasible involves making a judgment to determine whether the overall noise benefits outweigh the overall adverse social, economic and environmental effects, including the cost of the measure.*

The *ICNG* recommends that a quantitative assessment is carried out for all *'major construction projects that are typically subject to the EIA process'*. A quantitative assessment, based on a likely 'worst case' construction scenario, has been carried out for the proposed development.

Predicted noise levels at nearby noise sensitive receivers (residential, commercial and industrial premises) are compared to the levels provided in Section 4 of the *ICNG*. Where an exceedance of the criteria is predicted the *ICNG* advises that the proponent should apply all feasible and reasonable work practises to minimise the noise impact.

Criteria for residential receivers are set using the information in **Table 7**.

The initial construction works for the landfill facility are understood to involve partial clearing of the site, the construction of the site access and maintenance roads, drainage works, landscaping works and some excavation of the landfill area. Based on the assessed RBL outlined in Section 4.1, the construction noise criteria would be 40 dB(A) during the day-time at the nearest residential receiver.

Ongoing construction and capping of landfill cells after the initial works were complete would be required to comply with the operational noise criteria for the site.

Table 7 – Noise at residences using quantitative assessment

Time of Day	**Management Level L_{Aeq} (15min)***	**How to Apply**
Recommended standard hours: • Monday to Friday 7 am to 6 pm • Saturday 8 am to 1 pm • No work on Sundays or public holidays	Noise affected RBL + 10 dB	• The noise affected level represents the point above which there may be some community reaction to noise. • Where the predicted or measured $L_{Aeq\ (15\ min)}$ is greater than the noise affected level, the proponent should apply all feasible and reasonable work practices to meet the noise affected level. • The proponent should also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, as well as contact details.
	Highly noise affected 75 dB(A)	• The highly noise affected level represents the point above which there may be strong community reaction to noise. • Where noise is above this level, the relevant authority (consent, determining or regulatory) may require respite periods by restricting the hours that the very noisy activities can occur, taking into account: 1. times identified by the community when they are less sensitive to noise (such as before and after school for works near schools, or mid-morning or mid-afternoon for works near residences 2. if the community is prepared to accept a longer period of construction in exchange for restrictions on construction times.
Outside recommended standard hours	Noise affected RBL + 5 dB	• A strong justification would typically be required for works outside the recommended standard hours. • The proponent should apply all feasible and reasonable work practices to meet the noise affected level. • Where all feasible and reasonable practices have been applied and noise is more than 5 dB(A) above the noise affected level, the proponent should negotiate with the community. • For guidance on negotiating agreements see section 7.2.2 (ICNG).

* Noise levels apply at the property boundary that is most exposed to construction noise, and at a height of 1.5 m above ground level. If the property boundary is more than 30 m from the residence, the location for measuring or predicting noise levels is at the most noise-affected point within 30 m of the residence. Noise levels may be higher at upper floors of the noise affected residence.

5.0 Site Noise Emission Modelling

5.1 Modelling Methodology

A three dimensional noise model of the site and surrounds was constructed using SoundPLAN version 6.3. The noise levels at the receiver were calculated according to the CONCAWE algorithms for industrial noise sources.

5.1.1 Topography and Site Layout

The topography within the proposed site and surrounding area was based on 0.5m contour survey drawings and 10m contours, both provided by AECOM's designers.

The site boundary and layout of the landfill was based on AECOM's preliminary site layout drawings.

5.1.2 Meteorological Conditions

The INP requires temperature inversions to be considered for developments where night time operations are proposed and temperature inversions typically occur for more than 30% of the total night time during winter (June, July, August). As the proposed development will only operate during the daytime period, assessment of noise from the site with a temperature inversion is not required.

The INP also requires wind effects to be considered where a source to receiver wind speed of less than 3 m/s occurs for more than 30% of any assessment period in any season. At wind speeds above 3 m/s, noise produced by the wind itself generally obscures noise produced by industrial sources.

Meteorological data for a typical year (2002) has been assessed to determine the occurrence of wind conditions on the site that are likely to cause increased noise levels at the receiver. Table 8 presents the results of an analysis of the occurrence of wind speeds less than 3m/s in the area, based on meteorological data for 2002 from the Bureau of Meteorology weather station at Armidale Airport.

Table 8 - Occurrence of source to receiver wind speeds <3m/s at Armidale Airport, 2002

Direction (Site to Receiver)	**Day**				**Evening**				**Night**			
	Summer	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**
N	11%	12%	9%	10%	8%	12%	15%	11%	26%	26%	28%	24%
NE	13%	15%	9%	9%	8%	17%	17%	9%	29%	29%	23%	17%
E	14%	15%	9%	8%	7%	18%	17%	11%	29%	29%	21%	15%
SE	13%	16%	9%	8%	10%	21%	20%	15%	24%	24%	17%	11%
S	12%	13%	8%	7%	10%	16%	22%	17%	9%	9%	11%	8%
SW	12%	12%	10%	10%	11%	15%	25%	21%	10%	10%	20%	20%
W	11%	11%	10%	10%	12%	13%	23%	18%	9%	9%	21%	22%
NW	13%	11%	9%	11%	9%	12%	22%	15%	14%	14%	26%	26%

As shown in Table 8, source to receiver wind speed of less than 3 m/s were found to occur for less than 30% of the time for the Day time and Evening assessment periods throughout the year. Whilst the incidence of wind up to 3 m/s approaches 30% in some directions during the night time period, night time operations are not proposed. Therefore, in accordance with the INP guidelines, wind effects are not required to be included in the analysis.

Based on the above discussion, the noise emissions have been assessed under neutral meteorological conditions as this is would be the predominate condition in terms of sound propagation.

5.1.3 Equipment Noise Levels

Site measurements of the landfill compactor were undertaken at the existing Long Swamp Rd landfill facility. However, it is understood that much of the existing landfill equipment would be replaced and newer, higher capacity machinery would typically be used at the proposed landfill facility.

Therefore, sound power levels of typical landfill machinery have been used for the purpose of this assessment. These sound power levels were based on site measurements, AECOM's experience with similar equipment and the typical midpoint levels recommended in Australian Standard AS2436 – *Guide to Noise Control on Construction, Maintenance and Demolition Sites*.

The equipment sound power levels used in the model are summarised in Table 9.

Table 9 – Equipment Sound Power Levels

Equipment Description	Sound Power Level dB(A)
Excavator	110
Dozer (D5)	113
Water Cart	105
Compactor (Landfill)	107
Grader	114
Tipper Truck	105
Truck	97
Scraper	114

Sources were modelled as operating on the finished landfill contours to present a conservative estimation of noise levels at the receivers. In this instance minimal shielding is provided by the landfill waste itself and would be typical of the situation where the landfill cells are reaching their finished level. In practice, some additional shielding would be provided by the landfill cells and/or the natural contours for the majority of the operating life of the landfill.

5.2 Operational Assessment

The operational assessment was based on the equipment outlined below operating on the proposed site. The equipment was generally distributed along the south and the western areas of the landfill to represent the least favourable distribution of noise sources due to the proximity to Receivers 1 and 2. Two scenarios were addressed as follows:

- One scenario would be typical of the normal filling and compacting operations on the site with the following equipment operating within the working landfill cell.
  - 1 x compactor
  - 1 x dozer
  - 1 x tipper truck
- The other scenario would be typical of the covering operations on the site that would occur in the afternoon with the following equipment operating within the working landfill cell.
  - 1 x compactor
  - 1 x scraper
  - 1 x cover truck
  - 1 x excavator

The following traffic movements have been incorporated along the site roads for both operational scenarios and would be typical of the worst case operation of the site:

- 2 truck movements per hour along the site access road (it is understood that the site operations would be managed such that the three daily waste vehicles would arrive at the site at times spread throughout the day, and more than one vehicle would not arrive in any one hour period. The two truck movements per hour on the site access road equates to one truck arriving and departing the site);
- 1 truck movement per hour along the perimeter maintenance road;
- 1 movement per hour along the perimeter maintenance road for the water cart;
- The compactor, dozer and stationary truck distributed across the active landfill cell.

The dozer and compactor would generally be confined to the landfill cells and therefore it is unlikely that these machines would be regularly used on the perimeter haul road.

Both operational scenarios were repeated in cell 1, 3 and 5 to determine the worst repeating case noise levels for the southern, western and northern receivers over the 50 year life of the proposed landfill.

5.2.1 Calculated Noise Levels – No Mitigation

Noise levels were calculated at the identified receivers under neutral meteorological conditions. The calculated noise levels resulting from the proposed development for the operational scenario are summarised in Table 10, below.

Table 10 - Normal Operations During Daytime under Neutral Meteorological Conditions

Receiver	Location Of Equipment					
	Cell 1		Cell 3		Cell 5	
	Fill	Cover	Fill	Cover	Fill	Cover
Strathaven	33	34	33	35	34	35
Sherraloy	40*	43*	28	35	27	31
Riverton	23	25	25	27	25	27
4 North 1	27	29	30	31	30	32
5 North 2	27	28	29	30	30	31
6 North West	23	24	24	26	25	26

* Denotes exceedance of environmental criterion.

The analysis indicates that the environmental criteria would be met for all receivers when equipment is operating in Cell 3 and Cell 5. Where equipment is operating in Cell 1, at the south of the site, the noise level at Receiver 2 would be expected to exceed the criteria by up to 8 dB(A) and the mitigation measures discussed in Section 5.2.2 should be implemented to reduce the impact of the development on the existing acoustical environment. Noise contour plots for operations in Cell 1 have been included in **Error! Reference source not found.**

5.2.2 Recommended Operational Noise Control Measures

5.2.2.1 Silencers on Heavy Equipment

Permanent heavy equipment used on site should have noise attenuation measures installed which would typically make the equipment suitable for use in urban areas and which comply with regulatory requirements. The noise attenuation measures should include:

1. The encapsulation of engine chambers, with careful regard to ventilation requirements of the engines; and,
2. Fitting ‘Department of Environment and Conservation (DEC)’ approved silencers to all powered operated plant.

These mitigation measures would be expected to provide attenuation of between 5-10 dB(A) and should be applied to the Dozer, Excavator, Compactor and Scraper as required to achieve the sound power levels indicated in Table 11.

Table 11 – Attenuated Equipment Sound Power Levels

Equipment Description	Sound Power Level dB(A)
Excavator	105*
Dozer (D5)	108*
Water Cart	105
Compactor (Landfill)	102*
Grader	109*
Tipper Truck	105
Truck	97
Scraper	109*

*5 dB(A) reduction applied for silencing

5.2.2.2 Reversing Alarms

Reversing alarms are a common source of annoyance complaints from facilities that involve the use of heavy vehicles in their operation. Due to the low existing background noise levels in the vicinity of the proposed site it is recommended that consideration be given to noise emissions in the selection of reversing alarms that are fitted to vehicles using the facility.

Where equipment is required to have a reversing alarm, it is recommended that reversing alarms which automatically adjust output sound levels according to the prevailing ambient noise level be used. Preferably, broadband reversing alarms should be fitted in place of tonal alarms.

5.2.2.3 Staging Plan

It is noted that the equipment would generally operate below the level of the perimeter maintenance road during the early life of each cell and some additional natural shielding would be provided which has not been included in the modelling. Similarly, as the level of material in the landfill increases, additional shielding would be provided to the south and the east by the compacted waste itself.

It has been proposed that the landfill is filled from the east to the west and from the south to the north. However, it is noted that filling each cell from the west to the east would maximise the amount of shielding provided to Receiver 1 over the life of the landfill.

5.2.2.4 Location of Stockpiles

As far as practical, cover material should generally be stockpiled along the west or south of the active landfill cell in order to provide additional shielding to the most-affected receivers.

5.2.2.5 Minimise Dozer and Scraper Operations

Noise levels at all receivers are typically dominated by Dozer and Scraper operations. Therefore, the use of these items of plant should be minimised as far as practical, particularly when working at the extremities of the site.

Dozer and scraper operations would not be undertaken prior to 7am on weekdays and prior to 8am on weekends and public holidays, therefore there will be no noise impact during the night time assessment period.

5.2.3 Calculated Sound Power Levels with Plant Noise Attenuation

With the plant noise control measures outlined in Section 5.2.2.1and 5.2.2.2 implemented, the sound power levels for the equipment would be approximately as shown in Table 11.

5.2.4 Noise Levels at Receivers with Plant Noise Attenuation

The noise modelling was repeated to determine the expected noise impact in the situation where attenuated equipment is used. Noise levels were calculated at the identified receivers under neutral meteorological conditions with the recommended plant noise attenuation measures implemented. The calculated noise levels resulting from the operation of the proposed development with the recommended plant noise attenuation measures implemented are summarised in **Table 12**.

Table 12 – Attenuated Plant Operating During Daytime under Neutral Meteorological Conditions

Receiver	Location Of Equipment					
	Cell 1		Cell 3		Cell 5	
	Fill	Cover	Fill	Cover	Fill	Cover
Strathaven	29	30	30	31	30	31
Sherraloy	35	38*	24	31	23	27
Riverton	20	21	22	23	22	23
4 North 1	25	25	27	28	28	29
5 North 2	24	24	26	27	27	28
6 North West	19	20	21	22	22	23

*Denotes exceedance of environmental criterion.

The results indicate a minor exceedance of the criteria at the Sherraloy receiver of approximately 3 dB(A) during covering operations of Cell 1. However, it should be noted that the modelling assumes that the plant is operating on the finished contours of the landfill, which will only occur as the cell (or sub-cell) reaches capacity. This represents a “worst case” since, for the majority of the operating life of Cell 1, additional shielding to the Sherraloy receiver would be provided by the natural contours of the site.

Therefore, it is considered that with only the plant noise mitigation measures implemented, the proposed development would generally comply with the environmental criteria for the site, under the neutral meteorological conditions that have been shown to be typical of the site. Minor exceedances of the criterion of up to 3 dB(A) may occur at certain times near the end of the operating life of Cell 1.

However, since the day time criterion is equal to the night time criterion and the INP minimum assessment level, clause 2.1 of the INP would apply, meaning minor exceedances of 3 dB(A) would generally be acceptable for the daytime operations.

5.3 Construction Scenario

The assessment of the construction scenario was based on the following equipment operating on the proposed site.

- 20 truck movements per day along the site access road, with a peak of 5 movements per hour;
- 10 truck movements per hour along the perimeter maintenance road;
- 1 movement per hour along the perimeter road and site access road for the water cart;
- 1 Compactor and 1 Grader located along the western portion of the perimeter road; and,
- 1 Excavator and 1 Dozer working in the area of Cell 1.

Equipment would generally be distributed across the site, however, a worst case scenario where the equipment is predominantly working at the extremities of the construction area nearest Receivers 1 and 2 has been used for the purpose of the noise assessment.

5.3.1 Calculated Noise Levels

The analysis indicates that the proposed construction noise objective of 40 dB(A) would be expected to be met for the all receivers when equipment is operating in the typical configuration described above. Small variations in noise levels would be expected at the receivers based on variation in the location of the equipment and wind conditions. Under the maximum impact wind conditions outlined in the INP the noise levels would be expected to be 5-6 dB(A) higher then the levels in Table 13. However, these conditions have been shown to occur for less than 30% of any assessment period in any season and, in accordance with the guidance given in the INP are not considered to be significant.

Table 13 - All Construction Plant Operating During Daytime under Neutral Meteorological Conditions

Receiver	**L_{Aeq} dB(A)**
Strathaven	36
Sherraloy	38
Riverton	28
4 North 1	32
5 North 2	34
6 North West	28

5.3.2 Recommended Construction Noise Control Measures

A Construction Noise Management Plan (CNMP) should be prepared by the construction contractor prior to the start of site works. The noise management plan should detail the best practice construction methods to be used, presenting a reasonable and feasible approach. The CNMP would also include a noise monitoring program, reasonable and feasible noise mitigation measures, a complaint management strategy and contingency plans if noise exceedances or justified complaints were to occur.

Due to the extremely low existing background noise levels at the receiver locations, all reasonable opportunities to minimise noise emission from the site should be undertaken. The following general measures are typical of the best practice noise management and should be applied to minimise noise emission from the site during the construction period.

- Maximising the offset distance between noisy plant items and nearby noise sensitive receivers;
- Avoiding the co-incidence of noisy plant working simultaneously close together and adjacent to sensitive receivers;
- Orienting equipment away from sensitive areas;
- Carrying out loading and unloading away from noise sensitive areas;
- Selecting site access points and roads as far as possible away from sensitive receivers;
- Ensuring that vehicles required on site do not ‘queue’ outside the worksite prior to the morning start time;
- Ensuring all construction vehicles enter and leave the site in accordance with site entry controls;
- Ensuring no truck associated with the work is left standing with its engine operating;
- All equipment, including bulldozers, graders, excavators and trucks should have all reasonable and feasible noise controls fitted to reduce noise emission as much as is feasibly possible. The noise attenuation measures should include:
    - The encapsulation of engine chambers;
    - Fitting ‘Department of Environment and Conservation (DEC)’ approved silencers to all powered operated plant; and,
    - The use of reversing alarms which automatically adjust output sound levels according to the prevailing ambient noise level. Preferably, broadband noise alarms should be fitted in place of tonal alarms.
- Notifying the surrounding community via letter drops and/or local media announcements of any forthcoming unusual construction activities; and,
- Engaging community consultation prior to and throughout the construction phase.

6.0 Off Site Traffic Noise Assessment

6.1 Increase in Noise Levels

The proposed development would be expected to generate twelve traffic movements per day as outlined below:

- 3 x waste vehicles to and from the site (total 6 movements);
- 1 x cover truck to and from the site (total 2 movements); and,
- 2 x staff vehicles to and from the site (total 4 movements).

The increase in traffic noise levels was assessed to determine compliance with the ECRTN criteria.

6.1.1.1 Waste Vehicles from Long Swamp Road Facility

Waste vehicles bound for the proposed landfill facility from the Long Swamp Road transfer station would use Long Swamp Road and Canambe Street and would then turn right onto Grafton Road and proceed along Waterfall Way to the proposed site.

Long Swamp Road and Canambe Street currently experience heavy vehicle traffic associated with the operation of the existing landfill. The number of additional truck movements generated by the proposed landfill would be small. Assuming that the trucks that currently leave empty from the existing Long Swamp Rd Landfill would be used to meet the majority of the transport requirements between the transfer station and the proposed landfill site, a maximum increase in traffic noise levels due to trucks associated with the facility of 1.2 dB(A) would be expected. No significant change to light vehicle traffic noise would be expected.

It is noted that this is an inherently conservative assessment as only the waste vehicles serving the new landfill facility have been considered. In practice, additional traffic on the streets would reduce the impact further. As the number of additional traffic movements is expected to be small, at 3 trucks per day, a detailed assessment of the existing level of traffic noise was not undertaken.

6.1.1.2 Traffic along Waterfall Way

The cover trucks and the staff vehicles would be expected to travel between Armidale and the proposed landfill facility via Waterfall Way but would not originate from the existing transfer station. Upon arrival in Armidale, vehicles leaving the landfill would generally be identified as normal traffic.

The existing vehicle traffic along Waterfall Way has been based on the hourly traffic survey data supplied by Armidale Dumeresq Council.

Due to the small number of traffic movements generated by the facility, a maximum impact assessment has been undertaken, whereby the total number of waste vehicle movements per day has been assumed to occur in each operating hour of the landfill.

The assessment indicates that the volume of traffic movements associated with the development would not be expected to significantly increase traffic noise along Waterfall Way, with a maximum calculated increase in noise levels of 0.7 dB(A) between 7am and 8am on weekday mornings for the operational scenario. The maximum calculated increase in noise levels during the construction period is 0.9 dB(A) between 7am and 8 am on weekday mornings.

Based on the above discussion and the assessment detailed in Appendix **Error! Reference source not found.** the traffic generated by the proposed landfill facility would not be expected to increase traffic noise levels on Waterfall Way, Long Swamp Road or Canambe Street by more than 2 dB(A) and would therefore comply with the ECRTN criteria.

6.2 Sleep Arousal

The operating hours of the landfill and limited number of truck movements would be expected to limit the time of impact for heavy vehicle traffic through the residential areas along Long Swamp Road and Canambe Street to the daytime period. Therefore the development would not be expected to generate additional night time maximum noise events due to heavy vehicle pass bys.

7.0 Conclusion

The noise emission from the proposed landfill facility off Waterfall Way has been assessed against the criteria contained in the DEC *Industrial Noise Policy* to determine the impact at the nearest receivers throughout the life of the landfill site.

Due to the low existing background noise levels, the noise emission from site operations would need to be controlled to ensure compliance with the INP criteria. However, as discussed in Section 4.1.3 and in accordance with Section 2.1 of the INP, a 3 dB(A) exceedance of the day time environmental noise criteria is considered to be negligible and unlikely to have the same impact as an equivalent exceedance at night time. With the mitigation measures discussed in Section 5.2.2 implemented, it is expected that the noise levels at the nearest receivers would comply with the criteria for the typical operational scenarios that have been analysed.

The expected increase in traffic noise resulting from traffic generated by the proposed landfill facility was calculated and found to be less than 2 dB(A). Therefore the proposed landfill facility would be expected to comply with the criteria outlined in the DEC *Environmental Criteria for Road Traffic Noise.*

As the proposed landfill facility would be reliant on engineered noise control treatment, the ongoing maintenance of equipment will be critical to ensure the continuing compliance with the noise criteria. For this reason it is recommended that an annual compliance monitoring program be undertaken to confirm that the site noise emissions remain acceptable over the life of the landfill.

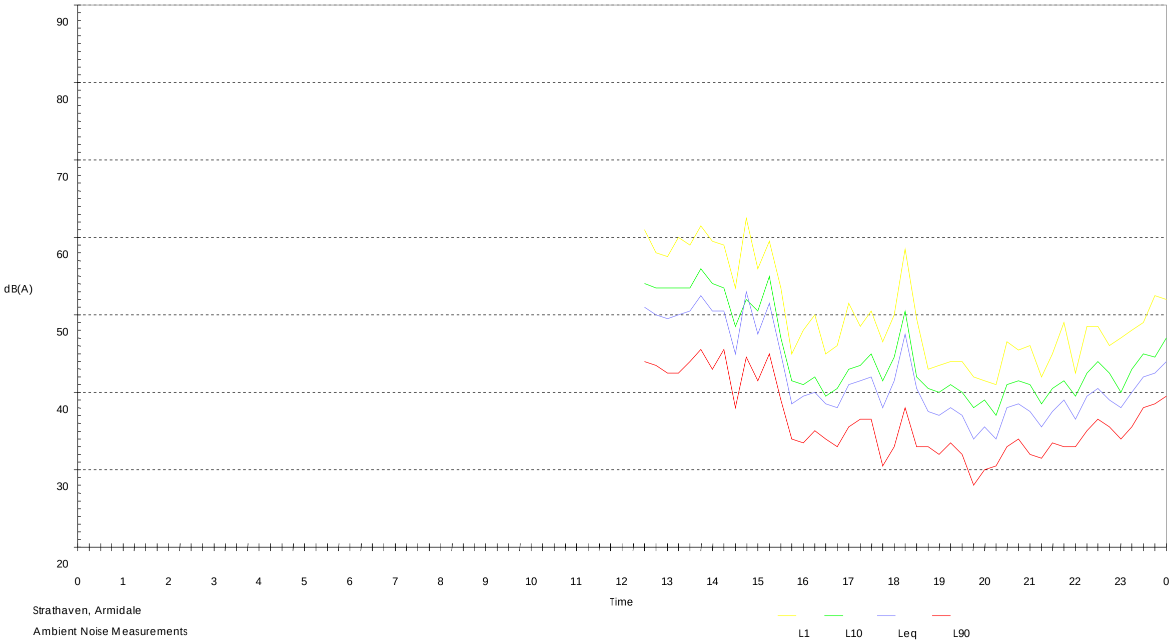
Appendix A

Graphical Measurement Results

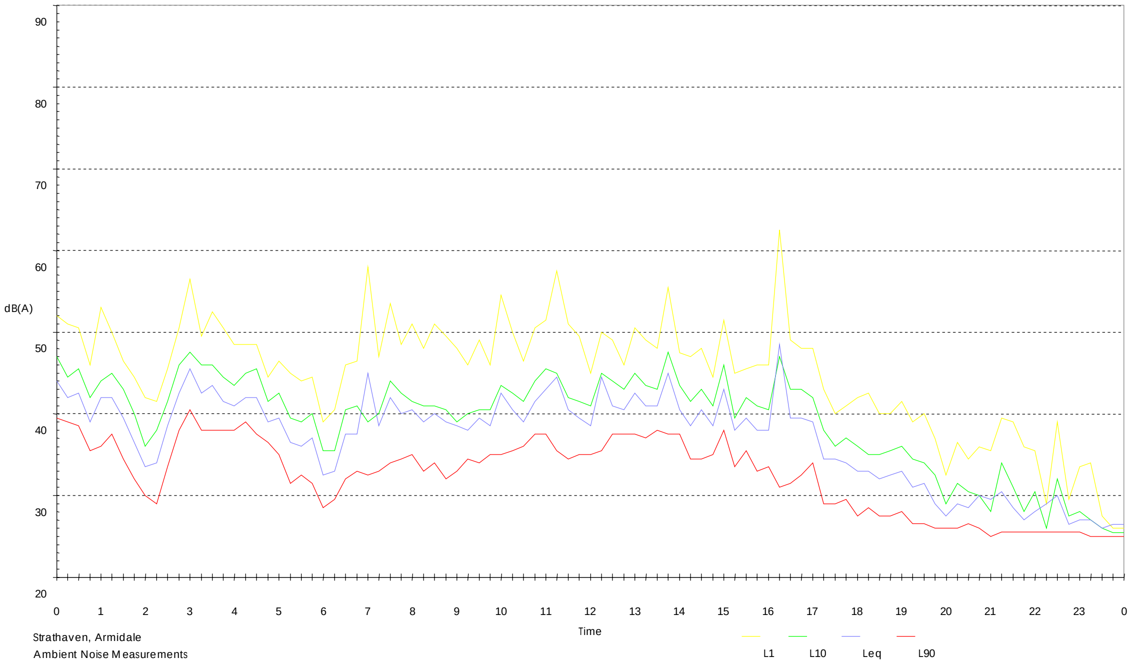
This page has been left blank intentionally

Strathaven, Armidale

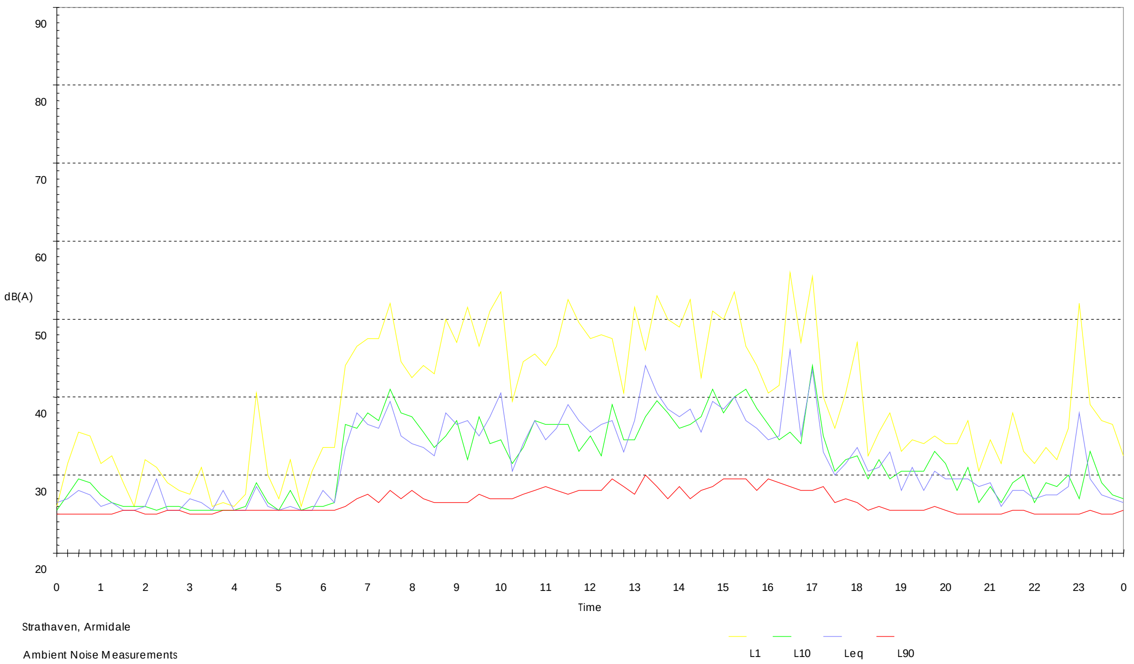
Friday 02 June, 2006



Saturday 03 June, 2006



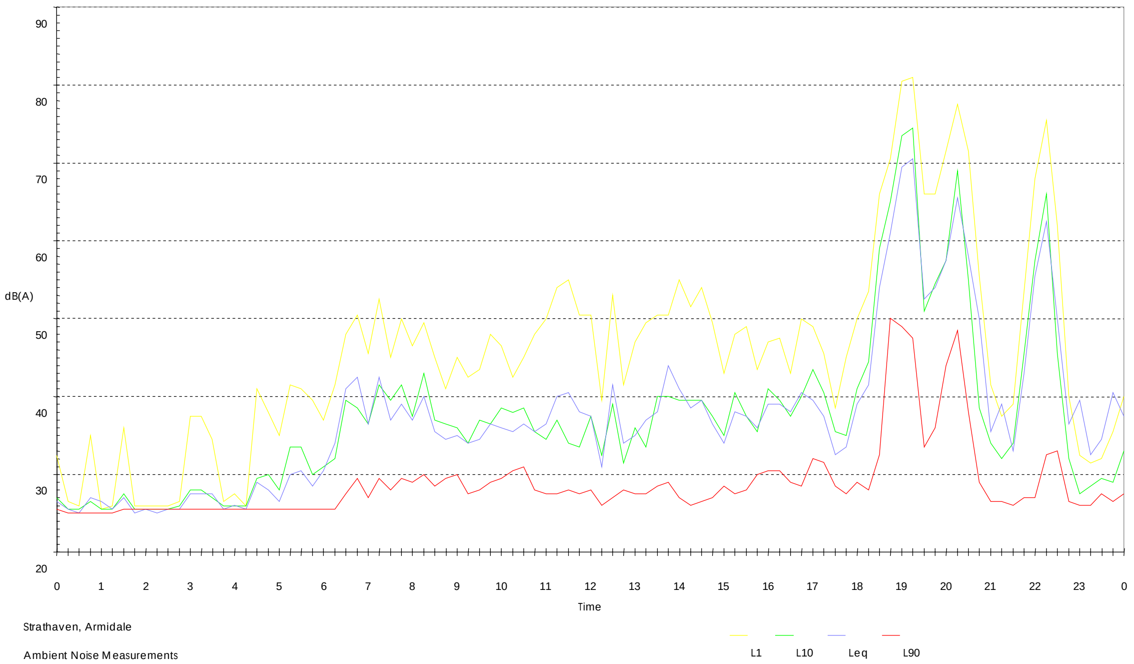
Sunday 04 June, 2006



Strathaven, Armidale

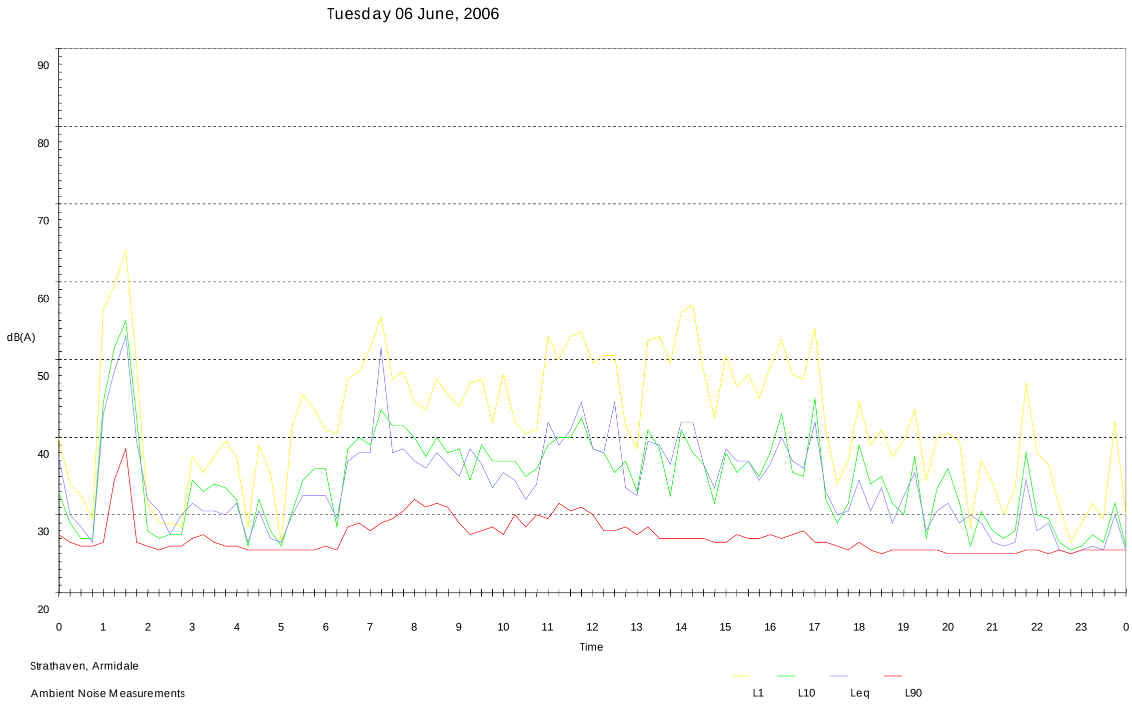
Ambient Noise Measurements

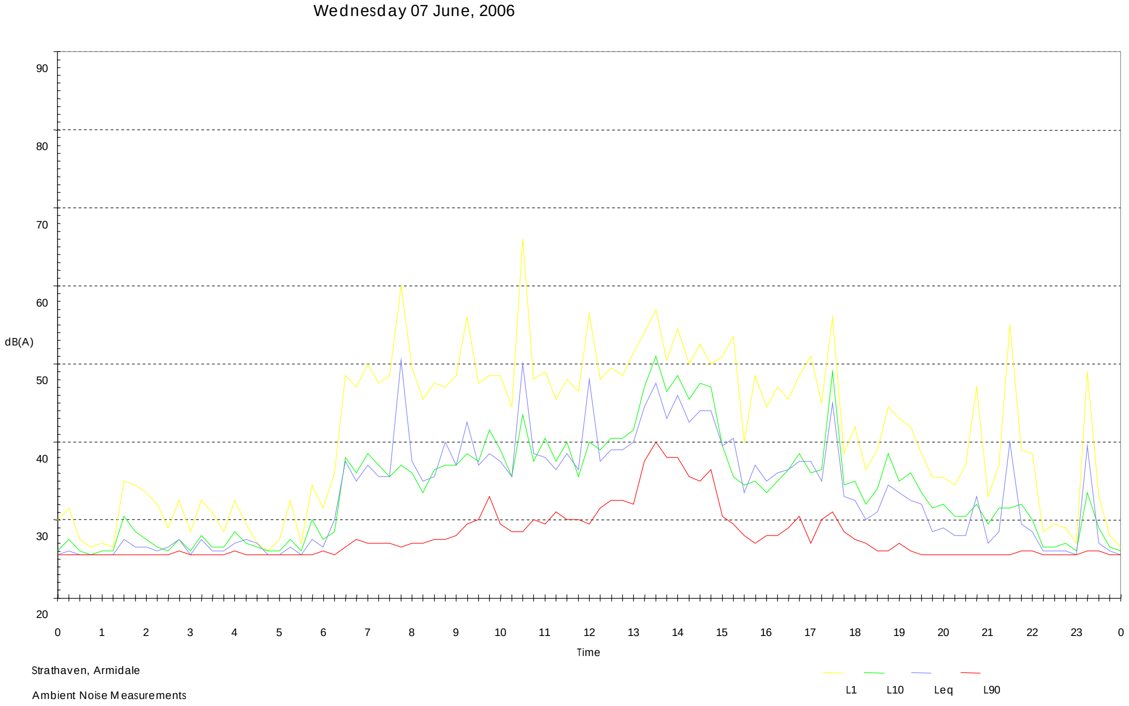
Monday 05 June, 2006



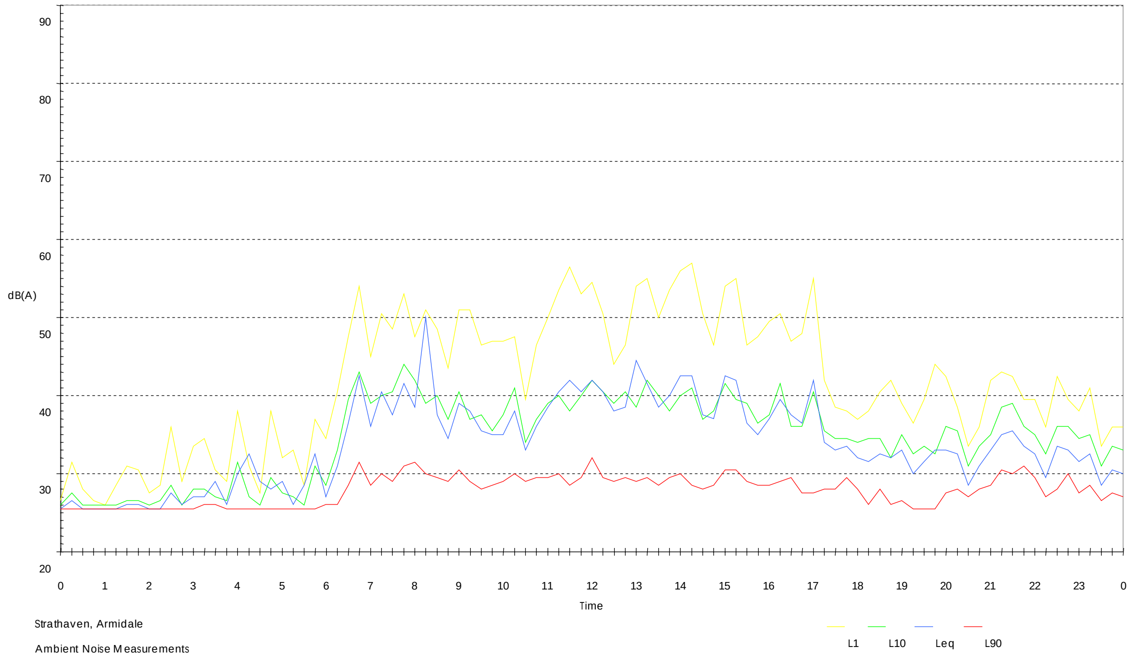
Strathaven, Armidale

Ambient Noise Measurements


Tuesday 06 June, 2006
90
80
70
60
50
40
30
20
dB(A)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0
Time
Strathaven, Armidale
Ambient Noise Measurements
L1
L10
Leq
L90


Wednesday 07 June, 2006
90
80
70
60
50
40
30
20
dB(A)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0
Time
Strathaven, Armidale
Ambient Noise Measurements
L1
L10
Leq
L90

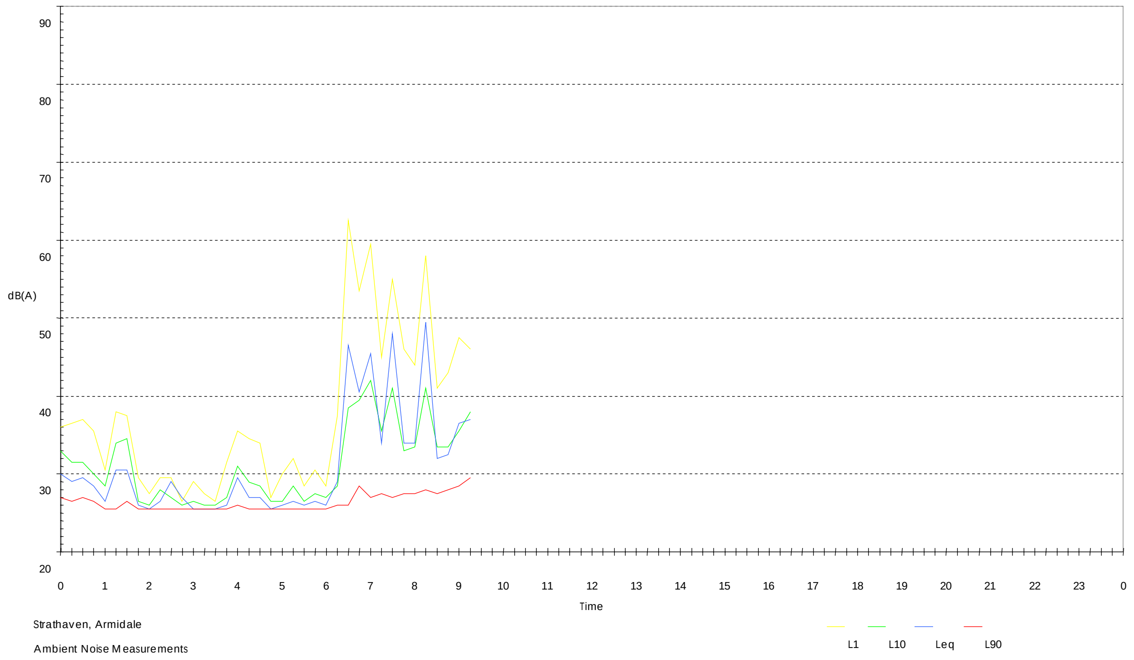
Thursday 08 June, 2006



Strathaven, Armidale

Ambient Noise Measurements

Friday 09 June, 2006

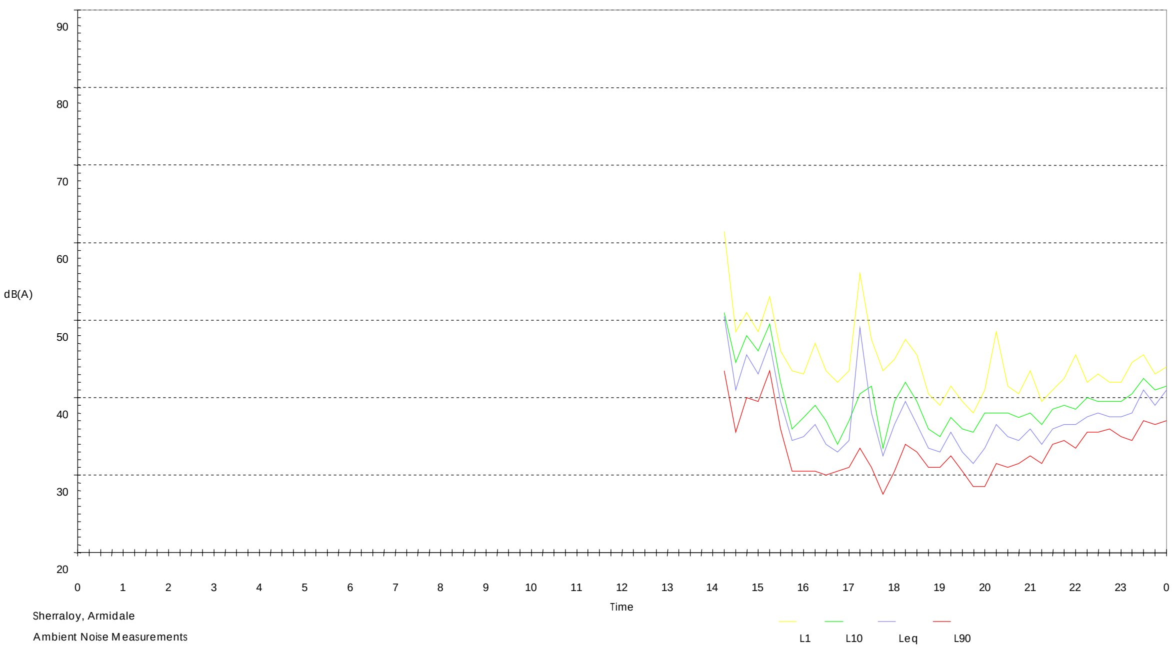


Strathaven, Armidale

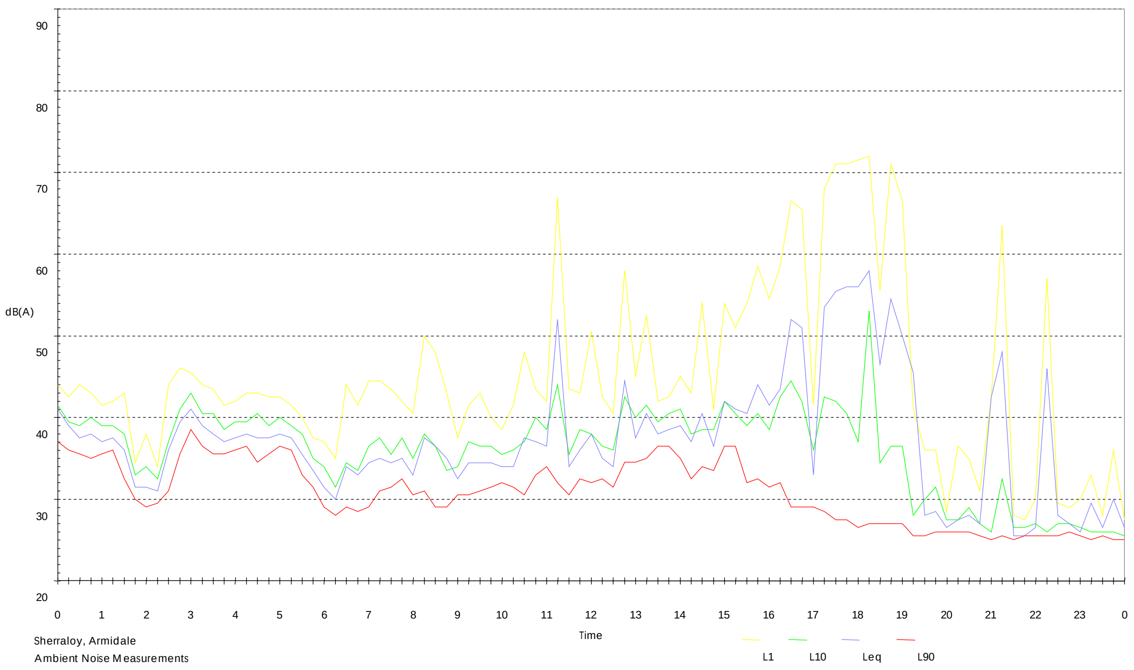
Ambient Noise Measurements

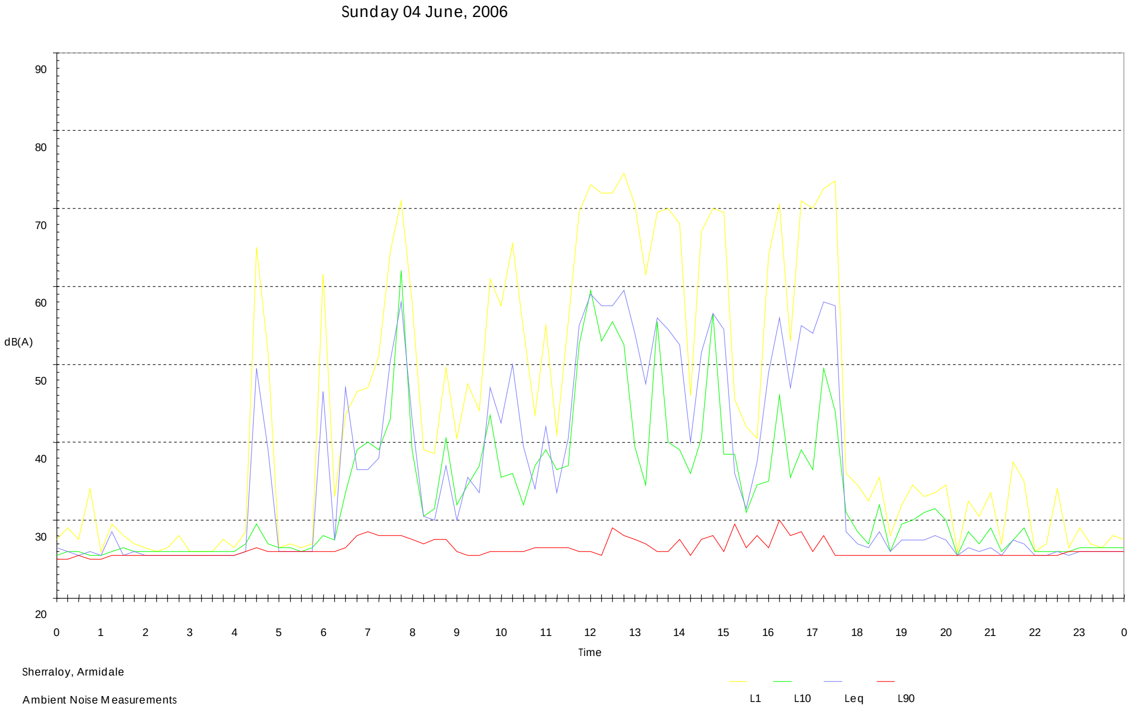
Sherraloy, Armidale

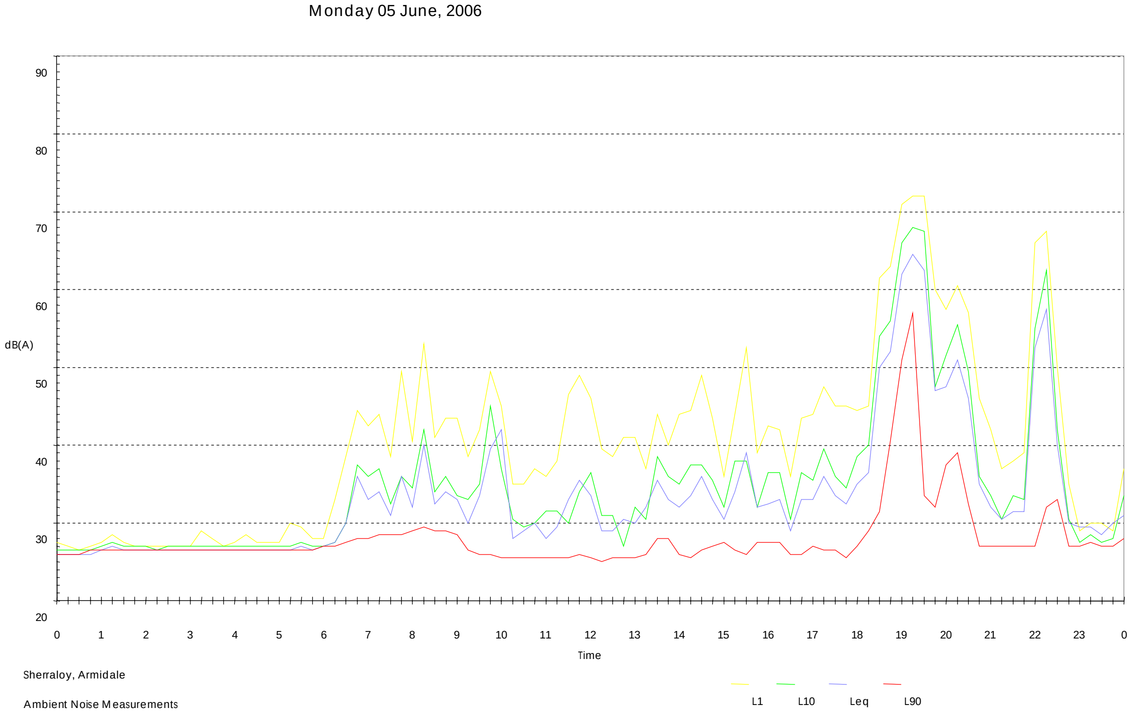
Friday 02 June, 2006

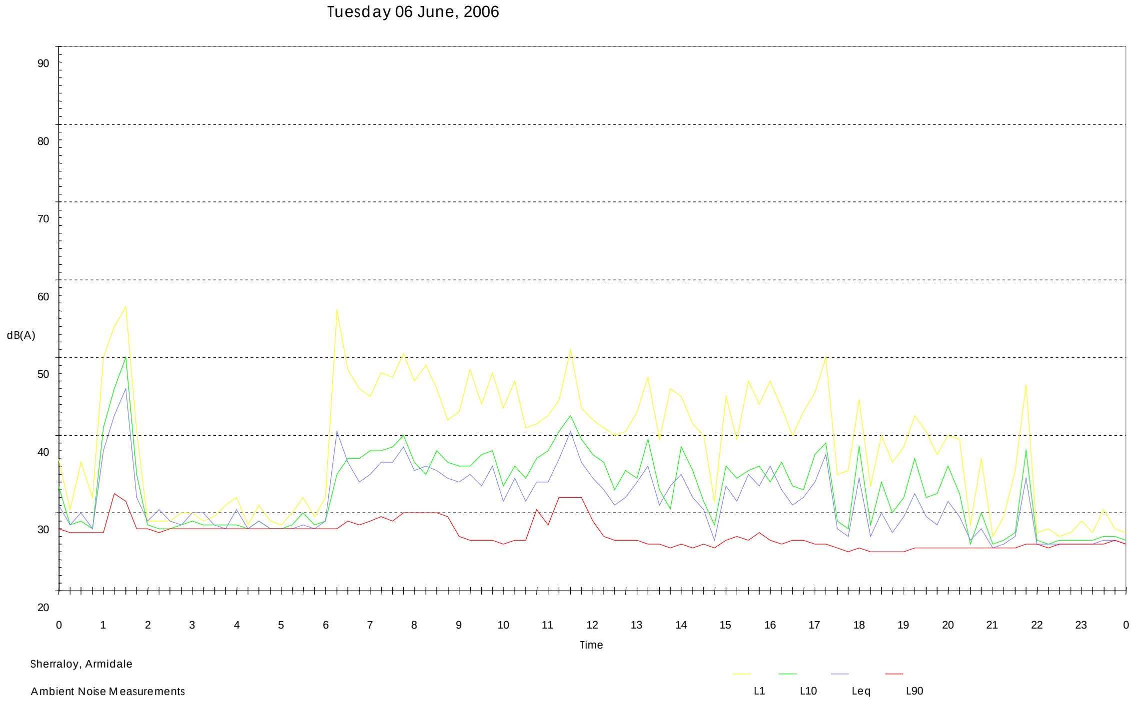


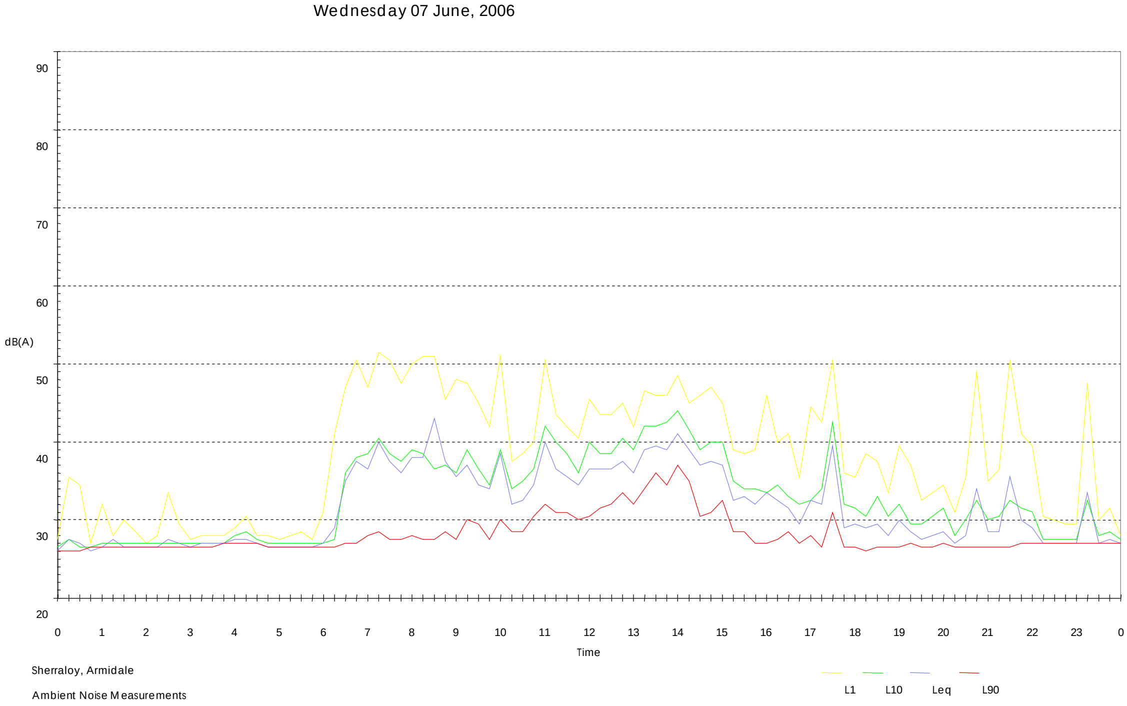
Saturday 03 June, 2006

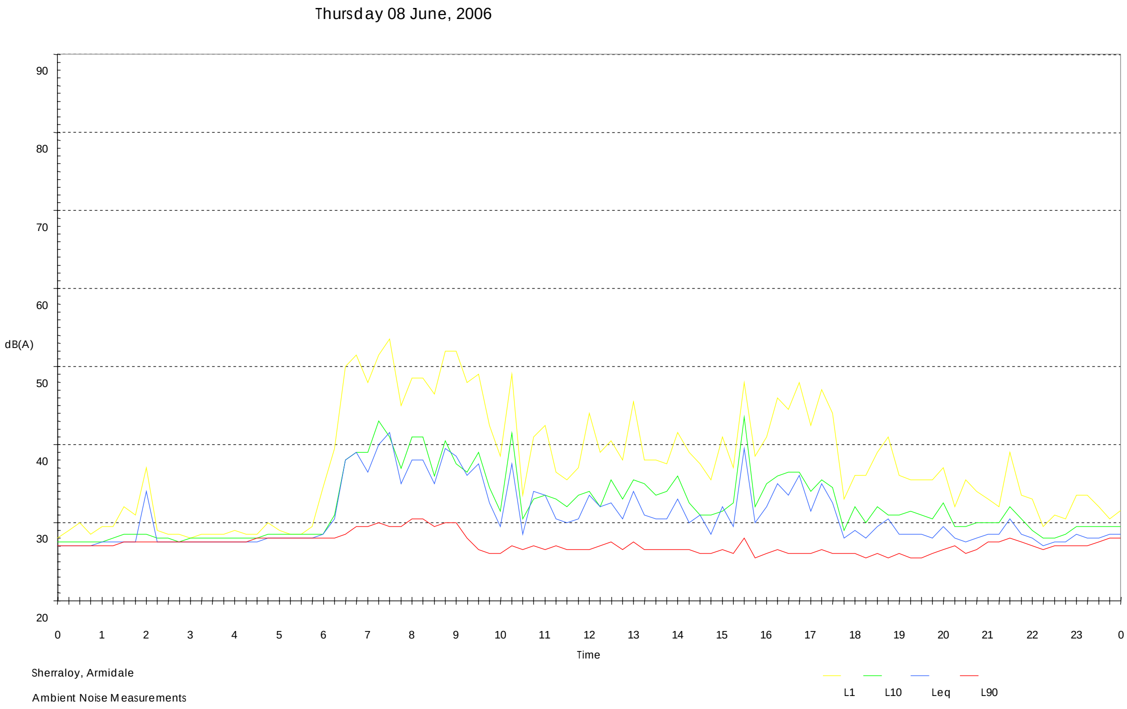


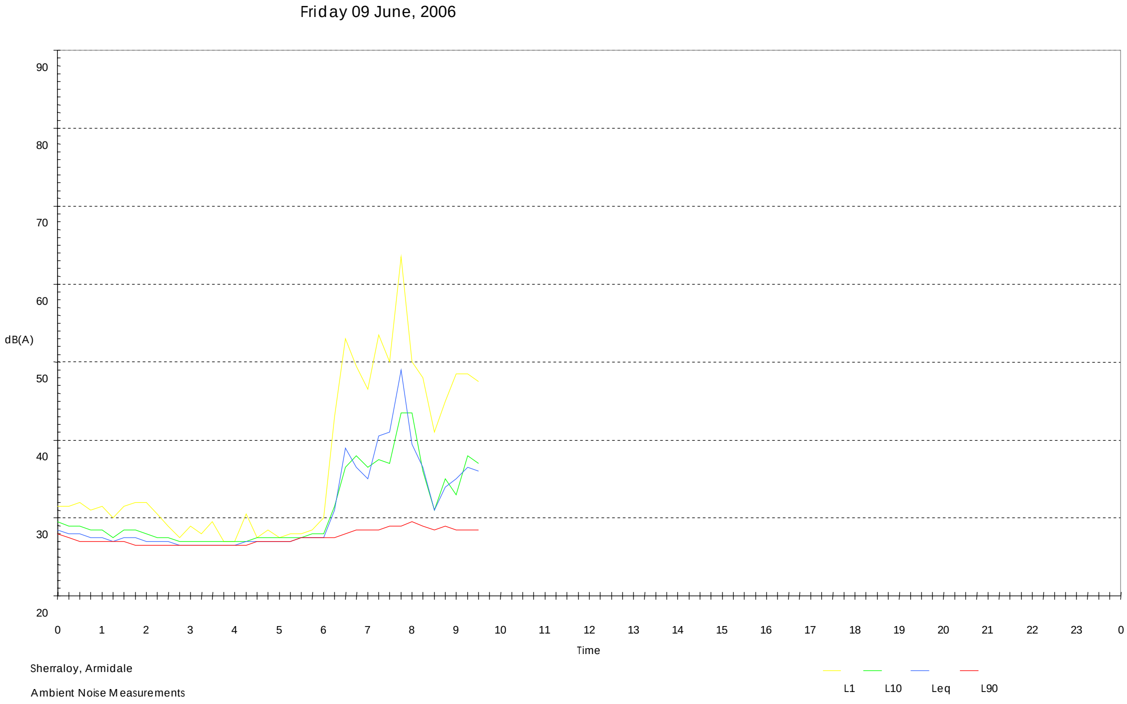

Sunday 04 June, 2006
dB(A)
90
80
70
60
50
40
30
20
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0
Time
Sherraloy, Armidale
Ambient Noise Measurements
L1
L10
Leq
L90


Monday 05 June, 2006
dB(A)
90
80
70
60
50
40
30
20
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0
Time
Sherraloy, Armidale
Ambient Noise Measurements
L1
L10
Leq
L90


Tuesday 06 June, 2006
dB(A)
90
80
70
60
50
40
30
20
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
0
Time
Sherraloy, Armidale
Ambient Noise Measurements
L1
L10
Leq
L90


Wednesday 07 June, 2006
dB(A)
90
80
70
60
50
40
30
20
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
0
Time
Sherraloy, Armidale
Ambient Noise Measurements
L1
L10
Leq
L90


Thursday 08 June, 2006
dB(A)
90
80
70
60
50
40
30
20
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
0
Time
Sherraloy, Armidale
Ambient Noise Measurements
L1
L10
Leq
L90


Friday 09 June, 2006
dB(A)
90
80
70
60
50
40
30
20
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
0
Time
Sherraloy, Armidale
Ambient Noise Measurements
L1
L10
Leq
L90

Appendix B

Glossary of Acoustic Terminology

Glossary of Acoustic Terminology

The following is a brief description of the acoustic terminology used in this report.

Ambient Sound	The totally encompassing sound in a given situation at a given time usually composed of sound from all sources near and far.
Audible Range	The limits of frequency which are audible or heard as sound. The normal ear in young adults detects sound having frequencies in the region 20 Hz to 20 kHz, although it is possible for some people to detect frequencies outside these limits.
Character, acoustic	The total of the qualities making up the individuality of the noise. The pitch or shape of a sound's frequency content (spectrum) dictate a sound's character.
Decibel [dB]	The level of noise is measured objectively using a Sound Level Meter. The following are examples of the decibel readings of every day sounds;

0dB	The faintest sound we can hear
30dB	A quiet library or in a quiet location in the country
45dB	Typical office space. Ambience in the city at night
60dB	Martin Place at lunch time
70dB	The sound of a car passing on the street
80dB	Loud music played at home
90dB	The sound of a truck passing on the street
100dB	The sound of a rock band
115dB	Limit of sound permitted in industry
120dB	Deafening

dB(A)	*A-weighted decibels* The ear is not as effective in hearing low frequency sounds as it is hearing high frequency sounds. That is, low frequency sounds of the same dB level are not heard as loud as high frequency sounds. The sound level meter replicates the human response of the ear by using an electronic filter which is called the "A" filter. A sound level measured with this filter switched on is denoted as dB(A). Practically all noise is measured using the A filter. The sound pressure level in dB(A) gives a close indication of the subjective loudness of the noise.
Frequency	Frequency is synonymous to *pitch*. Sounds have a pitch which is peculiar to the nature of the sound generator. For example, the sound of a tiny bell has a high pitch and the sound of a bass drum has a low pitch. Frequency or pitch can be measured on a scale in units of Hertz or Hz.
Loudness	A rise of 10 dB in sound level corresponds approximately to a doubling of subjective loudness. That is, a sound of 85 dB is twice as loud as a sound of 75 dB which is twice as loud as a sound of 65 dB and so on
L_{max}	The maximum sound pressure level measured over a given period.
L_{min}	The minimum sound pressure level measured over a given period.
L_1	The sound pressure level that is exceeded for 1% of the time for which the given sound is measured.
L_{10}	The sound pressure level that is exceeded for 10% of the time for which the given sound is measured.
L_{90}	The level of noise exceeded for 90% of the time. The bottom 10% of the sample is the L_{90} noise level expressed in units of dB(A) the L_{90} is usually described as the 'background noise level'
L_{eq}	The "equivalent noise level" is the summation of noise events and integrated over a selected period of time. The L_{eq} is usually described as the 'ambient noise level'

Appendix C

Traffic Noise Impact – Calculation Results

Traffic Noise Impact – Calculation Results

Table 14 - Increase in Traffic Noise Levels on Waterfall Way – Operation (Worst Case)

Time	Weekdays					Weekend				
	Existing Flow	Traffic Generated*		Proposed Flow	dB Increase	Existing Flow	Traffic Generated*		Proposed Flow	dB Increase
		Light Vehicles	Heavy Vehicles				Light Vehicles	Heavy Vehicles		
7:00	35	2	6	43	0.9	43			43	0.0
8:00	60		6	66	0.4	72	2	2	76	0.3
9:00	69		6	75	0.4	83		6	89	0.3
10:00	73		6	79	0.3	87		6	93	0.3
11:00	79		6	85	0.3	95		6	101	0.3
12:00	72		6	78	0.3	86		6	92	0.3
13:00	75		6	81	0.3	90		6	96	0.3
14:00	80		6	86	0.3	96		6	102	0.3
15:00	90		6	96	0.3	109		6	115	0.2
16:00	79		6	85	0.3	95		6	101	0.3
17:00	58	2	2	62	0.3	69		6	75	0.4
18:00	34			34	0.0	40	2	2	44	0.5
Total	**804**	**4**	**62**	**870**	**0.9**	**965**	**4**	**58**	**1027**	**0.5**

* Traffic generation based on 6 waste truck deliveries, 2 cover truck deliveries and 2 passenger vehicles per day with a peak of 6 vehicle movements per hour. Peak traffic movements were applied to each 1 hour period to determine the maximum impact.

Table 15 - Increase in Traffic Noise Levels on Waterfall Way – Construction (Worst Case)

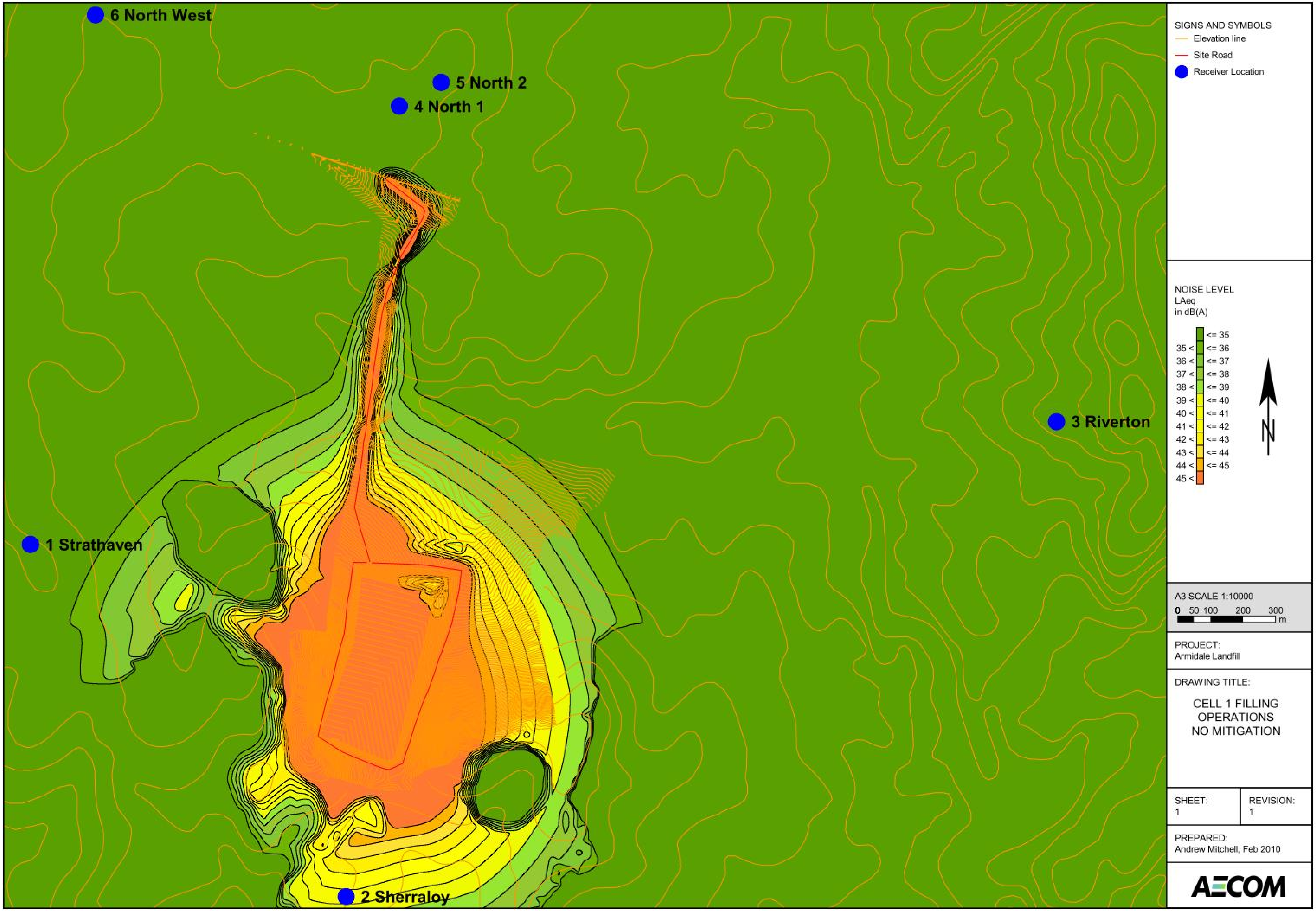
Time	Weekdays					Weekend				
	Existing Flow	Traffic Generated		Proposed Flow	dB Increase	Existing Flow	Traffic Generated		Proposed Flow	dB Increase
		Light Vehicles	Heavy Vehicles				Light Vehicles	Heavy Vehicles		
7:00	35	5	3	43	0.9	43			43	0.0
8:00	60		5	65	0.3	72	5	3	80	0.5
9:00	69		5	74	0.3	83		5	88	0.3
10:00	73		5	78	0.3	87		5	92	0.2
11:00	79		5	84	0.3	95		5	100	0.2
12:00	72		5	77	0.3	86		5	91	0.2
13:00	75		5	80	0.3	90		5	95	0.2
14:00	80		5	85	0.3	96		5	101	0.2
15:00	90		5	95	0.2	109		5	114	0.2
16:00	79		5	84	0.3	95		5	100	0.2
17:00	58	5	3	66	0.6	69	5	3	77	0.5
Total	**770**	**10**	**51**	**831**	**0.9**	**925**	**10**	**46**	**981**	**0.5**

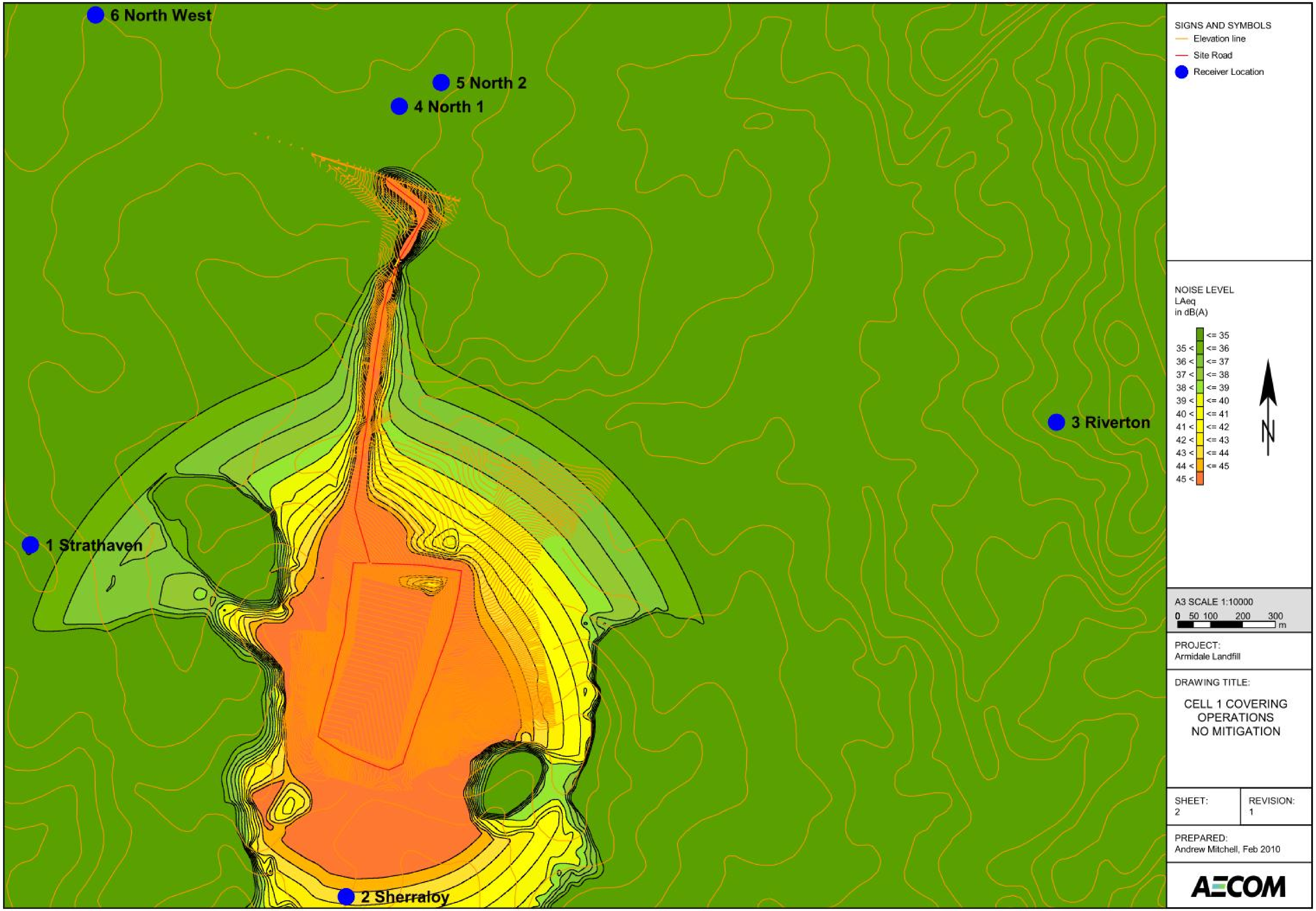
* Traffic generation based on 10 construction trucks and 5 passenger vehicles per day with a peak of 5 vehicles movements per hour. Peak traffic movements were applied to each 1 hour period to determine the maximum impact.

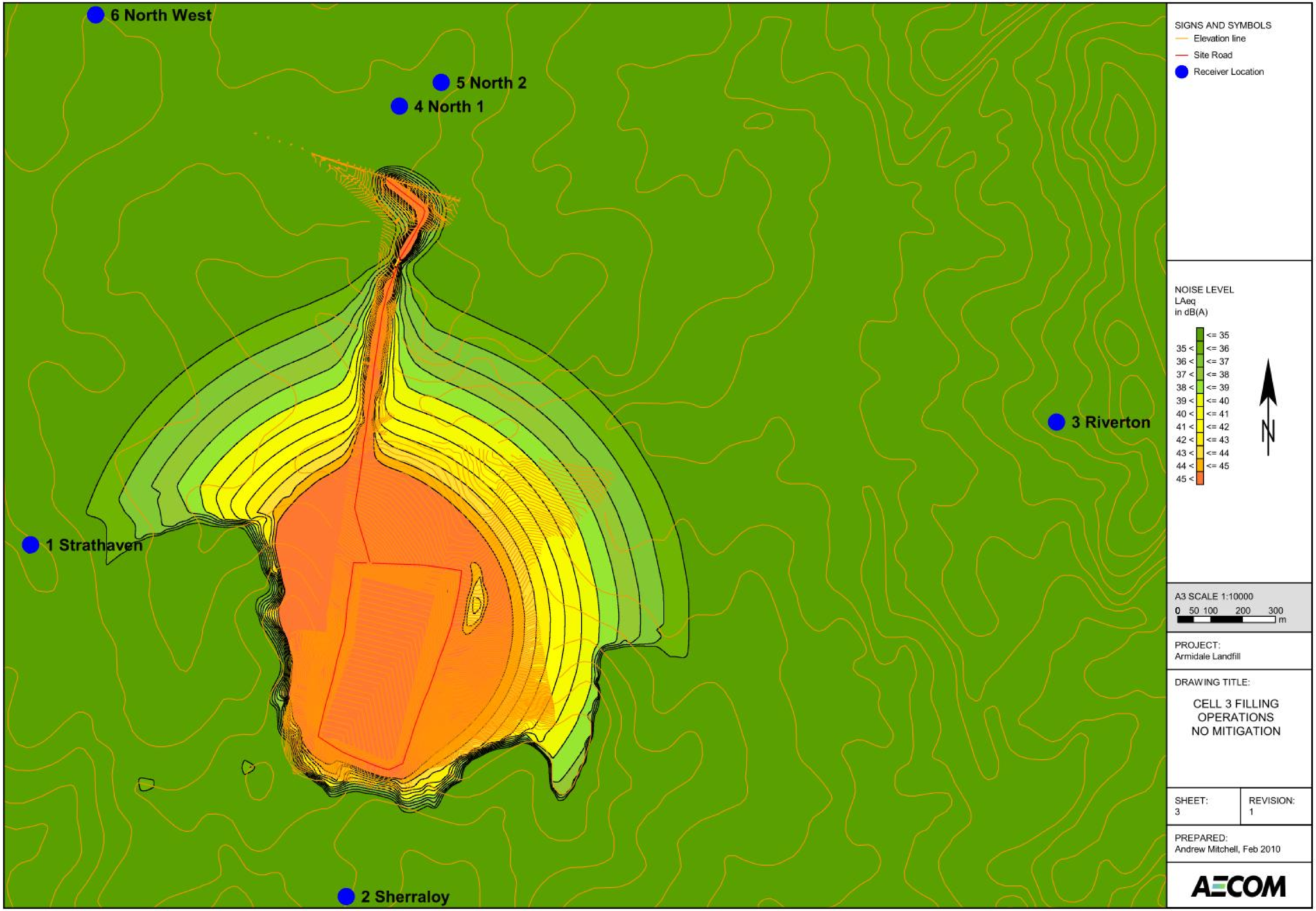
Appendix D

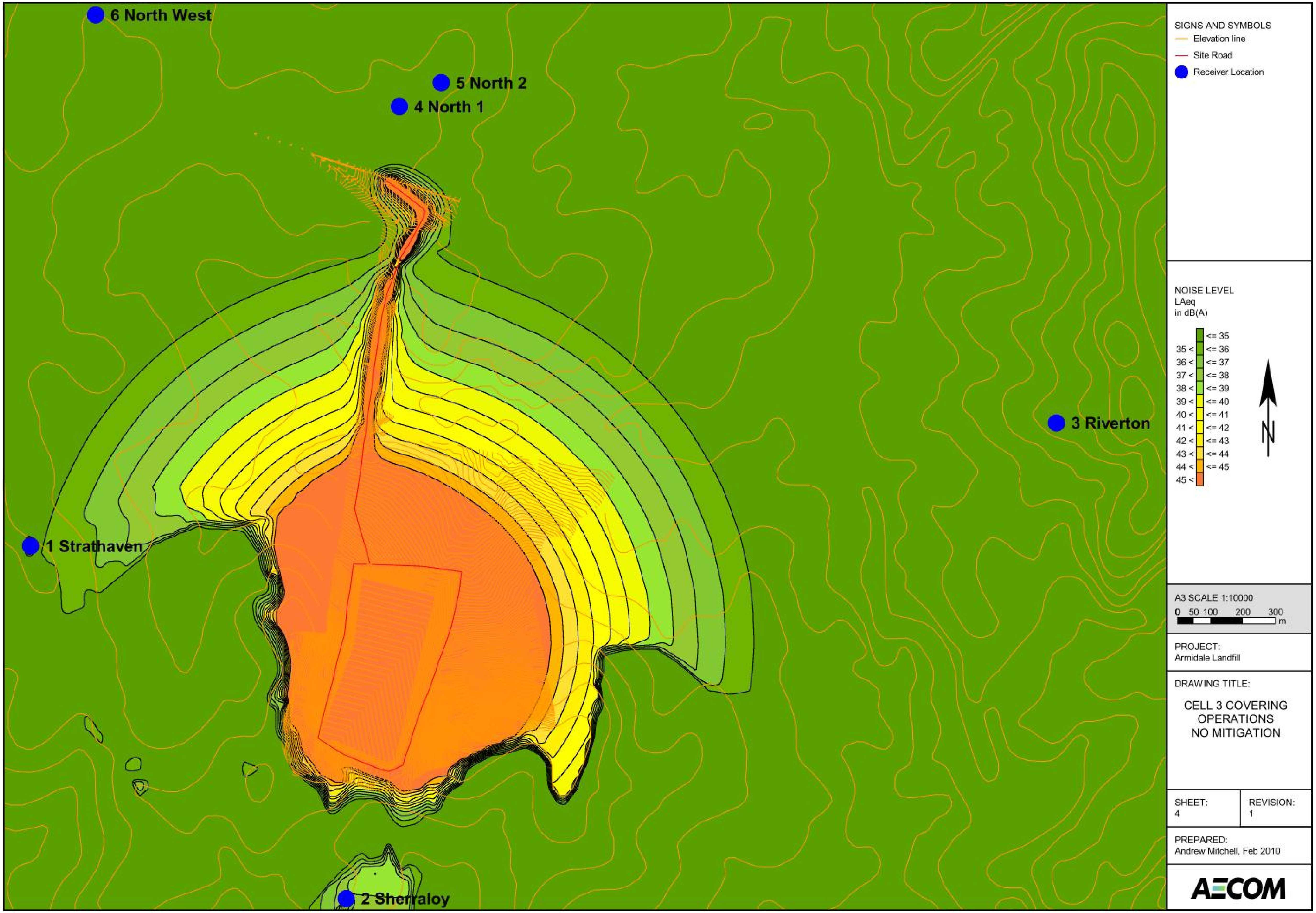
Noise Contour Plots

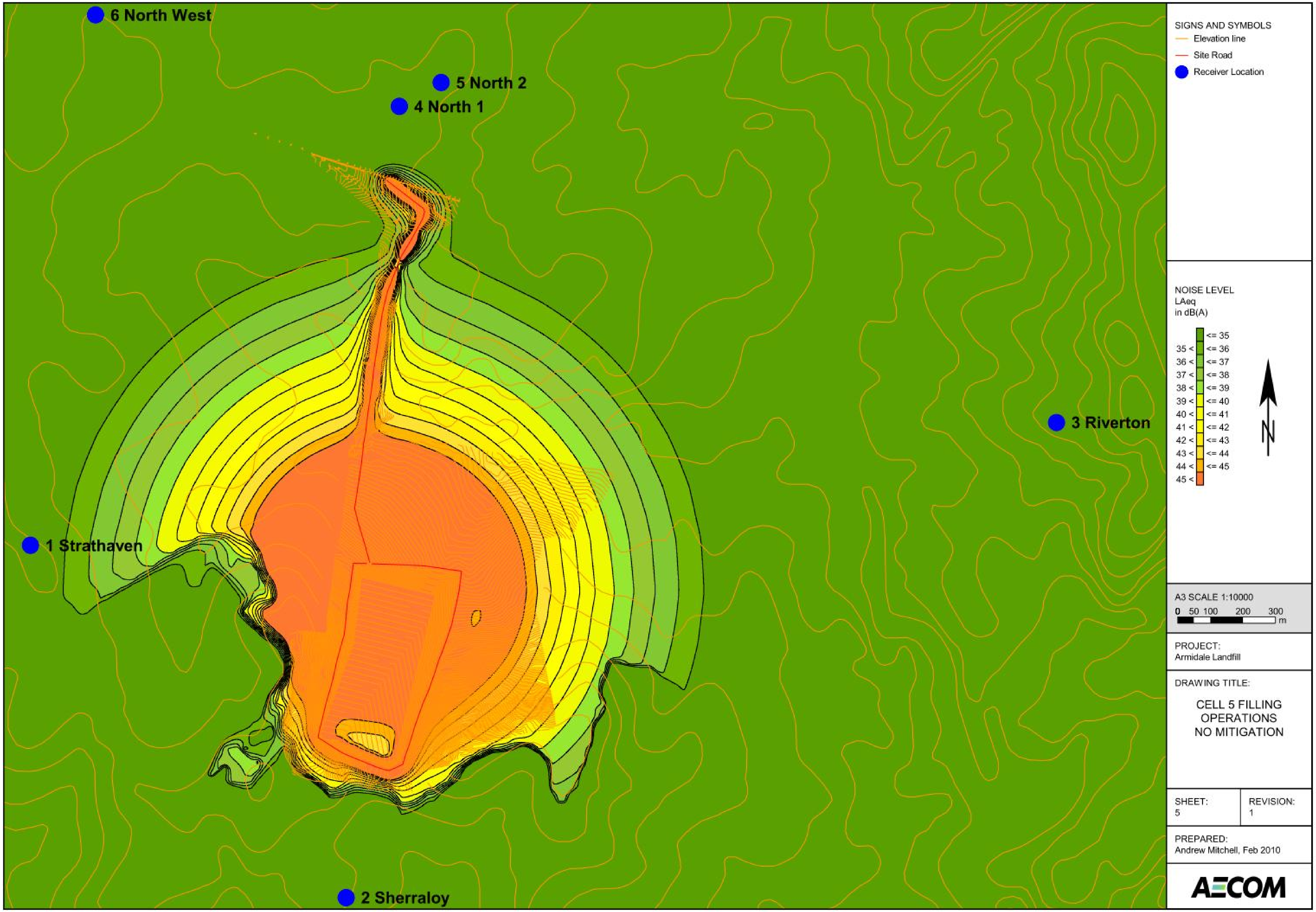
This page has been left blank intentionally

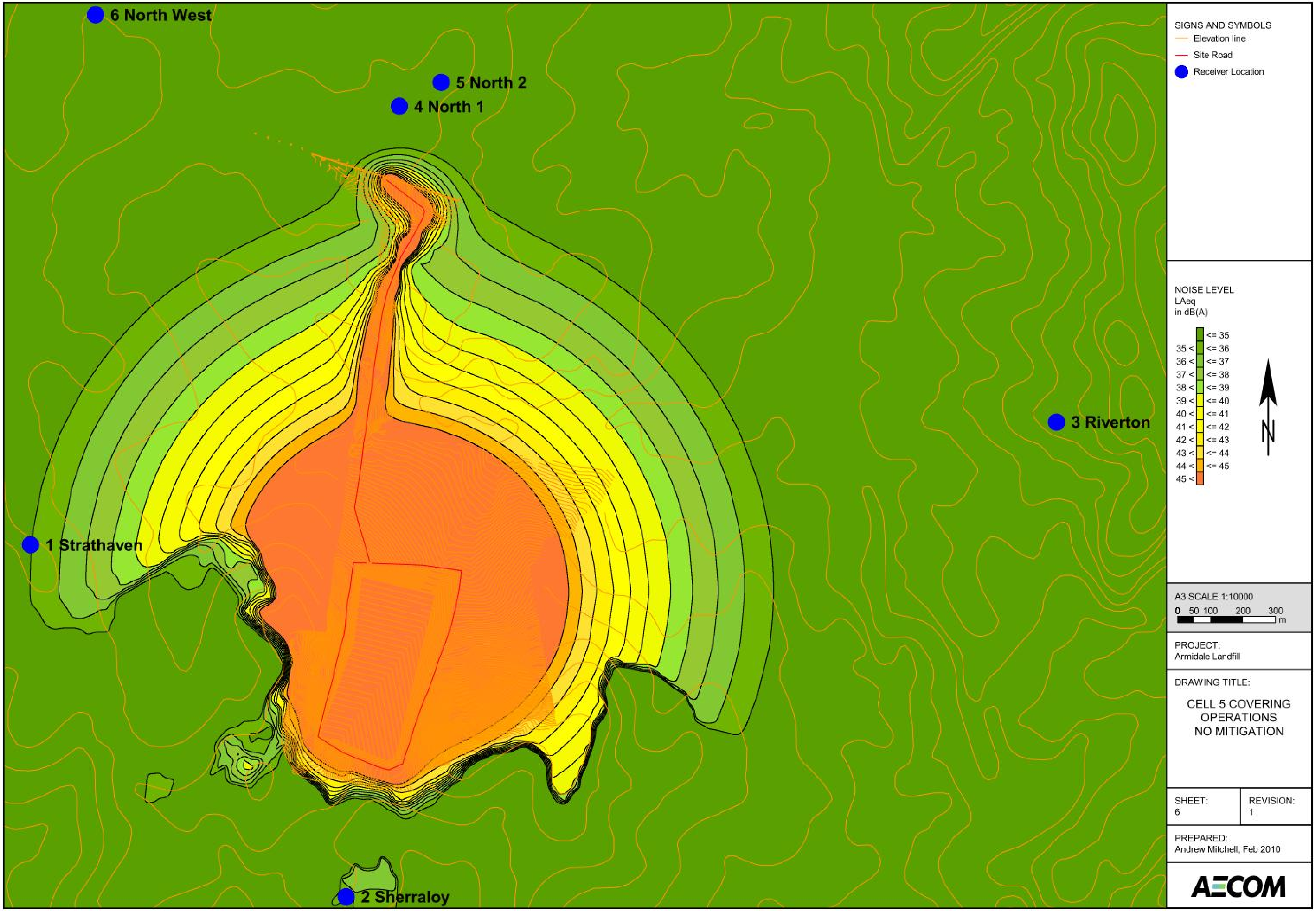

6 North West
5 North 2
4 North 1
3 Riverton
1 Strathaven
2 Sherraloy
SIGNS AND SYMBOLS
Elevation line
Site Road
Receiver Location
NOISE LEVEL
LAeq
in dB(A)
<= 35
35 < <= 36
36 < <= 37
37 < <= 38
38 < <= 39
39 < <= 40
40 < <= 41
41 < <= 42
42 < <= 43
43 < <= 44
44 < <= 45
45 <
N
A3 SCALE 1:10000
0 50 100 200 300 m
PROJECT:
Armidale Landfill
DRAWING TITLE:
CELL 1 FILLING OPERATIONS NO MITIGATION
SHEET:
1
REVISION:
1
PREPARED:
Andrew Mitchell, Feb 2010
AECOM

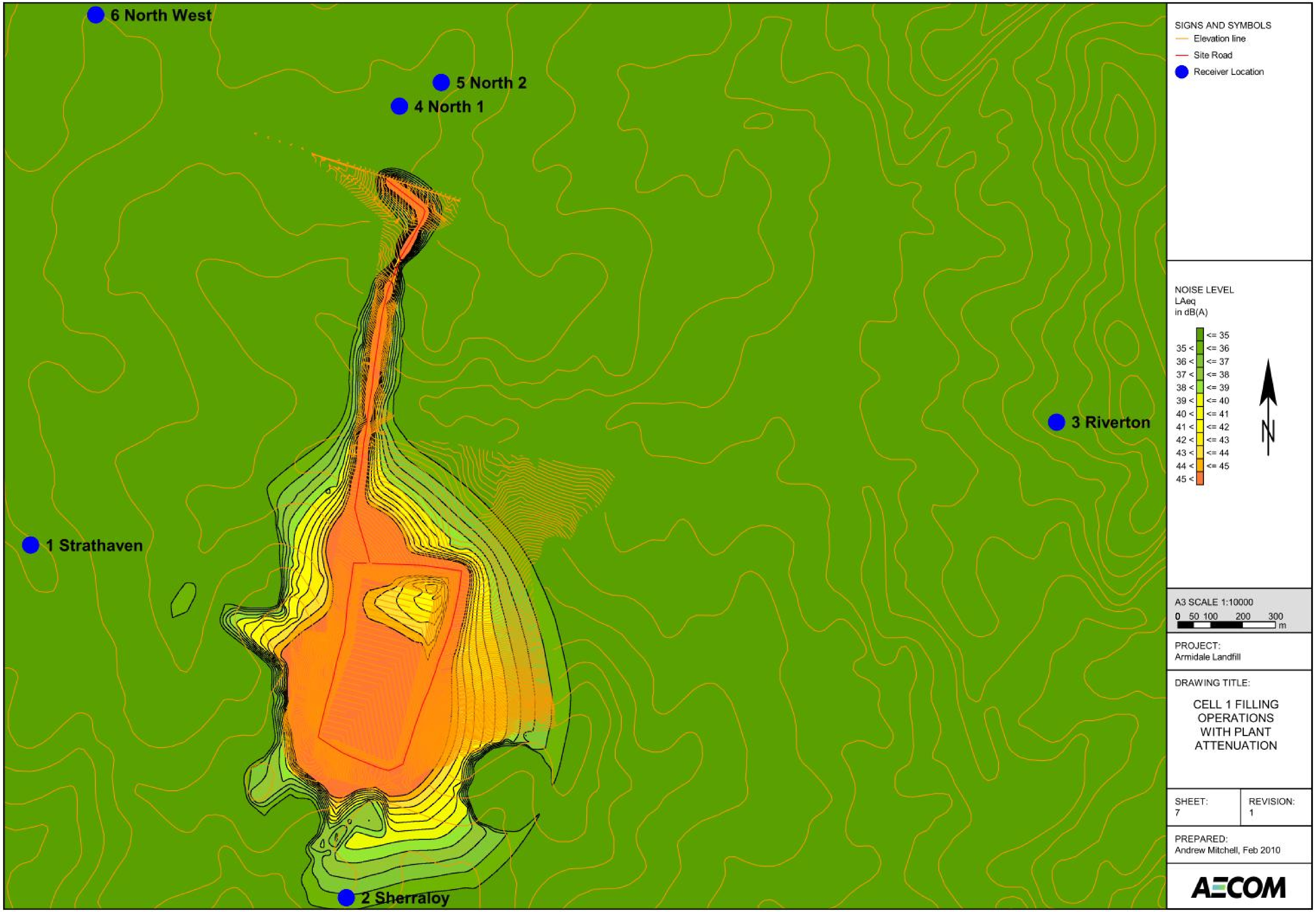

6 North West
5 North 2
4 North 1
3 Riverton
1 Strathaven
2 Sherraloy
SIGNS AND SYMBOLS
Elevation line
Site Road
Receiver Location
NOISE LEVEL
LAeq
in dB(A)
<= 35
35 < <= 36
36 < <= 37
37 < <= 38
38 < <= 39
39 < <= 40
40 < <= 41
41 < <= 42
42 < <= 43
43 < <= 44
44 < <= 45
45 <
N
A3 SCALE 1:10000
0 50 100 200 300 m
PROJECT:
Armidale Landfill
DRAWING TITLE:
CELL 1 COVERING OPERATIONS NO MITIGATION
SHEET:
2
REVISION:
1
PREPARED:
Andrew Mitchell, Feb 2010
AECOM


6 North West
5 North 2
4 North 1
3 Riverton
1 Strathaven
2 Sherraloy
SIGNS AND SYMBOLS
Elevation line
Site Road
Receiver Location
NOISE LEVEL
LAeq
in dB(A)
<= 35
35 < <= 36
36 < <= 37
37 < <= 38
38 < <= 39
39 < <= 40
40 < <= 41
41 < <= 42
42 < <= 43
43 < <= 44
44 < <= 45
45 <
N
A3 SCALE 1:10000
0 50 100 200 300 m
PROJECT:
Armidale Landfill
DRAWING TITLE:
CELL 3 FILLING OPERATIONS NO MITIGATION
SHEET:
3
REVISION:
1
PREPARED:
Andrew Mitchell, Feb 2010
AECOM


6 North West
5 North 2
4 North 1
3 Riverton
1 Strathaven
2 Sherraloy
SIGNS AND SYMBOLS
Elevation line
Site Road
Receiver Location
NOISE LEVEL
LAeq
in dB(A)
<= 35
35 < <= 36
36 < <= 37
37 < <= 38
38 < <= 39
39 < <= 40
40 < <= 41
41 < <= 42
42 < <= 43
43 < <= 44
44 < <= 45
45 <
N
A3 SCALE 1:10000
0 50 100 200 300 m
PROJECT:
Armidale Landfill
DRAWING TITLE:
CELL 3 COVERING OPERATIONS NO MITIGATION
SHEET:
4
REVISION:
1
PREPARED:
Andrew Mitchell, Feb 2010
AECOM


6 North West
5 North 2
4 North 1
3 Riverton
1 Strathaven
2 Sherraloy
SIGNS AND SYMBOLS
Elevation line
Site Road
Receiver Location
NOISE LEVEL
LAeq
in dB(A)
<= 35
35 < <= 36
36 < <= 37
37 < <= 38
38 < <= 39
39 < <= 40
40 < <= 41
41 < <= 42
42 < <= 43
43 < <= 44
44 < <= 45
45 <
N
A3 SCALE 1:10000
0 50 100 200 300 m
PROJECT:
Armidale Landfill
DRAWING TITLE:
CELL 5 FILLING OPERATIONS NO MITIGATION
SHEET:
5
REVISION:
1
PREPARED:
Andrew Mitchell, Feb 2010
AECOM


6 North West
5 North 2
4 North 1
3 Riverton
1 Strathaven
2 Sherraloy
SIGNS AND SYMBOLS
Elevation line
Site Road
Receiver Location
NOISE LEVEL
LAeq
in dB(A)
<= 35
35 < <= 36
36 < <= 37
37 < <= 38
38 < <= 39
39 < <= 40
40 < <= 41
41 < <= 42
42 < <= 43
43 < <= 44
44 < <= 45
45 <
N
A3 SCALE 1:10000
0 50 100 200 300
m
PROJECT:
Armidale Landfill
DRAWING TITLE:
CELL 5 COVERING
OPERATIONS
NO MITIGATION
SHEET:
6
REVISION:
1
PREPARED:
Andrew Mitchell, Feb 2010
AECOM



PROJECT:
Armidale Landfill

DRAWING TITLE:

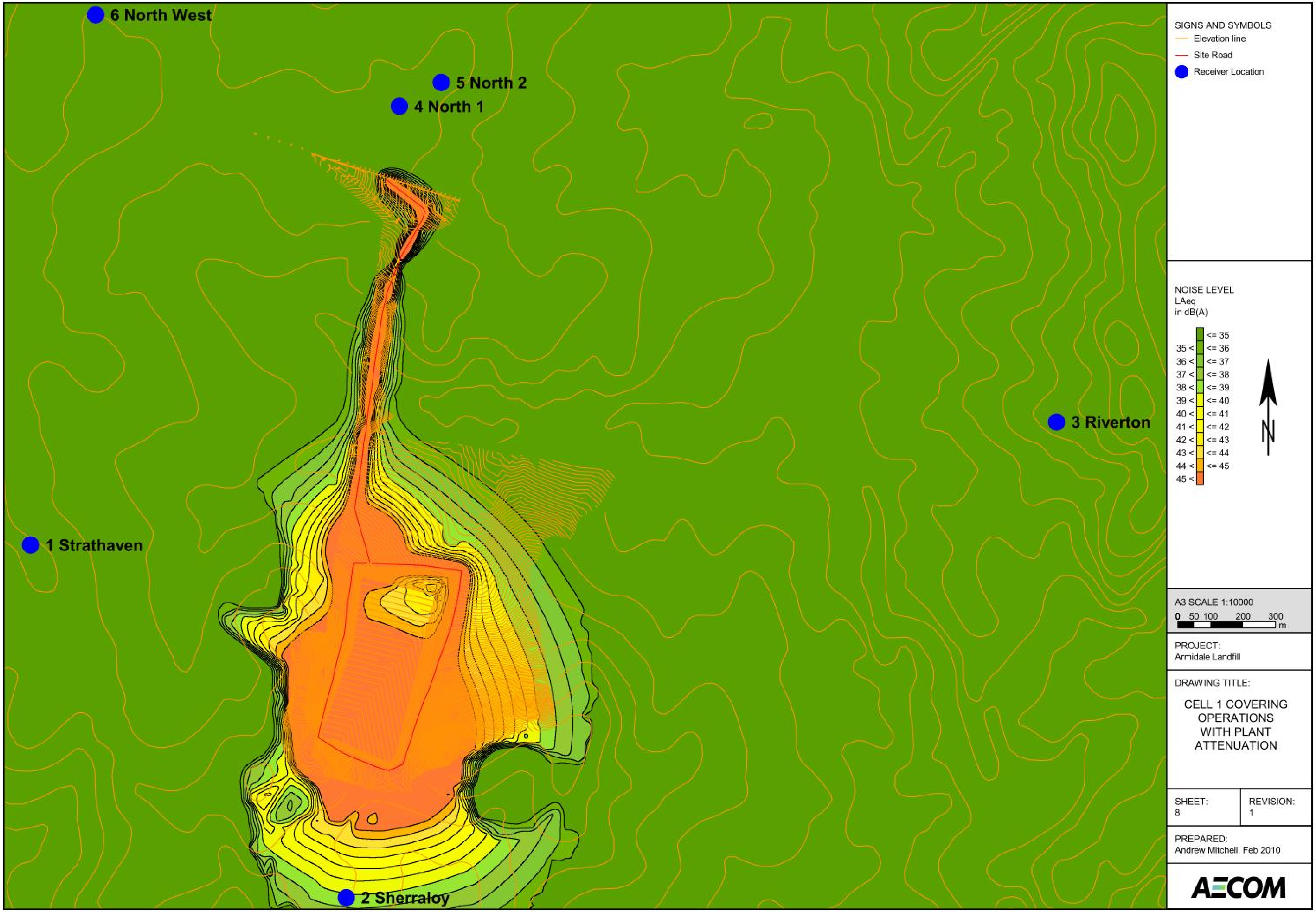
CELL 1 FILLING
OPERATIONS
WITH PLANT
ATTENUATION

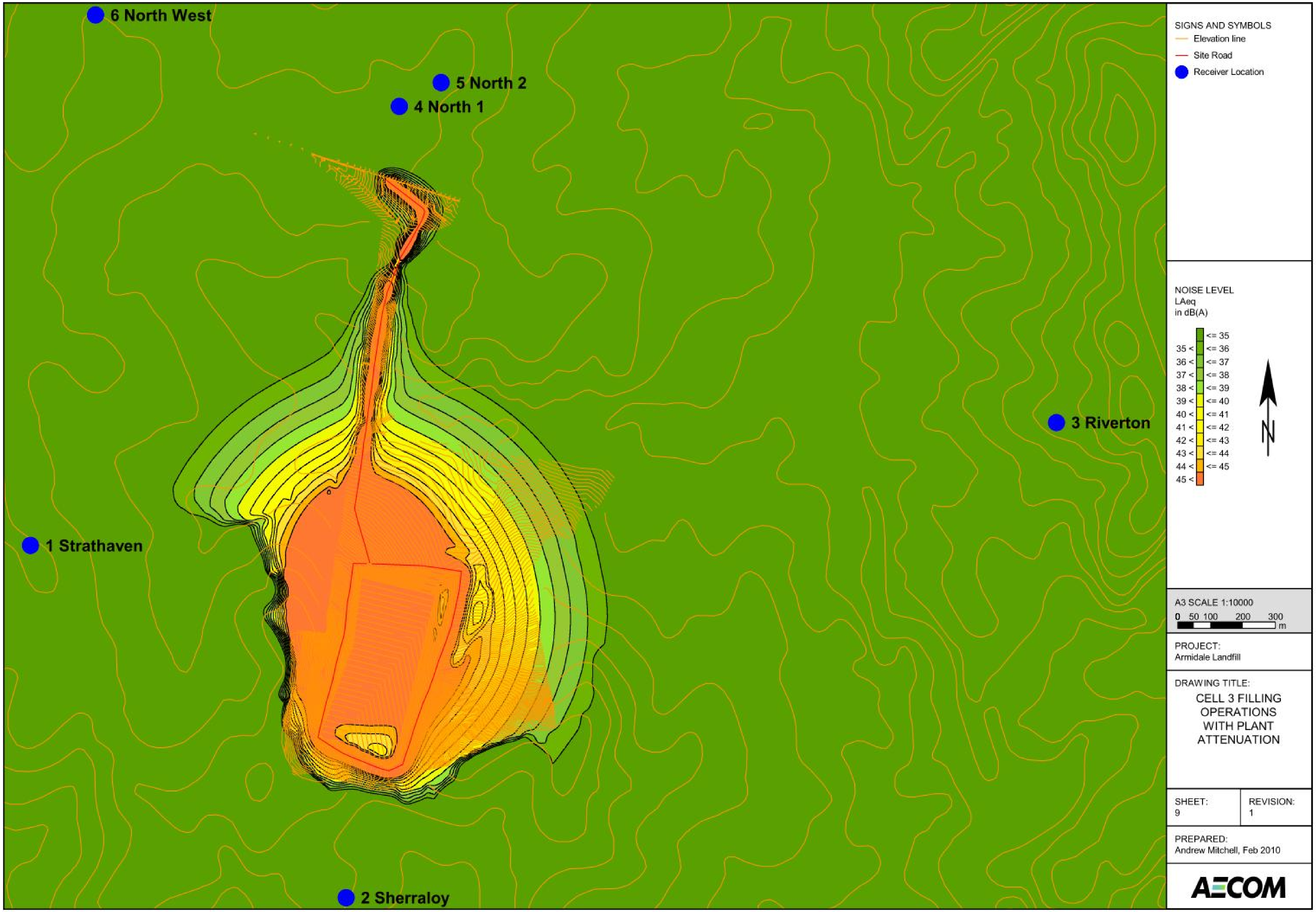
SHEET:
7

REVISION:
1

PREPARED:
Andrew Mitchell, Feb 2010

AECOM


6 North West
5 North 2
4 North 1
3 Riverton
1 Strathaven
2 Sherraloy
SIGNS AND SYMBOLS
Elevation line
Site Road
Receiver Location
NOISE LEVEL
LAeq
in dB(A)
<= 35
35 < <= 36
36 < <= 37
37 < <= 38
38 < <= 39
39 < <= 40
40 < <= 41
41 < <= 42
42 < <= 43
43 < <= 44
44 < <= 45
45 <
N
A3 SCALE 1:10000
0 50 100 200 300
m
PROJECT:
Armidale Landfill
DRAWING TITLE:
CELL 1 COVERING OPERATIONS WITH PLANT ATTENUATION
SHEET:
8
REVISION:
1
PREPARED:
Andrew Mitchell, Feb 2010
AECOM



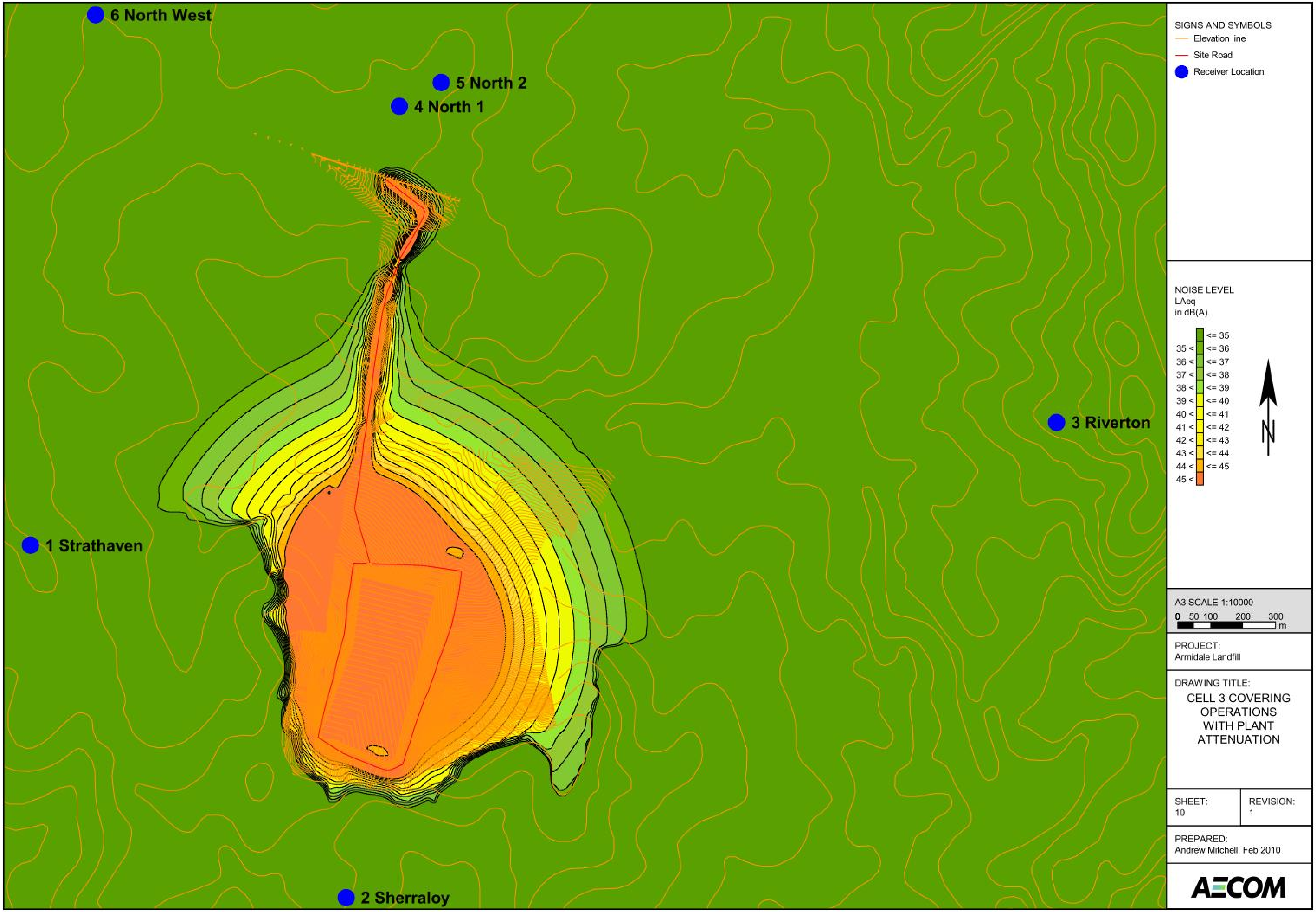
PROJECT:
Armidale Landfill

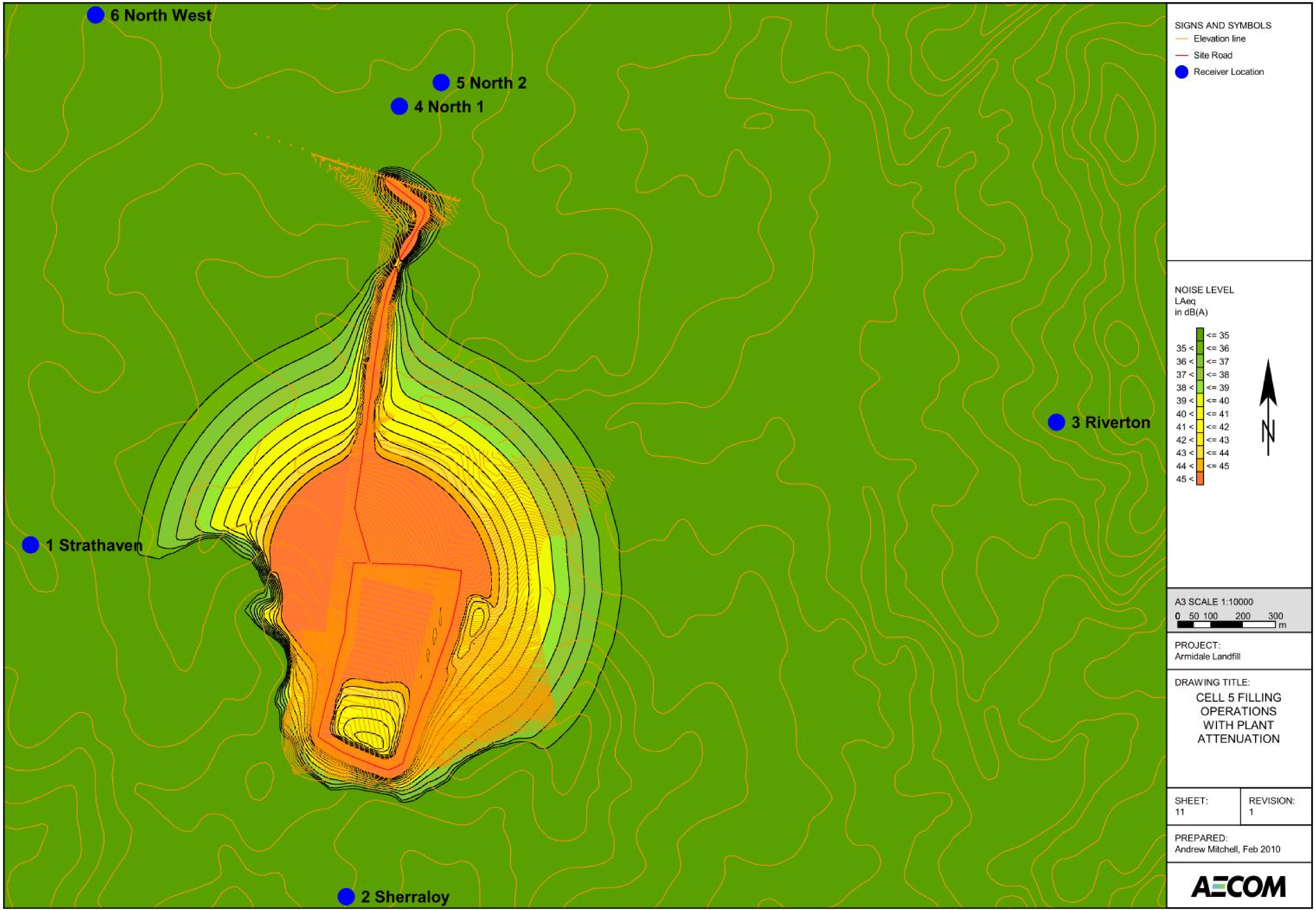
DRAWING TITLE:
CELL 3 FILLING OPERATIONS WITH PLANT ATTENUATION

SHEET:
9

REVISION:
1

PREPARED:
Andrew Mitchell, Feb 2010


6 North West
5 North 2
4 North 1
3 Riverton
1 Strathaven
2 Sherraloy
SIGNS AND SYMBOLS
Elevation line
Site Road
Receiver Location
NOISE LEVEL
LAeq
in dB(A)
<= 35
35 < <= 36
36 < <= 37
37 < <= 38
38 < <= 39
39 < <= 40
40 < <= 41
41 < <= 42
42 < <= 43
43 < <= 44
44 < <= 45
45 <
N
A3 SCALE 1:10000
0 50 100 200 300
m
PROJECT:
Armidale Landfill
DRAWING TITLE:
CELL 3 COVERING OPERATIONS WITH PLANT ATTENUATION
SHEET:
10
REVISION:
1
PREPARED:
Andrew Mitchell, Feb 2010
AECOM



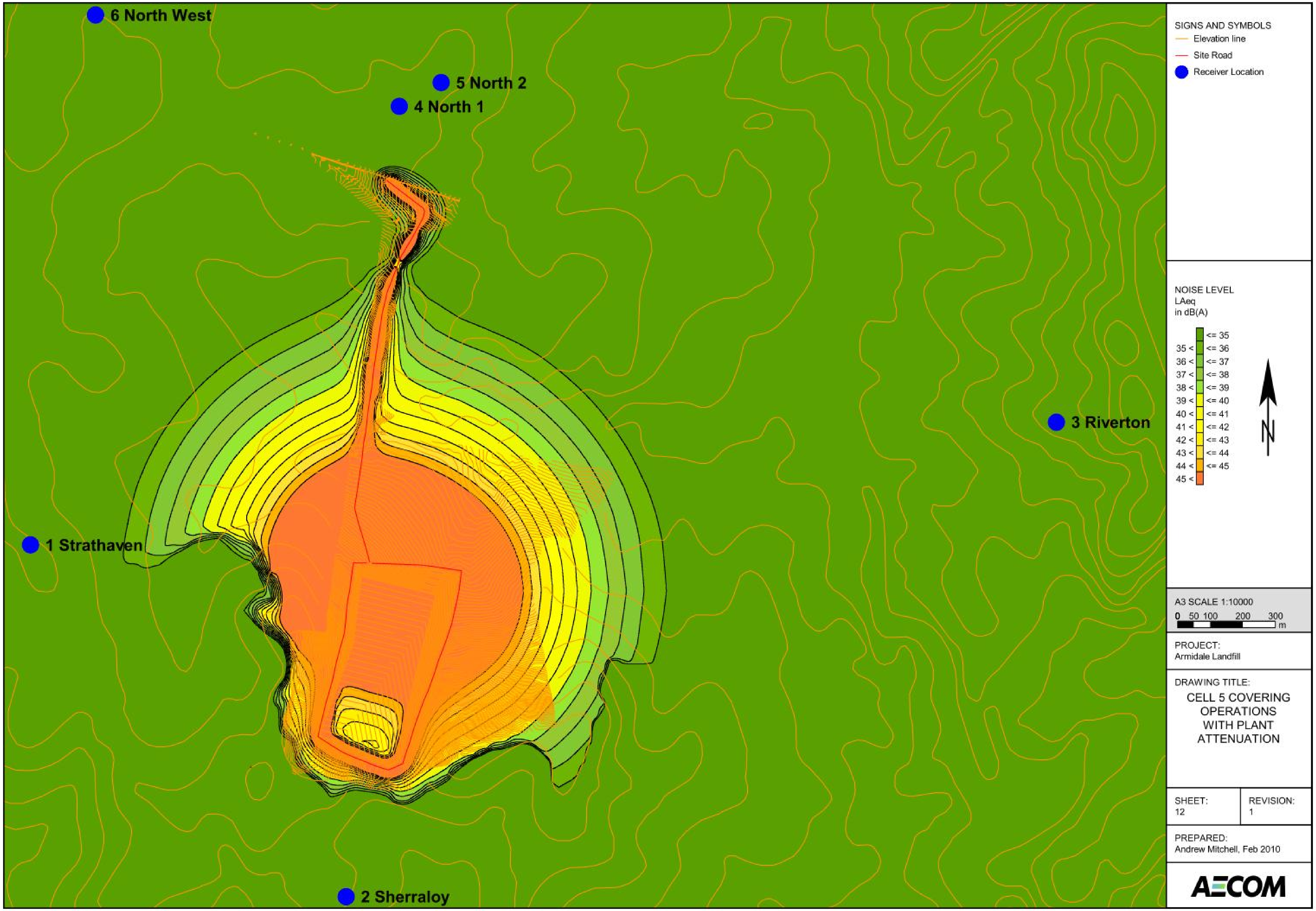
PROJECT:
Armidale Landfill

DRAWING TITLE:
CELL 5 FILLING
OPERATIONS
WITH PLANT
ATTENUATION

SHEET:
11

REVISION:
1

PREPARED:
Andrew Mitchell, Feb 2010



PROJECT:
Armidale Landfill

DRAWING TITLE:
CELL 5 COVERING
OPERATIONS
WITH PLANT
ATTENUATION

SHEET:
12

REVISION:
1

PREPARED:
Andrew Mitchell, Feb 2010

AECOM

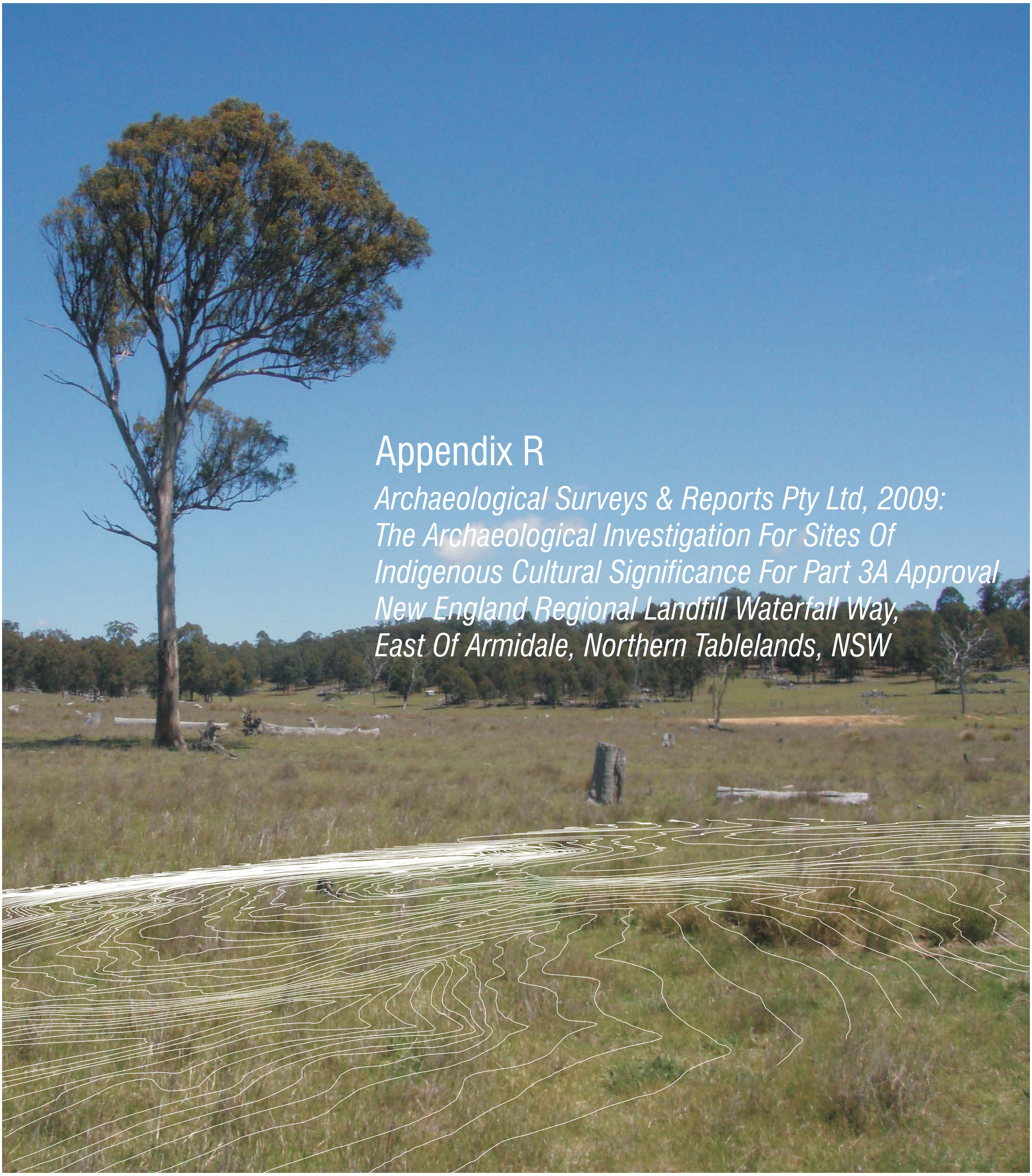
Worldwide Locations

Australia	+61-2-8484-8999
Azerbaijan	+994 12 4975881
Belgium	+32-3-540-95-86
Bolivia	+591-3-354-8564
Brazil	+55-21-3526-8160
China	+86-20-8130-3737
England	+44 1928-726006
France	+33(0)1 48 42 59 53
Germany	+49-631-341-13-62
Ireland	+353 1631 9356
Italy	+39-02-3180 77 1
Japan	+813-3541 5926
Malaysia	+603-7725-0380
Netherlands	+31 10 2120 744
Philippines	+632 910 6226
Scotland	+44 (0) 1224-624624
Singapore	+65 6295 5752
Thailand	+662 642 6161
Turkey	+90-312-428-3667
United States	+1 978-589-3200
Venezuela	+58-212-762-63 39

Australian Locations

Adelaide
Brisbane
Canberra
Darwin
Melbourne
Newcastle
Perth
Sydney
Singleton

www.aecom.com

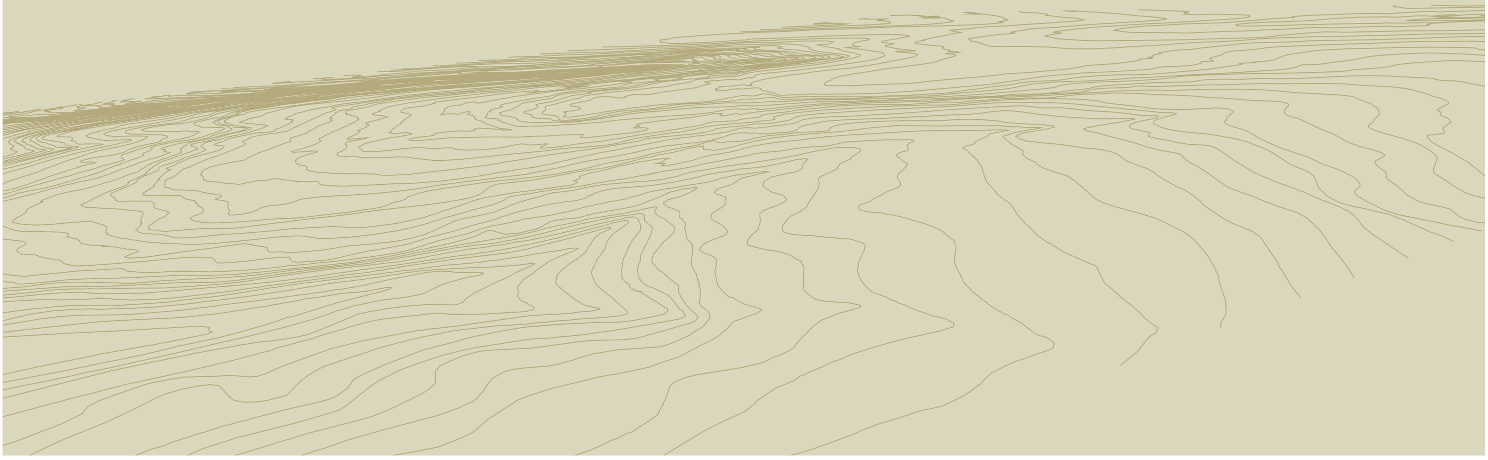


Appendix R

Archaeological Surveys & Reports Pty Ltd, 2009: The Archaeological Investigation For Sites Of Indigenous Cultural Significance For Part 3A Approval New England Regional Landfill Waterfall Way, East Of Armidale, Northern Tablelands, NSW

ARMIDALE REGIONAL LANDFILL

Environmental Assessment



The archaeological investigation for sites of Indigenous cultural significance for Part 3A Approval

NEW ENGLAND REGIONAL LANDFILL

Waterfall Way, east of Armidale, Northern Tablelands, NSW.

John Appleton

ARCHAEOLOGICAL SURVEYS & REPORTS PTY LTD

MARCH 2009

Report No. 473/09

For

AECOM

on behalf of

ARMIDALE DUMARESQ COUNCIL

ASR

This report has been compiled in ‘Plain English’,
but presented in a format suitable for developing policies
for the management of the cultural resources,
and as a basis for scientific reference
in future research studies.

Project No. 473/09

COPYRIGHT

ARCHAEOLOGICAL SURVEYS & REPORTS Pty Ltd

Client:

AECOM

Level 11, 44 Market Street

Sydney 2000

PO Box Q410, QVB Post Office, Sydney 1230

02 8295 4490

Contact: Chris Carloss, Principal Environmental Scientist

On behalf of:

Armidale Dumaresq Council

Copies of this report to:

The Archaeologist

Western Directorate DEC

PO Box 211

Dubbo 2830

02 6883 5330

The Chairperson

Armidale Local Aboriginal Land Council

The Chairperson

Nyakka Aboriginal Culture Heritage Corporation Archaeological & Cultural Heritage Consultants

265 Rusden Street

Armidale 2350

02 6771 3329

All inquiries in regard to this report should be addressed to:

John Appleton

Archaeological Surveys & Reports Pty Ltd

16 Curtis Street

Armidale 2350

Tel. 02 6772 6512 Fax. 02 6772 4567

Mobile: 0428 651 789

Email. japples@northnet.com.au

EXECUTIVE SUMMARY

This investigation was performed for AECOM on behalf of Armidale Dumaresq Council (ADC). AECOM was engaged by ADC to prepare an Environmental Assessment (EA) for the construction of a landfill facility at Gara, off Waterfall Way, approximately 12 km east of Armidale, on the Northern Tablelands, and AECOM engaged Archaeological Surveys & Reports Pty Ltd (ASR) to undertake an archaeological investigation of the property to meet the criteria for the EA.

The field investigation for this project was undertaken in May 2006 (Appleton 2006), but subsequently Council decided to seek approval for the project as a Part 3A "Major Project", under 'Section 6 Approvals' of the *National Parks and Wildlife Act 1974* (as amended).

In 2006 the scope of works was for ASR to conduct an archaeological investigation of the study area with the assistance of a representative of the Anaiwan Aboriginal Traditional Owners Resource and Cultural Heritage Management Association Incorporation (Anaiwan Aboriginal Traditional Owners), to identify any Aboriginal sites and relics that might be present. The results of the investigation were to be presented in a report, which was to include an assessment of the significance of any cultural relics or places identified, an appraisal of the options and opportunities arising from the discoveries, and clear recommendations for the management of those cultural resources.

Subsequently, when Council elected to apply for development approval as a Part 3A "Major Project" it became necessary to comply with the requirements of the "Guidelines For Aboriginal Cultural Heritage Impact Assessment and Community Consultation" (DECC 2005). This requirement stipulates that "all interested Aboriginal stakeholders" should be consulted and informed of the proposed development. The brief required ASR to undertake the consultation with the interested Aboriginal stakeholders and to report on the consultation process and outcomes.

This report describes the field investigation of the site undertaken in May 2006, and the additional consultation with the registered Aboriginal stakeholders required for Part 3A Approval undertaken in March 2009.

Two isolated artefacts were recorded during the investigation, one in an eroding creek bank in the proposed road corridor, and the other on a saddle in partially cleared and significantly disturbed open woodland in the proposed Landfill Site.

On the recommendations of the Aboriginal Elders and ASR Council agreed to avoid impacting upon the two site locations, and to ensure that accidental damage did not occur to the site in the access road corridor a circle of vertical posts would be placed around site “GL ISO2” at a radius of 10m from the artefact. Given that Part 3A does not require a developer to make such a concession Council is to be applauded for its sensitivity.

Council is advised that both of the two artefact locations were registered as Aboriginal sites on the AHIMS Site Register although the listing will not be a constraint to Part 3A Approval.

While Part 3A Approval would render any constraints that might otherwise have applied under the National Parks and Wildlife Act 1974 (as amended) ineffective, ASR recommends that in the interests of the Armidale Aboriginal Community Council should instruct their employees, sub-contractors, machine operators and representatives, whether working on the project Site or elsewhere, that in the event of any bone or stone artefacts, or discrete distributions of shell, or any objects of cultural association, being unearthed during earthmoving, work should cease immediately in the area of the find.

In the event that any bone cannot be clearly identified by a qualified archaeologist as being of animal remains the police are to be informed of its discovery, and officials and/or their representatives of Armidale LALC, Nyakka Aboriginal Culture Heritage Corporation Archaeological & Cultural Heritage Consultants, and the Manager, Planning & Aboriginal Heritage, DECC, Coffs Harbour, advised that the bone is subject to police investigation.

Work should not recommence in the area of the find, until both the police (if bone has been found) and those officials or representatives have given their permission to do so. Those failing to report a discovery and those responsible for the damage or destruction occasioned by unauthorised removal or alteration to a site or to archaeological material may be prosecuted under the National Parks and Wildlife Act 1974, as amended.

TABLE OF CONTENTS

TABLE

FIGURES

1. INTRODUCTION

This investigation was performed for AECOM on behalf of Armidale Dumaresq Council (ADC). AECOM was engaged by ADC to prepare an Environmental Assessment (EA) for the construction of a landfill facility at Gara, off Waterfall Way, approximately 12 km east of Armidale, on the Northern Tablelands, and AECOM engaged Archaeological Surveys & Reports Pty Ltd (ASR) to undertake an archaeological investigation of the property to meet the criteria for the EA.

The field investigation for this project was undertaken in May 2006 (Appleton 2006), but subsequently Council decided to seek approval for the project as a Part 3A “Major Project”, under ‘Section 6 Approvals’ of the *National Parks and Wildlife Act 1974* (as amended).

In 2006 the scope of works was for ASR to conduct an archaeological investigation of the study area with the assistance of a representative of the Anaiwan Aboriginal Traditional Owners Resource and Cultural Heritage Management Association Incorporation (Anaiwan Aboriginal Traditional Owners), to identify any Aboriginal sites and relics that might be present. The results of the investigation were to be presented in a report, which was to include an assessment of the significance of any cultural relics or places identified, an appraisal of the options and opportunities arising from the discoveries, and clear recommendations for the management of those cultural resources.

Subsequently, when Council elected to apply for development approval as a Part 3A “Major Project” it became necessary to comply with the requirements of the “Guidelines For Aboriginal Cultural Heritage Impact Assessment and Community Consultation” (DECC 2005). This requirement stipulates that “all interested Aboriginal stakeholders” should be consulted and informed of the proposed development. The brief required ASR to undertake the consultation with the interested Aboriginal stakeholders and to report on the consultation process and outcomes.

This report describes the field investigation of the site undertaken in May 2006, and the additional consultation with the registered Aboriginal stakeholders required for Part 3A Approval undertaken in March 2009.

1.1.1 Report Objectives

The objectives of this report are to describe the archaeological investigation of the survey area and to record any archaeological relics and sites that might be present. Further, the report documents the consultation process with the Aboriginal stakeholders, and the participation of an Aboriginal representative in the field survey, and their recommendations as to the future management of the survey area. In addition, the report includes a discussion of the results of the investigation in the context of other known sites in the area. Finally, the report includes a statement as to the recommendations for the future development of the survey area.

1.1.2 Report Format

The report is presented in the following format:

i Executive summary
ii Contents
iii Introduction
iv Aboriginal consultation
v The environmental context
vi The archaeological record
vii Models for site location
viii The survey
ix The results
x Discussion
xi Significance assessment
xii Recommendations.

1.2 The Survey Area

The irregularly shaped survey area occurs on two properties in the Parish of Gara, the northern section of the survey area on “Edington” – part of Lot 1 DP 253346, an area of approximately 18.5 ha; and the southern section on “Sherraloy” – parts of Lot 2 DP 253346 and Lot 1 DP 820271, an area of approximately 29.3 ha. The survey area occurs on, and is surrounded by pasture/grazing land, but the proposed northern access road will be from Waterfall Way via a defunct section of track through a Travelling Stock Reserve, and a road corridor across pastureland to the landfill site.

Figure 1 on the following page is detail from a Topographic map of the area, with the survey area outlined in red, and red diamonds to indicate the locations of Aboriginal sites previously recorded in the area, and black diamonds to indicate the locations of the two artefacts recorded during this investigation. **Figure 2** is detail from an aerial photograph showing the conceptual footprint of the landfill. **Figure 2** also shows the locations of the two sites recorded during the investigation – see ‘Results’ below.

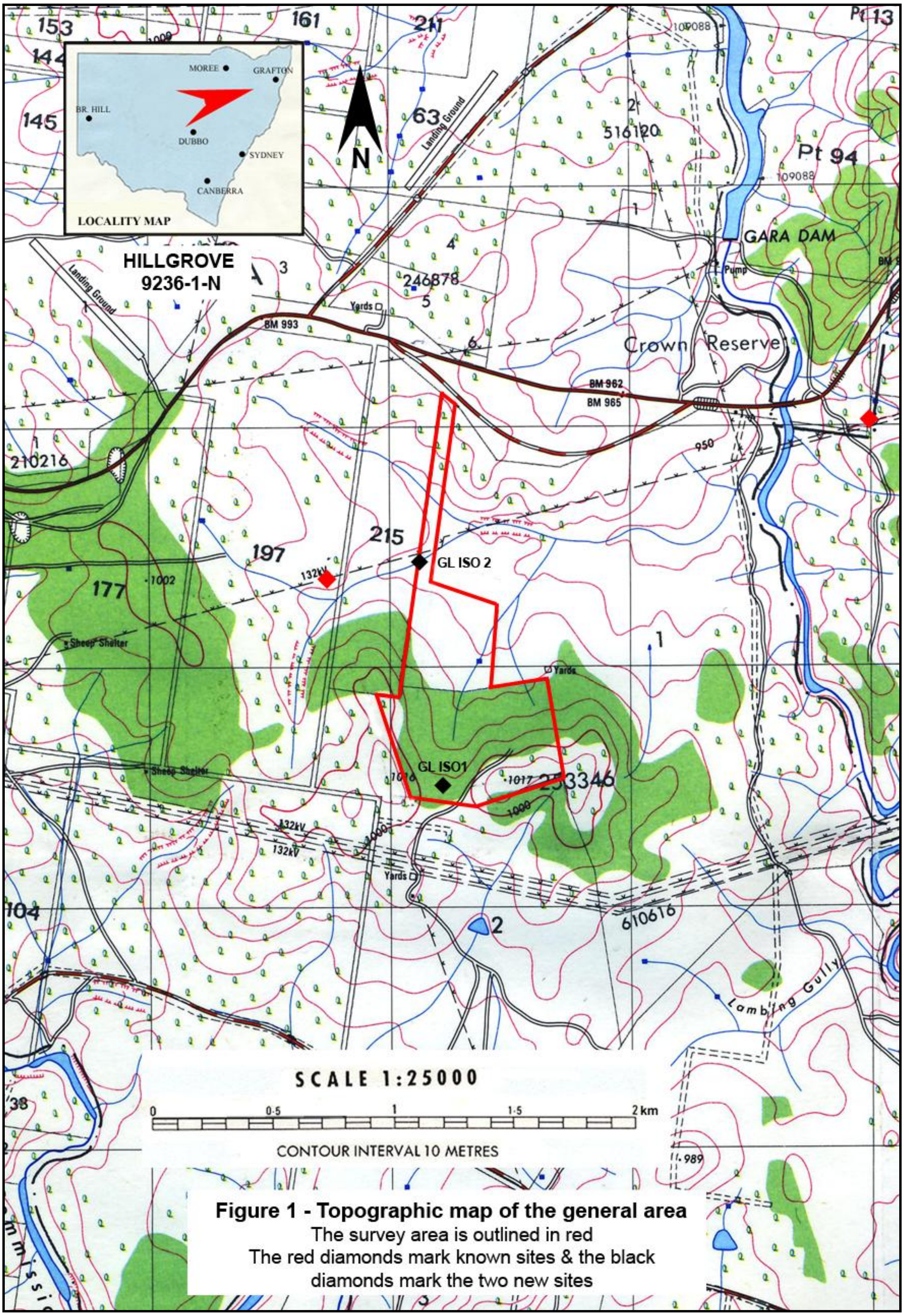


Figure 1 - Topographic map of the general area
The survey area is outlined in red
The red diamonds mark known sites & the black diamonds mark the two new sites

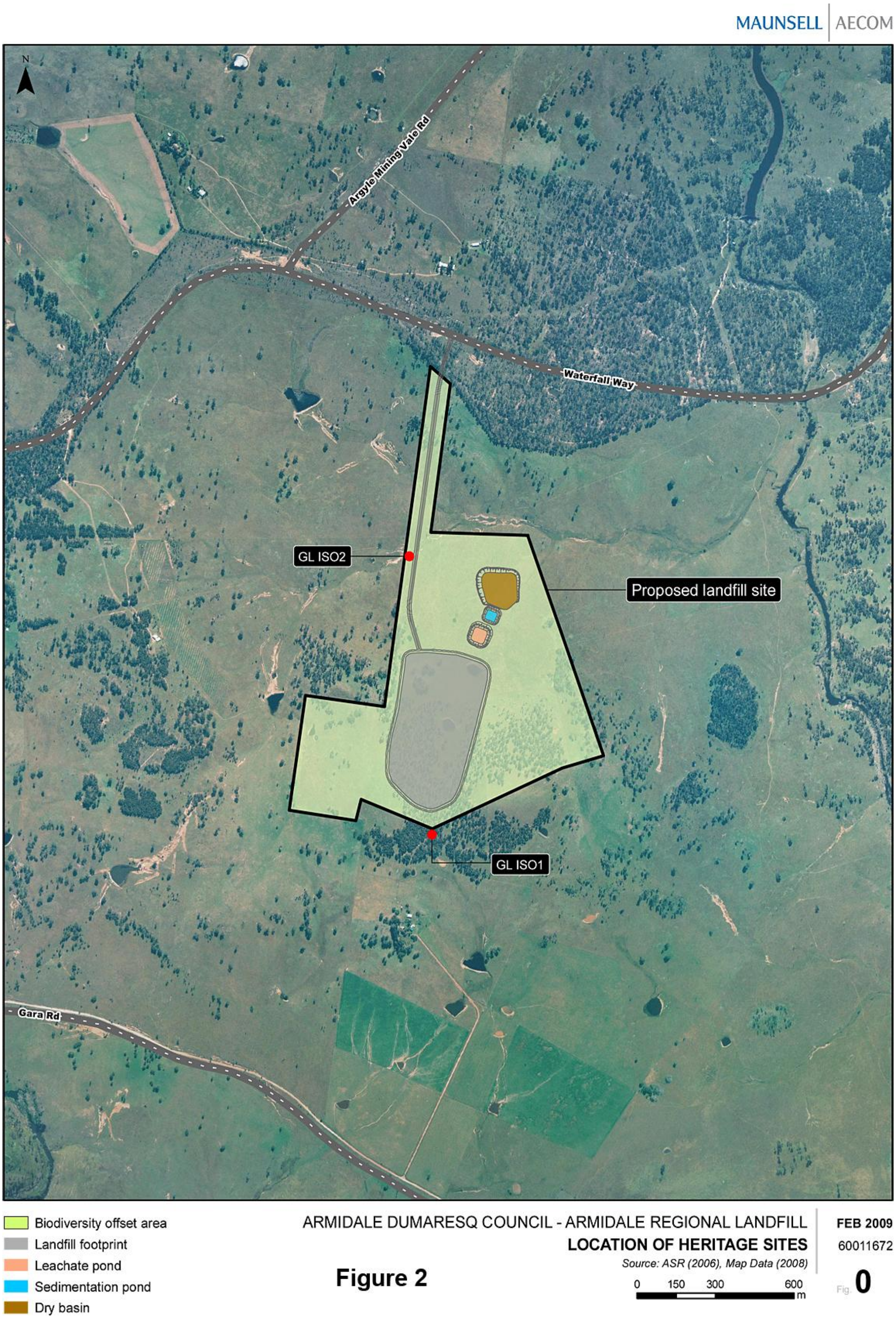

MAUNSELL | AECOM
N
Argyle Mining Vale Rd
Waterfall Way
Gara Rd
GL ISO2
GL ISO1
Proposed landfill site
🟩 Biodiversity offset area
⬜ Landfill footprint
🟧 Leachate pond
🟦 Sedimentation pond
🟫 Dry basin
ARMIDALE DUMARESQ COUNCIL - ARMIDALE REGIONAL LANDFILL
LOCATION OF HERITAGE SITES
Source: ASR (2006), Map Data (2008)
0 150 300 600 m
FEB 2009
60011672
Fig. 0

Figure 2

1.3 Potential impact of development.

The impact from the proposed development of the survey area has the potential to disturb or destroy any archaeological material or depositional contexts within the impacted areas, either from earthworks during site preparation, or during the construction of roads, or during the clearing of the vegetation and landscaping of peripheral areas, or from burial beneath the landfill.

As a consequence of this survey it is unlikely that the same area will be surveyed again, thus from an archaeological perspective, this was an opportunity to observe and record any sites that might be present, and to propose a strategy for the management of any known or potential archaeological and/or cultural material in the future development of the area.

2. ABORIGINAL CONSULTATION

DECC guidelines require that all investigations should be undertaken with an Aboriginal community representative and in most instances the Aboriginal representative is nominated by the Local Aboriginal Land Council, but unfortunately the office of Armidale LALC had been closed for several months prior to and at the time of the investigation in 2006, and Appleton (ASR) was unable to contact the past-Chairperson of Armidale LALC.

However, Appleton (ASR) had recently undertaken other investigations in the Armidale area with representatives of the Anaiwan Aboriginal Traditional Owners Resource and Cultural Heritage Management Association Incorporation (Anaiwan Aboriginal Traditional Owners), and so he contacted the Chairperson, Rhonda Kitchener, and requested that she provide someone to assist in the investigation to represent the Aboriginal Community. As a consequence Rhonda agreed to assist Appleton in the investigation, which was undertaken on 29th May 2006.

At various stages during the investigation Appleton and Kitchener discussed the survey strategy, the potential for sites to be present, and the results of the investigation. Following the survey they discussed the results and the likely recommendations that the Anaiwan Aboriginal Traditional Owners would make.

Kitchener agreed to provide ASR with a written statement of the recommendations on behalf of the Anaiwan Aboriginal Traditional Owners, a copy of which is included as **Appendix i.**

Subsequently, ASR was advised by AECOM that approval for the project would be sought as a Part 3A Major Project. The consequence of which was that further Aboriginal consultation was required to meet the provisions of the "Guidelines For Aboriginal Cultural Heritage Impact Assessment and Community Consultation" (DECC 2005), under Part 6 Approvals of the *National Parks & Wildlife Act* 1974 (as amended), in-so-far-as they applied to Part 3A Major Projects.

The Aboriginal consultation necessary for Part 3A approval required that an advertisement should be placed in the local newspaper inviting all Aboriginal stakeholders with an interest in the project to register their interest within 14 days of publication the advertisement. For that purpose an advertisement was placed in "*The Armidale Express*" of 2nd February 2009, and in "*The Armidale Independent*" of 4th February 2009 – see **Appendices ii** and **iii.**

Two responses to the advertisement were received, one from Nyakka Aboriginal Culture Heritage Corporation Archaeological & Cultural Heritage Consultants [Nyakka] (formerly Anaiwan Aboriginal Traditional Owners Resource and Cultural Heritage Management Association Incorporation); and Mr Tom Briggs Junior.

Registered stakeholders

Nyakka AHCA&CHC	Mrs Rhonda Kitchener	02 6771 3329
Mr Tom Briggs (Junior)		02 6771 2429

On 26th February ASR contacted both respondents and explained the purpose of the advertisement and the requirements of Part 3A Major Project legislation in relation to this particular project, and asked them if they required a stakeholder meeting to discuss the project further.

Rhonda Kitchener, Managing Director of Nyakka, advised that she would discuss the issue with the Community Elders. Similarly, Mr Briggs advised that he would confer with Rhonda Kitchener to discuss whether or not a stakeholders' meeting was required. Subsequently, on 26th March Rhonda Kitchener advised ASR that the Community Elders were satisfied with the information they had been given and that a meeting of registered stakeholders was not required.

There being no further issues to satisfy the requirements of the Application for the project as a Part 3A Major Project, ASR concluded that the requirements for full Aboriginal Community consultation had been met.

3. THE ENVIRONMENTAL CONTEXT

Any discussion of the likely presence of Aboriginal cultural remains or of the basis why such remains might be discovered must be within the context of the environment and the resources that would have been available to any Aboriginal occupants of the area.

3.1 The general geology and topography

The survey area occurs less than four kilometres to the north of Gara Gorge on the eastern escarpment of the Northern Tablelands. The Northern Tablelands is a complex unit within the Great Dividing Range, formed from steeply dipping Sandon Beds (Palaeozoic marine sediment deposits), overlain by the horizontally layered Armidale Beds (Eocene fluvial deposits), interrupted by various intrusive basalt batholiths, and partially overlain by remnant caps of basalt. Such a complex formation includes metamorphic rocks formed at the margins of the granites within the sedimentary deposits, and silcretes formed at the contact of the basalt with the sedimentary rock. Generally the contact zone between the basalt and the Armidale Beds occurs at about 1,030 m AHD, and outcropping of metamorphosed rock occurs between 960 and 1,030 m AHD.

The Landfill Site will be located in one of several drainage depressions that form the catchment to an unnamed creek that drains to the north-east then to the east, to flow into Gara River, some two kilometres to the north-east of the survey area. It is bracketed by two rounded hills and connecting saddle that form the backdrop to the landfill site. The hills are part of a north-west/south-east trending series of hills that separate the valleys of the southward-flowing Gara River and the eastwards-flowing Commissioners Waters to the south. Commissioners Waters flows into Gara River three kilometres to the south-east of the survey area a kilometre to the north of where Gara River enters Blue Hole, before beginning its descent into The Gorge Country.

The access road corridor enters the survey area from a ridge on Waterfall Way, and travels southwards over a mid-slope bench, before crossing a shallow drainage depression and a creek line, then continuing across the lower slopes of the westernmost of the southern hills flanking the landfill site.

While the survey area can generally be described as occurring within a landscape of rolling hills bisected by drainage depressions some of the ridges, particularly at the northern end of the survey area are marked by reef-like exposures of meta-sedimentary rock, while surface exposures along the drainage lines exhibit weathered almost stoneless sedimentary soils. Most slopes retain a surface layer, or A Horizon, of weathered coarse, sandy pasture soils formed on the surface of the Armidale Beds.

Elevation and soil type is an important predictor of site location in the Armidale region. McGarity (1977) observed that the variability of duplex soil associations in the Armidale district is due to the nature of the Palaeozoic metamorphic and sedimentary rocks on which they occur, and that the basement rocks contain metamorphosed sandstone, chert, some jasper and localised metabasalt.

Elevations in the survey area dip from 980 m AHD at the northern end of the road corridor down to approximately 955 m AHD where the road crosses the central creek bed, rising to the summits of the two hills at the southern end of the survey area at 1016 m and 1017 m AHD.

3.2 Vegetation

As the aerial photograph in **Figure 2** shows at least 60% of the survey area has been cleared for pasture, and much of the remaining 40% comprises eucalypt regrowth, or trees of less than 150 years old, in which grazing has severely limited regeneration and understorey growth.

3.3 Water resources

The proposed landfill site is positioned to utilise a ridge-flanked drainage depression but the creek lines are ephemeral at most, and would only have flowed briefly after heavy rain, as the metasedimentary soils of the surrounding slopes would absorb all but the heaviest of downpours. However, clean drinkable water was available to the Aboriginal occupants of the region, in the Gara River, a permanent water course only 1,200 metres to the east of the survey area. It is therefore unlikely that the absence of a reliable water source within the survey area was ever a constraint to its use by Aboriginal people.

3.4 Stone resources

As described above most of the soils of the survey area comprised of a shallow horizon of sedimentary pasture soils overlying Armidale Beds – neither of which would have contained stone suitable for knapping.

Many of the artefacts recorded during other investigations in the Armidale area including a site recorded less than 350 metres to the west of the survey area (see later) were manufactured from silcrete. Silcrete has frequently been observed and recorded in a number of locations in the Armidale area on the upper slopes of hills and ridges at about 1,030 m AHD at the contact zone of the basalt with the sedimentary rock (Armidale Beds). However the summits of the hills to the south of the survey area were less than 1,020 m AHD and therefore below the level at which silcrete formed in situ, although there is a possibility that remnant lag deposits, that might include silcrete, derived from the hill tops before they were eroded to their present height, might be found in drainage lines or on hill slopes.

However, no potential source of material that might have been suitable for knapping into stone tools or weapons was observed within the survey area, and so if artefacts do occur within the survey area then they were probably sourced from a lag deposit source or outcropping metasedimentary formation outside the survey area.

3.5 Potential food resources

With such a limited vegetation regime there would have been few reliable potential food resources in the survey area, however, as in most New England environments there was always a potential for kangaroos, koalas, possums, bats, goannas, lace monitors, lizards, skinks, snakes, turtles, birds, and insects – and “sugarbag” or native bees’ honey – to be present if only opportunistically.

3.6 Previous impacts

As discussed previously much of the survey area has been cleared for pasture. As a general observation the landscape remains relatively intact and free from significant alteration, other than for the two large dams in the footprint of the landfill site, and a small gravel-quarry in the eastern section on “Sherraloy”. However, while the general profile of the land remains relatively unaltered it is clear from the numerous piles of felled timber in the open woodland that there has probably been significant disturbance to the sod layer or shallow A Horizon, particularly in the wooded areas. These piles could only have been formed mechanically and probably by dozer and so there is the potential for surface deposits to have been displaced when the timber was pushed into piles, or by the tracks of the dozer reversing and turning in the shallow, looses surface deposits.

4. THE ARCHAEOLOGICAL RECORD

ASR made a search of the Aboriginal Heritage Information Management System (AHIMS: Site Register) for all sites within an area described by the AMG references Easting 380000-388000: Northing 6615000-6625000 (an area of 8 km west to east, by 10 km long north to south), centred on the survey area. Details of the results are included as **Appendix iv.**

Of the five sites occurring within the search area four were recorded by Appleton in October 1991 during an investigation for a Telecom optic fibre route (Appleton 1991), the fifth was recorded by Heather Burke and Wendy Beck on the western bank of Burying Ground Creek during a survey for a road realignment and bridge replacement on Waterfall Way (Heather Burke, pers. comm.).

Two of the sites were isolated artefacts (“TH/JA 4” & “TH/JA 6”), but one site, “TH/JA 4”, beside Billys Gully, approximately 1,500 metres to the east of Gara River and less than three kilometres to the east of the survey area, contained an estimated “at least 2,000 artefacts”. Another site, “TH/JA 3”, that was recorded less than 350 m to the west of the landfill road corridor on a knoll overlooking a confluence of two tributaries of the catchment area in which the landfill site will be located, contained 26 artefacts and it was estimated that the site probably contained at least 500 artefacts. The vast majority of all of the artefacts in all five locations were manufactured from silcrete, and the remainder from silicified metasedimentary rock such as greywacke.

Of the five listed sites only two occur within the map coverage of **Figure 1**, “TH/JA 3” to the west of the road corridor, and the isolated artefact at “TH/JA 4” to the east of Gara River. The large site at “TH/JA 5” occurs less than 1,100 m to the east of “TH/JA 4”.

The fact that only five sites have been recorded in the 80 sq.km, search area is not indicative of the distribution and density of sites in the region, but merely represents the results of two very confined and targeted investigations. Sites are generally recorded during investigations required to comply with Development Applications or to meet local or state government statutory requirements, and so in an area in which the only ‘developments’ since 1979 when the Environmental Planning & Assessment Act was enacted, have been a road upgrade and bridge replacement, and the installation of optic fibre cable there have been very few opportunities in which sites might be observed and recorded. In numerous other investigations throughout the Northern Tablelands Appleton has found many sites in various environments, and based on that experience, would predict that there might be at least another 50 or so sites yet to be observed and recorded within the 80 sq km search area, the vast majority of which will be found along creek banks or in saddles or on the summits of hills and ridges overlooking water courses.

5. MODELS FOR SITE LOCATION

5.1 Site types and their location

In order to design an investigative strategy it is firstly necessary to develop a predictive model for site location. This is not to determine where the investigation should be conducted, but to establish a theoretical model for the distribution of archaeological material against which the effectiveness and subsequent analysis of the survey results can be tested, compared and reasoned. The basis upon which the predictive model is derived must however be one of consideration of which archaeological material might realistically be expected to not only be present, but also detectable.

The first objective of any archaeological investigation must be to observe and record sufficient of the archaeological record that is present to be able to propose that it is representative of the record as a whole. The investigative strategy is therefore directed and designed to detect that which is representative of the record in the particular study area, and naturally, as different study areas will comprise variations in environment, vegetation, topography, etc., so the investigative strategy must be designed to best suit the circumstances. The objective must be to detect material evidence, and so it is necessary to consider the extent to which artefactual material may be present, and the degree to which it is visible or might be discovered.

There are several factors, which are likely to affect, firstly, where Aboriginal people are most likely to have been, secondly, where they have left evidence of their activities, and thirdly, the degree to which that evidence is observable in the present record.

People visited places mainly to obtain resources, and in general places that were richest in resources were more likely to have been visited by people than those places with fewer resources. Important resources were permanent water, ephemeral water, food resources, stone raw material sources, shelter (from sun, wind, and rain), and perhaps suitable surfaces for rock art, and proximity to mythological natural features. Those resources may have been a factor in the suitability of a location for particular ceremonial activities but cultural boundaries also influenced the choice of ceremonial grounds. Alternatively, sites frequently occurred along preferred access routes and particularly where that route coincided with a watercourse.

However, the attractions of such an environment frequently resulted in the archaeological record becoming discontinuous or significantly disturbed, as stock and vehicles impacted upon it in the post-European contact phase.

Frequency of visits and use of particular locations was also determined by the ‘accessibility’ or freedom from environmental constraints in the area. For example, whether there were alternative, preferred or easier ways to travel around or over natural barriers, be they geological, geographical, cultural, or imposed by fauna or flora, or whether they were only seasonally accessible, such as mounds on flood terraces, or the availability of water during periods of drought, or whether or not floods, fire or snow hindered access.

Few past Aboriginal activities are represented by surviving material evidence. This in part is because many activities did not leave material evidence (eg. tools were reused), but it is also because very little cultural material survived. An exception to this was shellfish, which was very durable.

The survival of material that is durable was also affected by recent European land use. Cultivation has destroyed many archaeological sites. However, cultivation can also help expose sites that might otherwise be covered. This brings us to the other important point about site distribution, which is that to a great extent site distribution recorded by archaeologists reflects the distribution of places where the ground surface is sufficiently eroded to expose artefactual material.

By far the majority of recorded sites have been stone artefact scatters or isolated stone artefacts, and in the vast majority of sites they were found in one or more of the following contexts:

i) On or adjacent to deposits containing quartz, quartzite, jasper, silcrete, chert, chalcedony, metamorphosed greywacke, and other indurated or siliceous sedimentary rocks, or redeposited fine-grained volcanics, or

ii) On river banks or adjacent to river banks where the watercourse contains river pebbles of quartz, quartzite, jasper, silcrete, chert, fine-grained volcanics, basalts, etc., and particularly at the junctions of watercourses, or

iii) On ridges and spurs overlooking watercourses or on high vantage points affording uninterrupted views of swamps, water holes, saddles, passes, and any other likely access path into the observer's area, or

iv) In the vicinity of outcrops of suitable raw material such as basalt, silcrete, chert, or other highly silicified sedimentary rock.

Other site types do occur and perhaps because of their lower and less predictable profile, are present in far greater numbers than we are aware of. People died but there are few recorded burials. One reason may be that in many instances the soils are too acid for the preservation of bone, but a far more likely reason is simply that burial frequently entailed subsurface internment, and a surface survey will only discover a burial where there has been erosion of significant disturbance to the surface deposits. As a consequence many burials have only been discovered when exposed by erosion of a sand body or river terrace.

Other site types such as carved trees, scarred trees, stone arrangements, Bora rings, etc., may once have been present, but are unlikely to have survived in easily accessible country from the attention of non-indigenous people. Thus, much of what might have existed is now lost or destroyed, and the archaeological record has become biased by the post-contact utilisation of resources, and by the selective exploitation and preservation of particular environments.

Other factors which affect the degree to which sites are recorded during an investigation include the time of year at which the fieldwork is performed (the seasonality of some vegetation growth) and the conditions under which the survey is performed – (wet, dry, cold, windy, poor light, etc.).

A brief description of site types such as isolated artefacts, open scatters, camp sites, knapping floors, quarries, middens, mounds, hearths, carved trees, scarred trees, stone arrangements, Bora rings, burials, engravings, paintings, grinding grooves, occupation deposits (and PADs), and ceremonial and mythological sites is given in **Appendix v**.

5.2 A predictive model for the study area

Based on all of the above the following model for site distribution was proposed for the study area in which there were no stone resources suitable for knapping material, no mature trees, no reliable water source, no particular food resources, no overhangs or shelters, and no exposed rock surfaces.

- Isolated artefacts may be present and visible in erosion features
- Low-density artefact scatters may be present and visible in erosion features, but it is unlikely that any debitage will be visible
- There is very little potential for any scarred trees to be present as there are few trees likely to be a hundred and fifty years old, which is the minimum age they would have to be to have been useful to the Aboriginal people at the time of European contact in the mid-19th century.
- There is very little potential for any carved trees to be present as there are few trees likely to be a hundred and fifty years old.
- There will be no shell middens
- In the absence of any shelters there will be no art sites

- There will be no surfaces exhibiting engravings, or grinding grooves
- There will be no intact occupation deposits
- There are no known Mythological sites in or near the survey area
- There will be no stone quarries
- There will be no visible evidence of burials
- There will be no surviving or visible Bora rings
- There will be no stone arrangements

6. THE SURVEY

6.1 The survey strategy

It was clear from the brief for the investigation that there was easy access to the area to be surveyed and it would possible to undertake a comprehensive survey on foot. In the absence of any significant features in the survey area it was decided to follow a transect strategy, walking two-abreast and about 10-15 metres apart.

The investigators commenced the foot survey at the north-western corner of that part of the survey area in “Sherraloy”, at the southern end of the road corridor, or midway along the western boundary of the landfill site. They then proceeded southwards along the boundary to the south-western corner, then turned eastwards entering the woodland to target ground exposures in the area of the southern saddle. From there they ascended the slopes of the eastern hill to the central north/south (electrified) fence. They then briefly followed the fenceline northwards before turning westwards and descending into the woodland between the saddle and the southern dam, then turned northwards and surveyed the central track down to the southern dam. From there the investigators followed the drainage depression down as far as the corner of the fenceline on the property boundary, and then crossed into the eastern section of “Sherraloy”. From there they turned southwards and followed the fenceline to the summit of the eastern hill. From there the investigators turned eastwards following the crest the hill to just short of the eastern boundary, where they turned northwards and descended the northern slopes to the gravel quarry, then turned north-westwards crossing the property boundary and heading back to the starting point via the northern dam. Once back at the western boundary the investigators turned northwards and followed the road corridor to the northern boundary, before returning back to the starting point.

The area in the north-eastern section of the proposed landfill area was not surveyed because of the dense grass cover.

6.2 Details of the survey

Rhonda Kitchener, Chairperson, Anaiwan Aboriginal Traditional Owners, assisted Appleton in the field survey, which was undertaken on foot, in light ideal for observing artefactual material. All of the areas shown shaded in pink in **Figure 3** were surveyed on foot.

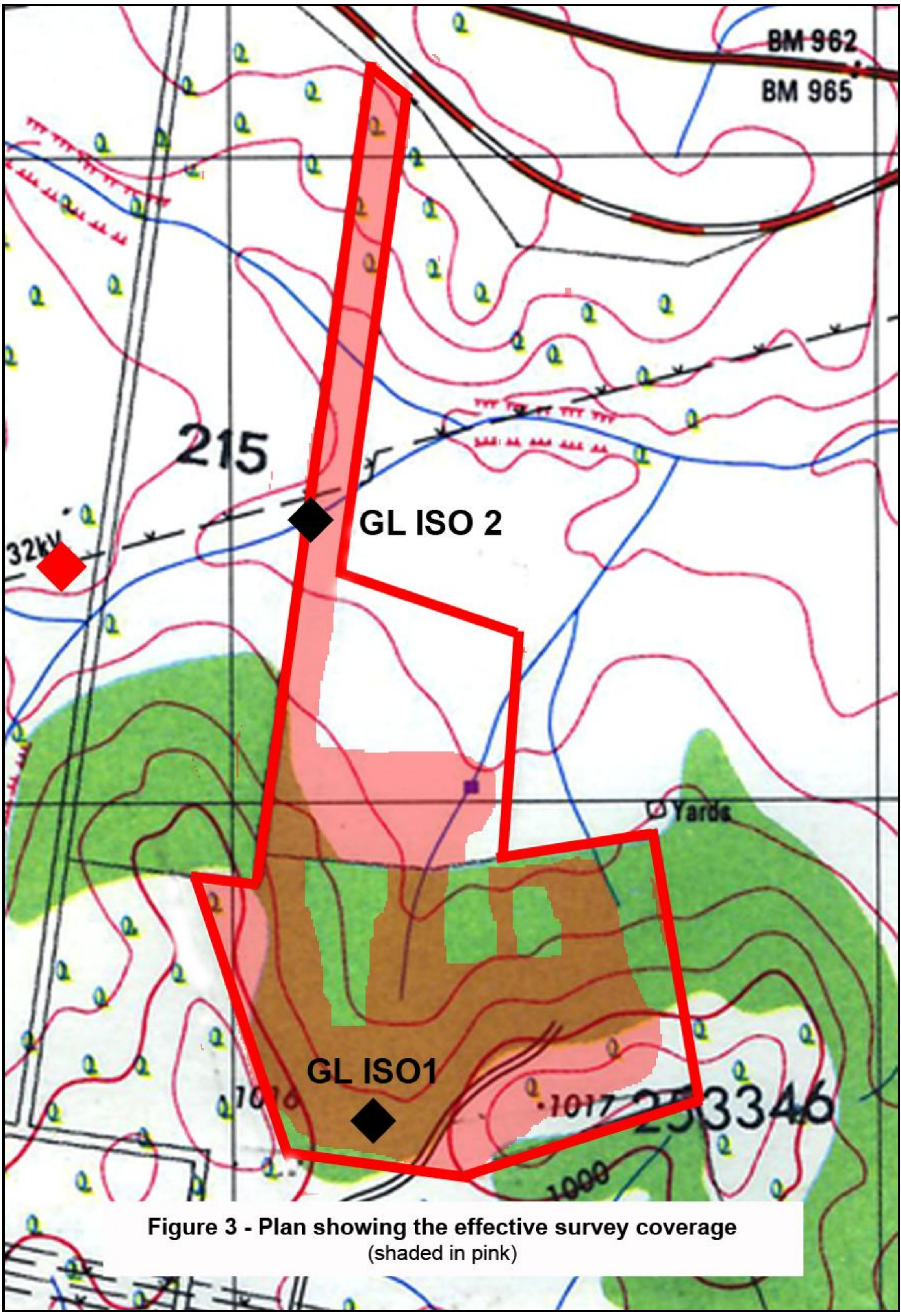


Figure 3 - Plan showing the effective survey coverage
(shaded in pink)

6.3 Site recording

All relevant observations as to the topography, vegetation cover, and conditions, were recorded in a field-log, and photographs taken with an Olympus Camedia C-3030 Zoom Digital Camera, to record the character of the survey area, and to witness survey conditions. The sites were recorded using a hand-held GPS (Global Positioning System) the site references being corrected to their location on the Topographic Map.

6.4 Effectiveness of the survey technique

As described previously other than for the two hills and saddle that formed the southern backdrop, and the larger of the two creek lines in the road corridor, the survey area was generally featureless. And while there were some surface exposures in those environments in which it had been predicted sites were most likely to occur, leaf and twig detritus severely restricted archaeological visibility in most woodland areas, while grass cover was a constraint to archaeological visibility in cleared and open areas.

The survey technique was the most appropriate one to use in the circumstances, and the results are believed to be generally representative of the archaeological record in the survey area, in which it was predicted very little artefactual material would be observed

6.5 Effective coverage

The following table is divided into units delimited by observed topographical features, environments, and/or land use, briefly described in terms of ‘horizontal’ or map area, soil, and archaeological visibility, and the percentage of the area actually surveyed.

Figure 3 shows the effective survey coverage based on the assumption that most artefactual material if exposed and visible can be observed for up to 5 metres to either side of the path of the observer. Clearly this would vary significantly between a path walked through dense vegetation, and a path across a claypan, and is given as a guide only.

The sequence of the photographic record that follows commences at the northern boundary of the road corridor, continuing to the south-western corner of the landfill site, then turning eastwards (in an anti-clockwise direction) to the central electrified fence. It then continues to the northern “Sherraloy” fenceline before doubling back along the eastern side of the electrified fence to the summit of the south-eastern ridge. From there the sequence goes northwards to the gravel pit, and then westwards back to the southern end of the road corridor.

Effective Survey Coverage

Area	Description	Survey area (467.9 ha/ 4,679,000 sqm)	Rock/soil	Vegetation	Average surface visibility	Exposures	Approx area surveyed on foot	Average arch. visibility of exposures	Archaeology
1	Road corridor ("Edington")	45,0000 sqm	Reef-like exposures of meta-sedimentary rock on northern ridge and upper slopes: middle, lower slopes and valley floor weathered met-sed deposits.	Cleared pasture all but for a few isolated eucalypts on northern ridge slopes	< 5%	Slumped and stock-worn creek banks	80%	95%	"GL ISO 2"
2	South-western hill slopes ("Sherraloy")	45,000 sqm	Reef-like exposures of meta-sedimentary rock on ridge and upper slopes: middle, lower slopes weathered met-sed deposits.	Open eucalypt woodland (regrowth) on lower slopes, upper slopes cleared pasture.	< 5%	Stock trails and driplines, minor vehicle tracks	60%	< 10%	Nil
3	South-eastern hill slopes ("Sherraloy")	130,000 sqm	Reef-like exposures of meta-sedimentary rock on ridge and upper slopes: middle, lower slopes weathered met-sed deposits.	Open eucalypt woodland (regrowth) on lower slopes, upper slopes cleared pasture.	< 5%	Stock trails and slopewash	50%	< 10%	Nil
4	Central drainage depression (Sherraloy")	118,000 sqm	Weathered meta-sedimentary deposits	Open eucalypt woodland (mostly regrowth).	< 15%	Track and driplines, as well as dozer scrapes	50%	< 40%	"GL ISO 1"
5	Lower landfill site ("Edington")	140,000 sqm	Weathered meta-sedimentary deposits	Cleared pasture all but for a few isolated eucalypts on western rise	< 3%	Minor exposures on dam wall, and some sheep overgrazed exposures on western rise	15%	< 10%	Nil

Figure 4 – Looking southwards along the road corridor from the northern boundary.

Figure 5 – Looking southwards down the road corridor from the northern ridge.

Figure 6 – Looking southwards along the road corridor towards the landfill site, across the main creek line.

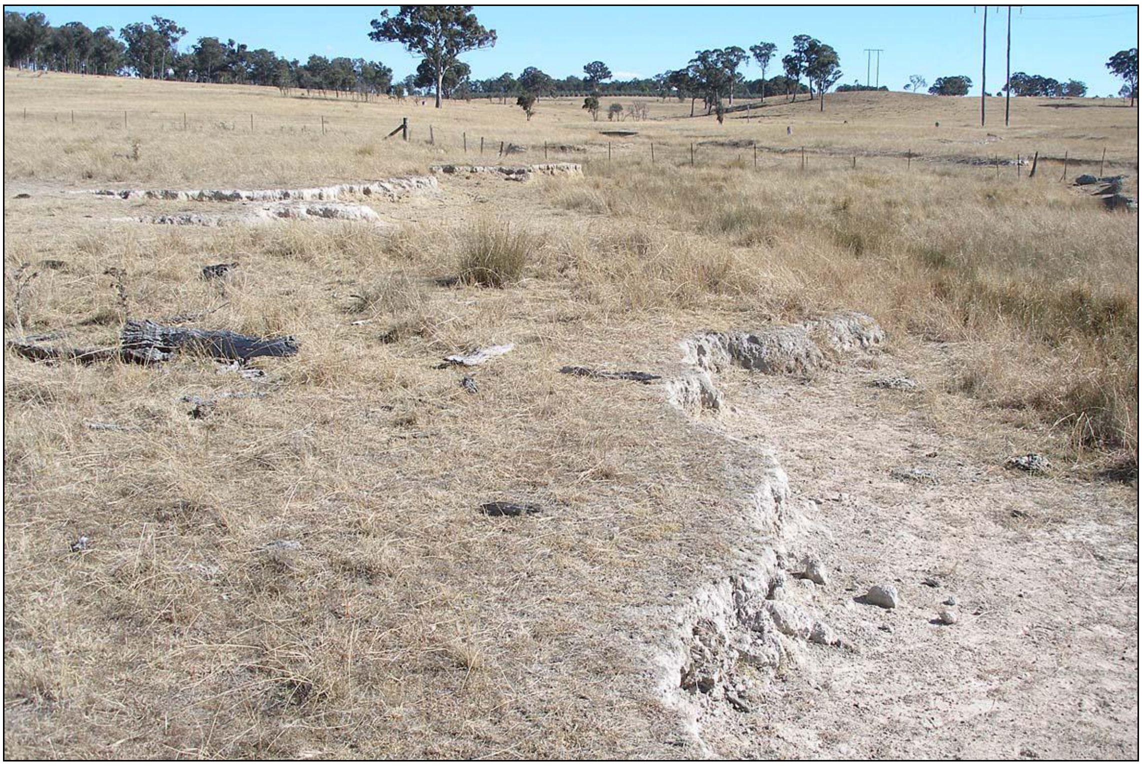


Figure 7 – Looking westwards across the road corridor, along the southern bank of the main creek.

Figure 8 – The bag marks the artefact find-spot at “GL ISO2”.

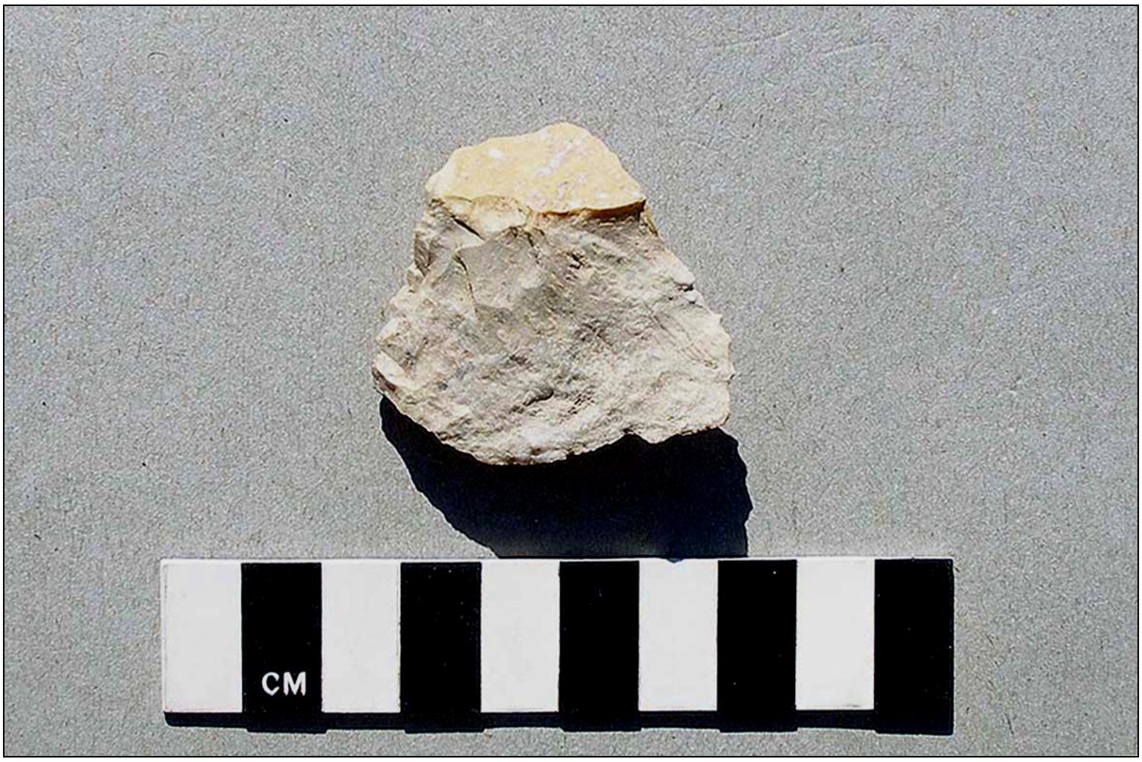


Figure 9 – The ventral face of the artefact in “GL ISO2” (scale 10 cm).

Figure 10 – Looking northwards along the road corridor from the southern end.

Figure 11 – Looking eastwards across the centre of the landfill site from the western boundary on “Edington”.

Figure 12 – Looking eastwards into the landfill site in “Sherraloy” from the western boundary.

Figure 13 – Looking southwards towards the south-western corner of the survey area on “Sherraloy”.

Figure 14 – The leather bag marks the find-spot of the artefact in "GL ISO1".

Figure 15 – The dorsal surface of the artefact at "GL ISO1" - note the steep retouch to the upper right margin.

Figure 16 – “GL ISO1” is just beyond the pile of felled timber in the right foreground.

Figure 17 – Looking northwards down the centre of the landfill site towards the dams.

Figure 18 – Looking northwards down the central fenceline in “Sherraloy”.

Figure 19 – Looking northwards towards the dams in the centre of the landfill site.

Figure 20 – Looking eastwards towards the summit of the eastern hill in “Sherraloy”.

Figure 21 – Looking northwards down the middle slopes of the eastern hill in “Sherraloy”.

Figure 22 – The gravel pit in the eastern section on “Sherraloy”.

Figure 23 – Looking north-eastwards towards the north-eastern corner of the landfill site.

7. THE RESULTS

Two isolated artefacts were recorded during the investigation. They were recorded as follows:

Site : **"GL ISO1"**

Site type: Isolated artefact.

Location: Map: Hillgrove 9236-1-N, 1: 25,000 scale Topographic map
Map ref: (GPS) 56J 0383235 6618414 (corrected to Topo ref. 383200 6618520)

Material: Silcrete

Description: Flake scraper
62 x 52 x 24 mm
Broad platform 15 x 11
Overhang removal
Core rotation
Cortex nil

Average archaeological visibility within 1 m radius: 60%

Background: Small, fragmentary and angular meta-sedimentary rubble on coarse-grained weathered meta-sedimentary deposits.

Context: The artefact was found in an erosion feature in open dry eucalypt woodland of predominantly regrowth eucalypts with some casuarina. The woodland has been logged/thinned by saw and dozer and the felled timber heaped into unburnt piles. There is likely to be significant displacement of surface material, but the artefact depositional location was probably within 20 m radius of the find-spot. The location is on a saddle between two hills and was probably a route between Gara River and Commissioners Waters. It is unlikely that this was a camp site, and the artefact was probably dropped or left behind accidentally as it is still in usable condition as a scraper.

Site : **"GL ISO2"**

Site type: Isolated artefact.

Location: Map: Hillgrove 9236-1-N, 1: 25,000 scale Topographic map

Map ref: (GPS) 56J 0383143 6619426 (corrected to Topo ref. 383150 6619420)

Material: Silcrete

Description: Flake

31 x 46 x 15 mm

Broad platform 27 x 16 (cortex)

Possible retouch to both margins – but could also be partly or solely from stock treadage

Feather termination

Strike plane 75º

Cortex 10% (platform)

Average archaeological visibility within 1 m radius: 95%

Background: Coarse-grained weathered meta-sedimentary deposits with very few stone pieces.

Context: The artefact was found in the southern eroded face of the creek bank in cleared pasture. The location is approximately 350 m from a small camp site previously recorded on the summit of a small hillock overlooking the creek – see **Figure 7** on page 20, the 'earlier' site is at the base of the twin power-poles at the right of centre in the distance. Because the creek bank deposits are likely to be both alluvial and colluvial in origin, and the area has both been cleared of vegetation and subjected to stock grazing for many years, it is not possible to say where the artefact was originally deposited, but if we assume that it has not travelled far then there is a potential for other artefacts to exist along the creek banks to either side.

8. DISCUSSION

While it is difficult to be confident that there are no other Aboriginal sites of cultural significance in the survey area, primarily as a consequence of clearing, and general disturbance, it is reasonable to assume that if there is any artefactual material present that it is likely to occur along the banks of the main creek, and consist of isolated artefacts and/or low density artefact scatters, neither of which would be visible. Because of the likelihood that any artefacts would be so sparsely distributed it would not be practical to undertake subsurface investigation, merely to recover one or two more artefacts, however it is reasonable to suppose that monitoring of earthworks along the creek banks in the vicinity of the artefact find-spot might yield additional artefactual material.

Generally, campsites would have been on elevated well-drained land, overlooking or adjacent to reliable water resources. The survey area occurs on the lower slopes and valley floor in an area of open dry eucalypt woodland, in which there were few natural resources – such as water, stone suitable for knapping, shelter, or food resources not available elsewhere. It is unlikely that the area would have been suitable as a camp-site, and so any artefacts found in the survey area were probably accidentally dropped or discarded during transit, perhaps while travelling along the valley, or between the Gara River and Commissioners Waters.

This particular valley of what was only an ephemeral creek was generally unsuitable for campsites and it is probable that it was only ever used for opportunistic activities, such as catching, killing and butchering animals, or for tool maintenance, or as a transit corridor. None of these activities would have left much in the way of archaeological evidence other than the occasional dropped or discarded flake, or trimming flakes of less than 5 mm length discarded during the maintenance of tools.

In summary, although the survey areas occur in a region in which there are known to be places of Aboriginal association, there is very little potential for the survey area to contain any significant archaeological material. Primarily as a consequence of the extent to which the survey area has been significantly altered, there are few undisturbed contexts in which archaeological material could occur. If however archaeological material is present, it is likely to consist of small isolated artefacts or low density open scatters only, none of which will be observed other than by chance.

In its report of the field survey Anaiwan Aboriginal Traditional Owners recommended that their representative should be present during any turf stripping, or clearing of the piled timber, or removal of existing vegetation in the wooded areas of the survey area. At the time ASR also recommended that a representative of Anaiwan Aboriginal Traditional Owners should monitor any earthworks within 25 metres to either side of the main creek line in the road corridor.

Given that the road corridor is 60 m wide it would be possible to avoid the site at "GL ISO2" which is only 7 m from the fenceline, thus avoiding the necessity of obtaining Section 90 Consent for Salvage for the site. However, the creek banks both upstream and downstream of the site are of potential archaeological sensitivity and ASR recommended that any earthworks that require excavation of the banks should be monitored.

Subsequently, the decision by Council to apply for Part 3A Approval changed the options available to the Aboriginal Community with regard to monitoring. The effect of Part 3A Legislation was to negate any pre-existing legislation that might otherwise have been a constraint to development, thus Section 90 Consent to Salvage and Destroy was not required to develop the site. Consequently the only recourse Aboriginal stakeholders had was to either request the developer to avoid impacting upon sites wherever practical, and if not practical to avoid the sites, to salvage the artefactual material. The stakeholders elected to request that the two artefact locations should be avoided and that the artefacts should remain in situ.

In this instance Council agreed to avoid impacting upon the two site locations, and to ensure that accidental damage did not occur to the site in the access road corridor a circle of vertical posts would be placed around site "GL ISO2" at a radius of 10m from the artefact. Given that Part 3A does not require a developer to make such a concession Council is to be applauded for its sensitivity.

Council is advised that Site Recording Forms for the two artefact locations were lodged with DECC to ensure that they were listed as Aboriginal sites on the AHIMS Site Register.

9. SIGNIFICANCE ASSESSMENT

9.1 Cultural significance

The DEC policy to safeguard all sites, Aboriginal places, and archaeological material of significance wherever possible requires that some means of assessing the significance of the sites is necessary. This is not only for the purpose of determining whether the proposed development can proceed as proposed, but also to provide Cultural Resource Managers with the information for future management of the area.

Following the investigation Rhonda Kitchener, Chairperson, Anaiwan Aboriginal Traditional Owners Natural Resource and Cultural Heritage Management Association Incorporated, discussed the results with Armidale Aboriginal Community Elders. Subsequently Rhonda forwarded a report of their recommendations to Appleton, a copy of which is included as **Appendix i**.

When Appleton received the report he contacted Rhonda to obtain a clearer understanding of the recommendations and implications of the report. Rhonda advised Appleton that the Elders had expressed concern that other artefacts might be present beneath the piles of felled timber or in the grass-covered surface deposits in the wooded areas in the saddle at the southern end of the landfill site. As a consequence they recommended that a representative of the Anaiwan Aboriginal Traditional Owners should be present during any turf stripping, or clearing of the piled timber, or removal of existing vegetation in the wooded areas.

As discussed above the decision to proceed with an application for Part 3A Approval for the project introduced a different set of rules to those that would otherwise have applied for a non-Part 3A Project, and once Part 3A Approval has been given the developer is not required to engage Aboriginal people to monitor earthworks.

9.2 Research potential

Although two isolated artefacts were recorded and one of the sites occurred in a context in which others might exist beneath the surface (“GL ISO2”), ASR assessed the research potential of both sites to be low.

The artefact at “GL ISO1” was on a degraded surface in a highly disturbed context, and it was therefore unlikely that the artefact was in its depositional location. There was therefore no indication of where the artefact might have been deposited.

The artefact recorded at “GL ISO2” was on a degraded surface and it is possible others might exist further back from the creek line, and it could be argued that the intact bank upslope of the degraded area was therefore an area of potential archaeological interest. But typically many sites on the Northern Tablelands are of only isolated artefacts.

The issue was should the site be declared a PAD (see Glossary) or could the road be realigned to avoid the site?

Appleton (ASR) discussed the options with the client’s representative, who advised Appleton that the road could be realigned to avoid the site, and that the artefact location (at “GL ISO2”) could be contained within a buffer zone. Thus it became unnecessary to investigate the site any further.

When considering whether or not a site is likely to be of research potential, it is necessary to consider who would be undertaking the research. At the present time the cost of undertaking research in the field is such that unless there is a very strong potential for further information to be recovered from a site, that the researcher will use what funds they have on far more promising sites than this. By protecting the site within a buffer zone the site remains intact until such time as more funds are available for research, or a project is undertaken in which the site is just one of many being investigated.

Having undertaken over 480 archaeological projects across the state over a period of nineteen years Appleton has assessed both sites to be of very low potential research value.

10. RECOMMENDATIONS

Council is advised that both of the two artefact locations were registered as Aboriginal sites on the AHIMS Site Register although the listing will not be a constraint to Part 3A Approval.

While Part 3A Approval would render any constraints that might otherwise have applied under the National Parks and Wildlife Act 1974 (as amended) ineffective, ASR recommends that in the interests of the Armidale Aboriginal Community Council should instruct their employees, sub-contractors, machine operators and representatives, whether working on the project Site or elsewhere, that in the event of any bone or stone artefacts, or discrete distributions of shell, or any objects of cultural association, being unearthed during earthmoving, work should cease immediately in the area of the find.

In the event that any bone cannot be clearly identified by a qualified archaeologist as being of animal remains the police are to be informed of its discovery, and officials and/or their representatives of Armidale LALC, Nyakka Aboriginal Culture Heritage Corporation Archaeological & Cultural Heritage Consultants, and the Manager, Planning & Aboriginal Heritage, DECC, Coffs Harbour, advised that the bone is subject to police investigation.

Work should not recommence in the area of the find, until both the police (if bone has been found) and those officials or representatives have given their permission to do so. Those failing to report a discovery and those responsible for the damage or destruction occasioned by unauthorised removal or alteration to a site or to archaeological material may be prosecuted under the National Parks and Wildlife Act 1974, as amended.

GENERAL GLOSSARY: The definitions that follow are for terms used in this and other reports written by the author, and do not necessarily apply to their use in different contexts.

ADZE : A modified flake with at least one steeply-retouched working edge. While all adzes are generally considered to be wood-working tools it is probable that some also served as cores and others as scrapers. Adzes with a uniform butt were frequently hafted to make a chisel-like tool, but the intended use of the adze determined the size of the adze and whether it was hafted (Flenniken and White, 1985).

ARCHAEOLOGICAL DEPOSIT : Sediments which contain evidence of past Aboriginal use of the place, such as artefacts, hearths, burials etc.

ARTEFACT : Any object that has attributes as a consequence of human activity (Dunnell, 1971). In this report 'artefacts' has been used generally to describe pieces of stone that have been modified to produce flakes, flaked pieces, cores, hammerstones, or axes.

BACKED BLADE : A stone tool manufactured from a flake on which one margin has been modified by the removal of small flakes to blunt the edge or margin opposite the cutting edge.

BORA GROUND : A ceremonial site comprising of one or two connected circles composed of compacted or mounded earth, or defined by an arrangement of stones, of 2 to 30m diameter, generally used in male initiation rites.

CAMPSITE : A place at which the density of artefacts and the variety of material indicates that people ‘frequently’ used the place as a stopping or resting place. Such places are also likely to contain or be close to water resources, food resources, or stone material resources. In this report a campsite is used to describe artefact scatters that are associated with hearths or fireplaces, as distinct from scatters that are not associated with hearths or fireplaces, which are described as Open Scatters.

CHALCEDONY : A form of silica (partially translucent), which occurs as linings in cavities in rocks. When banded it is known as AGATE (Department of Mines, 1973). Chalcedony is uniformly coloured and agate has curved bands or zones of varying colour (Cook & Kirk, 1991).

CHERT : Another name for sedimentary chalcedony. It occurs most frequently in limestones, or in marine sedimentary rock, or as pebbles in sedimentary rock. In its depositional context it is often concentrated in bedding planes. Chert found in deep-water limestones is formed from radiolaria and diatoms (siliceous planktonic micro-organisms) (Cook & Kirk, 1991).
Chert is a form of amorphous or extremely fine-grained silica, partially hydrous, found in concertions and beds. It is classified as a chemical sedimentary rock although it may be precipitated both organically and inorganically (Department of Mineral Resources, n.d.).

CONGLOMERATE : Naturally cemented gravel. Conglomerate is a coarse-grained clastic sedimentary rock composed of generally rounded fragments of other rock types larger than 2 mm in diameter, set in a fine-grained matrix of sand, silt, or any of the common natural cementing materials (Department of Mineral Resources, n.d.).

CORE : A piece of stone from which flakes have been removed, that cannot otherwise be described as a retouched or modified artefact.

CORTEX : The naturally altered surface of stone – eg. the water-worn surface of river pebbles.

DEBITAGE : The small waste material observed in knapping floors. Generally, waste material is described as all those fragments having a maximum dimension of less than 10mm

FLAKE : A fragment of stone exhibiting features indicating that it has been deliberately removed from a core piece. These features are evident as:

i) Platform: Plane or point at which a blow was delivered to remove the flake.
ii) Bulb of Percussion: Convex surface that occurs on the face or ventral surface of a flake, radiating from the point of impact, produced as a consequence of the force pattern.
iii) Eraillure: see below.

Other terms:

i) Dorsal: The back or outer face of a flake as it would have been prior to removal from a core. Frequently either ridged or exhibiting negative flake scars when removed in secondary flaking, with a natural weathered cortex when removed in primary flaking.
ii) Ventral: The 'chest' or inner face of a flake as it would have been prior to removal from the core. The surface upon which the Bulb of Percussion occurs.
iii) Platform Preparation: The removal of flakes from a surface to produce a level platform. May be evidenced by retouch scars to the platform.
iv) Retouch: The removal of small flakes from an edge or margin of an artefact to modify its shape or resharpen its edge.
v) Proximal: The end of a flake closest to the striking platform.
vi) Distal: The end of a flake furthest from the striking platform.
vii) Margin: The edge of an artefact.
viii) Eraillure: A small circular to elliptical negative flake scar occurring on the surface of the bulb of percussion on flakes of very fine-grained or highly silicified material. It occurs 'naturally' as a consequence of internal forces generated at the time of flake removal.
ix) Split Cone: Occurs when the flake splits down its axis frequently removing part of the striking platform. Generally believed to be produced by faulty knapping technique, but is also probably a consequence of flawed material.
x) Transverse Snap: Occurs when a flake snaps across its axis. Generally believed to be caused by post-depositional impacts such as human or stock treadage, or vehicular traffic.

FLAKED PIECE :

A fragment of stone exhibiting flake scars indicating that it is an artefact, but not displaying diagnostic features, such as a Bulb of Percussion, Striking Platform, or an Eraillure.

GREYWACKE :

A type of sandstone, grey or greenish-grey in colour, tough and well indurated and typically poorly sorted (Clark & Cook, 1986).
A generally poorly sorted, dark sandstone containing feldspar and sand-sized rock fragments of metamorphic or volcanic rocks (Department of Mineral Resources, n.d.).
Usually a dark and coarse-grained rock compared to mudstones and siltstones that are much finer-grained and better sorted.

HOLOCENE PERIOD :

The period from 10,000 years ago to the present.

IGNEOUS ROCK :

Rock formed by the cooling and solidification of magma on or below the earth's surface (Geography Dictionary, 1985).

In situ : In its original place – as deposited.

ISOLATED ARTEFACT :

A solitary stone artefact, at least 50m from its nearest neighbour. This is based on NPWS policy that two artefacts within 50m of each other constitute a site.

KNAPPING FLOOR:

A discrete scatter of artefacts in which at least two artefacts are recognisably of the same material, and derive from the same piece of stone. Also described as a stone tool manufacturing site or floor.

LOCATION : The place at which an artefact is found, or a place identified as having either archaeological or Aboriginal significance.

MEASUREMENT :

- I) Flake:
  - i) Length: Measured along the percussion axis at right angles to the platform.
  - ii) Width: The greatest width measured at right angles to the percussion axis.
  - iii) Thickness: The greatest thickness measured at right angles to the percussion axis.
- II) Flaked piece:
  - i) Length: The longest dimension
  - ii) Width: The greatest width measured perpendicular to the length.
  - iii) Thickness: The greatest thickness measured perpendicular to the length.
- III) Core:
  - i) Length: The longest dimension.
  - ii) Width: The greatest width measured perpendicular to the length.
  - iii) Thickness: The greatest thickness measured perpendicular to the length.

MIDDEN : A refuse heap or stratum of food remains, such as mollusc shells, and other occupational debris (Dortch, 1984 – see also Meehan, 1982).

MUDSTONE : A fine-grained detrital rock, usually quite massive and well consolidated. May be black through grey to off-white, browns, reds and dark blues/greens. Frequently found in association with sandstones (Cook & Kirk, 1991).
Identification is often aided by colour variations in layering. A source for stone material tool manufacturing material found as river pebbles in creek beds, and artefacts often display a water-worn cortex.

NEGATIVE FLAKE SCAR :
A concave surface resulting from the removal of a flake, occurring on the surface of the rock from which a flake has been removed.

PLEISTOCENE PERIOD :
The period from about 10,000 years ago to 2 million years ago.

POTENTIAL ARCHAEOLOGICAL DEPOSIT (PAD) :
Synonymous with Potentially Archaeologically Sensitive : Having the potential to contain archaeological material although none is visible.

QUARTZITE :
Quartzites are formed by the regional or contact metamorphism of quartz arenites, siltstones, and flints (cherts). They are composed essentially of quartz, and usually have a fine-grained granoblastic (grains are roughly the same size) texture. Generally massive, but may sometimes show sedimentary structures (Cook & Kirk, 1991).

ROTATION :
The removal of flakes from a core by blows directed at different angles, to different platforms. May be evident on the dorsal surface of a flake as negative flake scars, which do not follow the same direction as the percussion axis of the flake. This may be confused with scars produced during core preparation.

SCAT : The solid waste material produced by an animal – dung, droppings, manure (Triggs, 1985).

SCATTER : Two or more artefacts occurring within 50 metres. Scatter may also be used in the context of ‘background scatter’, meaning the general distribution of artefacts across the landscape that cannot be recognised as discrete concentrations.

SILCRETE : A near surface or surface siliceous induration (Desen & Peterson, 1992).
A conglomerate consisting of surficial sand and gravel cemented into a hard mass by silica.
A siliceous duricrust (Bates & Jackson, 1980).

Crusts may form as a result of low, infrequent rainfall, on reasonably flat surfaces. These are known as duricrusts – those cemented by silica are known as silcretes (Clark & Cook, 1986), sometimes referred to locally as 'billy' (Gentilli, 1968), or 'grey billy'.

Silcrete on the northern tablelands of NSW forms at the surface contact between sediments of the Sandon Beds and the Armidale Beds with overlying basalt, where groundwater (more rich in silica than surficial water) interacts with surficial water and precipitates new quartz as the matrix to the sediments (N.D.J. Cook, Dept. of Geophysics, UNE, pers. Comm.).

In softer formations of quartz sands, groundwater has apparently been responsible for the formation of concretionary layers of silcrete. Under altered climatic conditions, the less competent beds erode away leaving concretions. Since they are often the size of old-fashioned woolsacks and are greyish and white, they are popularly known as gray billy (slang for billy goat) (Fairbridge, 1968).

SITE : A discrete area or concentration of artefactual material, place of past Aboriginal activity, or place of significance to Aboriginal people.

SOIL SCIENCE TERMS (taken from Banks, 1995, and others as referenced).

BEDROCK : Outcrop of *in situ* rock material below the soil profile.

BENCH : A strip of relatively level earth or rock breaking the continuity of a slope.

BLOWOUT : A closed depression formed in the land surface by wind eroding sands and depositing them on adjacent land.

CLAYPAN : A depression caused by the aeolian deflation of sediments, or by the presence of a prior lake.

DUNE : A ridge built up by wind action composed of sands, silts, or sand-sized aggregates of clay.

FLOODPLAIN : A large flat area, adjacent to a watercourse, characterised by frequent active erosion and aggradation by channelled and overbank stream flow.

GIBBER : A level surface covered by a thick deposit of gravel or broken siliceous pebbles, occurring in the more arid parts of the continent, thought to have been formed from the break-up of a siliceous (silcrete) surface crust, and termed gibber plains (Whittow, 1984) – see also silcrete.

GILGAI : Surface microrelief associated with soils containing shrink-swell clays. Gilgai consists of mounds and depressions, or irregularly distributed small mounds and subcircular depressions varying in size and spacing. Vertical interval usually <0.3m; horizontal interval usually 3-10m, and surface almost level.
Sometimes called ‘crab-hole’ soils.

GULLY : An open incised channel in the landscape generally greater than 30cm deep and characterised by moderately to very gently inclined floors and steep walls.

HUMMOCK : A small raised feature above the general ground surface.

LANDFORM ELEMENTS :
Crest : Landform element standing above all points in the adjacent terrain.
Flat : Neither a crest or a depression <3% slope.
Upper slope : Adjacent to and below a crest or flat but not a depression.
Midslope : Not adjacent to a crest, a flat or a depression.
Lower slope :Adjacent to and above a flat or a depression but not a crest.

LITHOSOLS : Shallow soils showing minimal profile development and dominated by the presence of weathering rock and rock fragments.

RILL : A small channel cut by concentrated runoff through which water flows during and immediately after rain.

RUNOFF : That portion of precipitation not immediately absorbed into or detained upon the soil and which thus becomes surface flow.

SCARP/CLIFF : A steep slope terminating a plateau or any level upland surface.

SCRUB : vegetation structure consisting of shrubs 2-8m tall.

SHEET EROSION : The removal of the upper layers of soil by raindrop splash and/or runoff.

SOIL PROFILE :
“A HORIZON” : The top layer of mineral soil. This may consist of two parts:
A_1 HORIZON: Surface soil and generally referred to as the topsoil.
A_2 HORIZON: similar in texture, but paler in colour, poorer in structure, and less fertile.

“ B HORIZON” : The layer below the A Horizon. This consists of 2 parts:

B_1 HORIZON: A transitional horizon dominated by properties characteristic of the underlying B_2 horizon.
B_2 HORIZON: typically contains concentrations of silicate clay and/or iron, and/or aluminium and/or translocated organic material.

“C HORIZON” : The parent rock. Recognised by its lack of pedological development, and by the presence of remnants of geologic organization.

“R HORIZON” : Hard rock that is continuous (Charman & Murphy, 1993; 350-1).

SPUR : A ridge which projects downwards from the crest of a mountain as a water-parting (Whittow, 1984).

SUBSOIL : Sub-surface material comprising the B and C Horizons of soil with distinct profiles; often having brighter colours and higher clay contrasts.

SURFACE CONDITION :
Gravelly : Over 60% of the surface consists of gravel (2-69mm).
Hardsetting : Soil is compact and hard.
Loose : Soil that is not cohesive.
Friable : Easily crumbled or cultivated.
Self-mulching : A loose surface mulch of very small peds forms when the soil dries out.

SWALE : A linear level-floored open depression excavated by wind or formed by the build-up of two adjacent ridges.

SWAMP : Watertable at or above the ground surface for most of the year.

TERRACE : A flat or gently inclined surface bounded by a steeper ascending slope on its inner margin and a steeper descending slope on its outer margin (Whittow, 1984).

TOPSOIL : A part of the soil profile, typically the A_1 horizon, containing material that is usually darker, more fertile and better structured than the underlying layers.

UNDERSTOREY : A layer of vegetation below the main canopy layer.

BIBLIOGRAPHY

Appleton, J. 1991. A report of the archaeological investigation of the proposed cable route: Armidale Telephone Exchange to Hillgrove Telephone Exchange, Northern Tablelands, NSW. Unpublished report for Telecom Australia.

Appleton, J. 2006. The archaeological investigation for sites of Indigenous cultural significance on the site of the proposed New England Regional Landfill, Waterfall Way, east of Armidale, Northern Tablelands, NSW. Unpublished report for Maunsell Australia Proprietary Limited on behalf of Armidale Dumaresq Council.

Banks, R.G. 1995. *Soil landscapes of the Curlewis 1:100,000 sheet*. Department of Conservation and Land Management.

Bates, R.L., and J.A. Jackson (Eds). 1980. *Glossary of Geology.* Second Edition. American Geological Institute, Virginia.

Clark, I.F., and B.J. Cook. 1986. *Geological Science: Perspectives of the Earth*. Australian Academy of Science, Canberra.

Cook, D., and W. Kirk. 1991l. *Field Guide to the Rocks and Minerals of the World*. Kingfisher Books, London.

Charman, P.E.V., & B.W. Murphy. 1993. *Soil: Their Properties and Management*. Sydney University Press.

Department of Mineral Resources. 1980. Metallogenic Series Sheet SH/56 13-14, SI/56 1-2, ‘Tamworth-Hastings’.

Department of Mineral Resources. n.d. Information Sheet : Sedimentary Rocks.

Department of Mines. 1973. *Minerals and their Characteristics*. Geological Survey of New South Wales, Number 141.

Desen, J.L., and J. Peterson. 1992. Mapping the Australian Duricrusts: can Distribution be derived from Terrain Maps. *Australian Geographical Studies*, 30(1): 87-94.

Dortch, C. 1984. *Devil’s Lair: a study in prehistory*. Western Australian Museum.

Dunnell, R.C. 1971. *Systematics in prehistory*. Free Press, New York.

Fairbridge, R.W. 1968. Induration. *Encyclopaedia of Geomorphology, Encyclopaedia of Earth Science Series,* Vol. III, pp.554-55. Reinbold Book Corporation, New York.

Flenniken, J.L., and L.P. White. 1985. Australian flaked stone tools: a technological perspective. *Records of the Australian Museum*, 36: 131-51.

Gentilli, J. 1968. Duricrust. In R.W. Fairbridge (Ed.), *The Encyclopaedia of Geomorphology, Encyclopaedia of Earth Science Series,* Vol. III, pp.296-7. Reinbold Book Corporation, New York.

Geography Dictionary. 1985. Longman Group, Harlow.

McGarity, J.W. 1977. Soils. In D.A.M. Lea, J.J.J. Pigram and L. Greenwood (Eds), An Atlas of New England, Vol 2, The Commentaries, pp.41-70. Department of Geography, University of New England, Armidale.

Meehan, B. 1982. *Shell bed to shell midden*. Australian Institute of Aboriginal Studies, Canberra.

Simpson, B. 1966. *Rocks and Minerals*. Pergamon Press, Oxford.

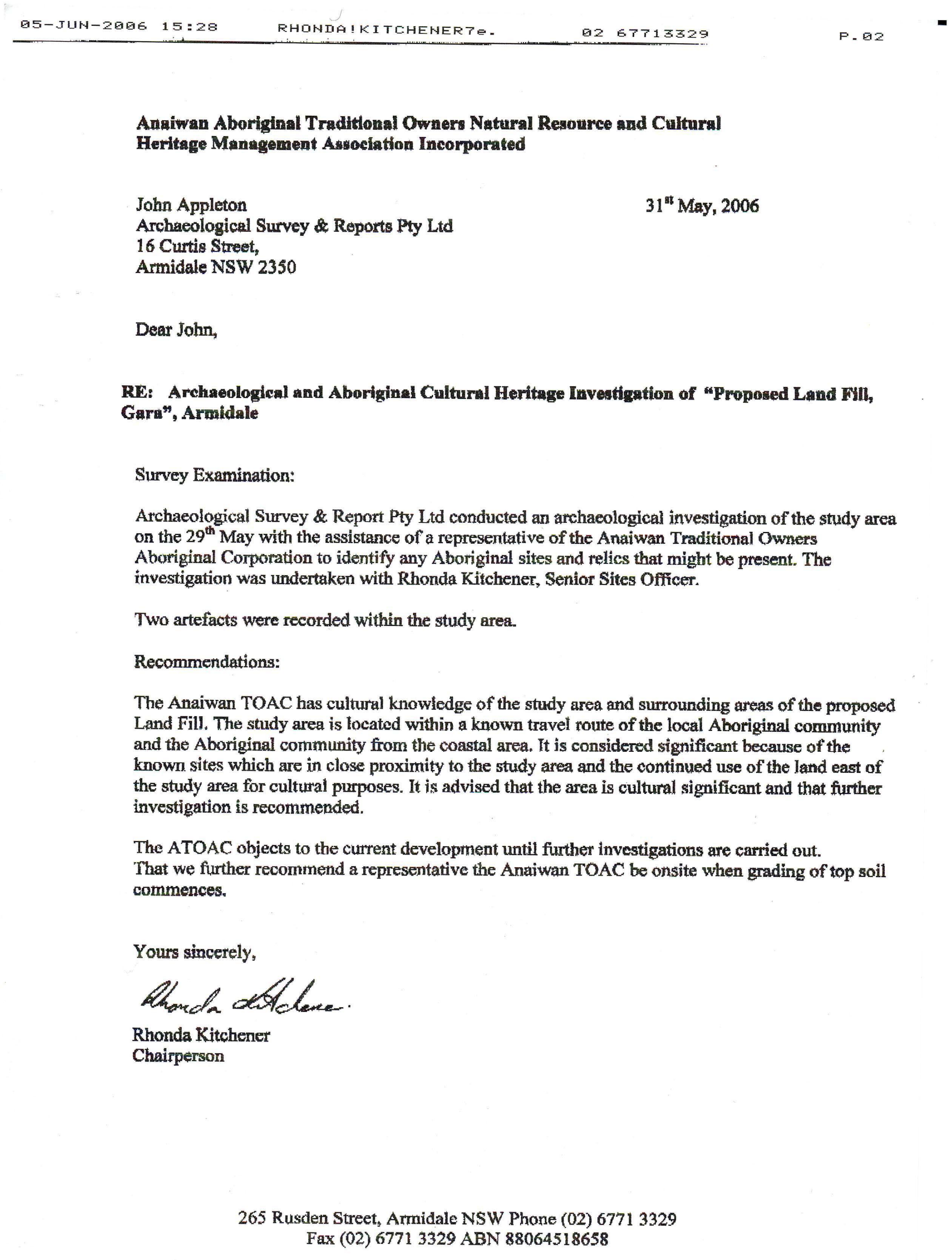
Triggs, B. 1985. *Mammal tracks and signs: a fieldguide for southeastern Australia*. Oxford University Press, Melbourne.

Walker J., & M.S. Hopkins. 1990. Vegetation. In R.C. McDonald, R.F. Isbell, J.G. Speight, J. Walker & M.S. Hopkins (Eds), *Australian Soil and Land Survey*, pp. 58-86. Inkata Press, Sydney.

Whittow, J. 1984. *Dictionary of Physical Geography*. Penguin, London.

APPENDICES

Appendix i - Correspondence from Anaiwan Aboriginal Traditional Owners.



05-JUN-2006 15:28 RHONDA!KITCHENER7e. 02 67713329 P.02

Anaiwan Aboriginal Traditional Owners Natural Resource and Cultural Heritage Management Association Incorporated

John Appleton
Archaeological Survey & Reports Pty Ltd
16 Curtis Street,
Armidale NSW 2350

31st May, 2006

Dear John,

RE: Archaeological and Aboriginal Cultural Heritage Investigation of "Proposed Land Fill, Gara", Armidale

Survey Examination:

Archaeological Survey & Report Pty Ltd conducted an archaeological investigation of the study area on the 29th May with the assistance of a representative of the Anaiwan Traditional Owners Aboriginal Corporation to identify any Aboriginal sites and relics that might be present. The investigation was undertaken with Rhonda Kitchener, Senior Sites Officer.

Two artefacts were recorded within the study area.

Recommendations:

The Anaiwan TOAC has cultural knowledge of the study area and surrounding areas of the proposed Land Fill. The study area is located within a known travel route of the local Aboriginal community and the Aboriginal community from the coastal area. It is considered significant because of the known sites which are in close proximity to the study area and the continued use of the land east of the study area for cultural purposes. It is advised that the area is cultural significant and that further investigation is recommended.

The ATOAC objects to the current development until further investigations are carried out.
That we further recommend a representative the Anaiwan TOAC be onsite when grading of top soil commences.

Yours sincerely,

Rhonda Kitchener

Rhonda Kitchener
Chairperson

265 Rusden Street, Armidale NSW Phone (02) 6771 3329
Fax (02) 6771 3329 ABN 88064518658

Appendix ii – Detail from “The Armidale Express” 2nd February 2009.

SELL IT SOONER!

'Good as Sold' Classifieds

PRODUCE

CHAFF Lucerne Oaten Wheaten $25. Lucerne hay $15. Lucerne mulch $8.80. 6775 3790 ah.

MEETINGS

HOCKEY NEW ENGLAND AGM, Thursday Feb 19th, Services Club, 7pm. All Welcome.

PUBLIC NOTICES

ARCHAEOLOGICAL INVESTIGATION

Application is to be made for Part 3A Approval for the Armidale Regional Landfill site, Waterfall Way.

An archaeological investigation of the site for sites of Indigenous cultural significance was undertaken with Aboriginal Community representatives in May 2006.

In accordance with "Guidelines for Aboriginal Cultural Heritage Impact Assessment and Community Consultation", Part 6 Approvals of the National Parks & Wildlife Act 1974 (as amended) Aboriginal stakeholders with an interest in the project are invited to register their interest within 14 days, with John Appleton, Archaeological Consultant, Tel. 02 6772 6512, Fax. 02 6772 4567, Mob. 0428 651 789.

GALLERY CAFE @ NERAM, trading hours, Wed - Sun from 10am - 3pm. Dinner by appointment only. Call Daniel or Barbara 6771 4425 for bookings.

LEARN TO DANCE CLASSES

Armidale & Uralla resumes Tues 3rd Feb. Fully licensed & registered dance teacher (2053TDI). Teaching all styles of dance inc Salsa. PH Robyn Kaluder 6764 0133 or 0427 468 317.

TABLE TENNIS players of any standard interested in teams social competition, Contact Brian 6771 2986. Practice available. Grading 12th February. Competition starts 19th Febru-

POSITIONS VACANT

Program Consultant
Armidale/Inverell – Full Time

Good with people?
Enjoy making a real difference?

A self motivated and engaging individual is required to deliver Structured Employment and Training Projects, Employment and Related Services (STEP ERS) throughout the New England. This program aims to provide sustainable employment opportunities for Indigenous Australians and help them realise their potential;

Essential requirements:
- Enthusiasm for assisting and mentoring
- Communication skills to consult with people from diverse backgrounds
- Focus on achieving results
- Computer/admin skills

Desirable:
- Ability to actively promote clients in the employment market

For further information about this role, visit our website www.joblinkplus.com.au or contact our HR dept on (02) 6764 6678.

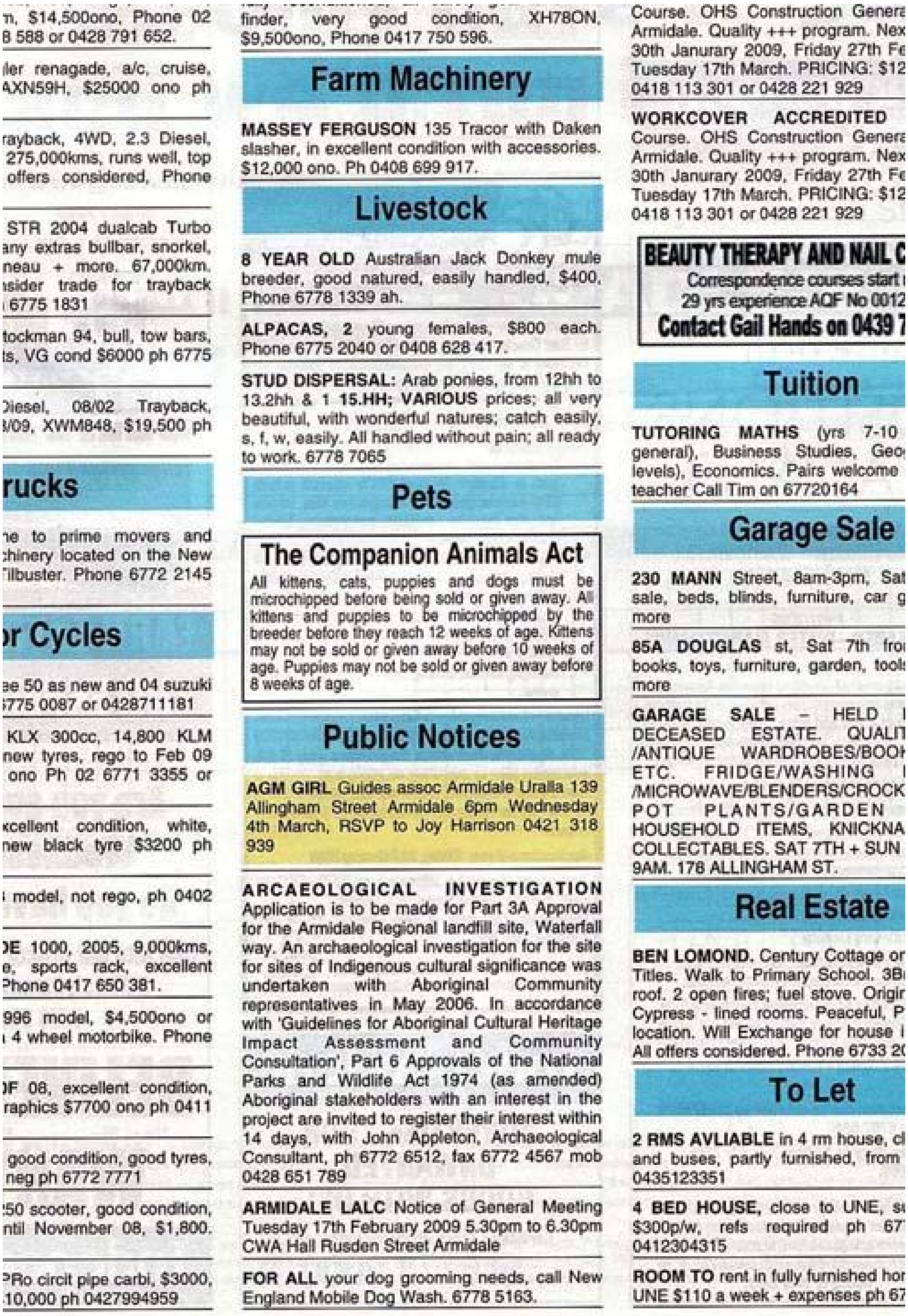
Applications close COB 12th February 2009.

JOBLINKplus
Focused on our Community

PF
P/T (One
diploma
months
Drummo
Armidale
6772 556

SALES
potential
calling. T
message

Appendix iii - Detail from "The Armidale Independent" 4th February 2009.



n, $14,500ono, Phone 02 8 588 or 0428 791 652.

ler renagade, a/c, cruise, AXN59H, $25000 ono ph

rayback, 4WD, 2.3 Diesel, 275,000kms, runs well, top offers considered, Phone

STR 2004 dualcab Turbo any extras bullbar, snorkel, neau + more. 67,000km. nsider trade for trayback 6775 1831

tockman 94, bull, tow bars, ts, VG cond $6000 ph 6775

Diesel, 08/02 Trayback, 3/09, XWM848, $19,500 ph

rucks

ne to prime movers and chinery located on the New Filbuster. Phone 6772 2145

or Cycles

ee 50 as new and 04 suzuki 6775 0087 or 0428711181

KLX 300cc, 14,800 KLM new tyres, rego to Feb 09 ono Ph 02 6771 3355 or

xcellent condition, white, new black tyre $3200 ph

model, not rego, ph 0402

DE 1000, 2005, 9,000kms, e, sports rack, excellent Phone 0417 650 381.

996 model, $4,500ono or 4 wheel motorbike. Phone

DF 08, excellent condition, raphics $7700 ono ph 0411

good condition, good tyres, neg ph 6772 7771

250 scooter, good condition, ntil November 08, $1,800.

PRo circit pipe carbi, $3000, 10,000 ph 0427994959

finder, very good condition, XH78ON, $9,500ono, Phone 0417 750 596.

Farm Machinery

MASSEY FERGUSON 135 Tracor with Daken slasher, in excellent condition with accessories. $12,000 ono. Ph 0408 699 917.

Livestock

8 YEAR OLD Australian Jack Donkey mule breeder, good natured, easily handled, $400, Phone 6778 1339 ah.

ALPACAS, 2 young females, $800 each. Phone 6775 2040 or 0408 628 417.

STUD DISPERSAL: Arab ponies, from 12hh to 13.2hh & 1 **15.HH; VARIOUS** prices; all very beautiful, with wonderful natures; catch easily, s, f, w, easily. All handled without pain; all ready to work. 6778 7065

Pets

The Companion Animals Act

All kittens, cats, puppies and dogs must be microchipped before being sold or given away. All kittens and puppies to be microchipped by the breeder before they reach 12 weeks of age. Kittens may not be sold or given away before 10 weeks of age. Puppies may not be sold or given away before 8 weeks of age.

Public Notices

AGM GIRL Guides assoc Armidale Uralla 139 Allingham Street Armidale 6pm Wednesday 4th March, RSVP to Joy Harrison 0421 318 939

ARCAEOLOGICAL INVESTIGATION Application is to be made for Part 3A Approval for the Armidale Regional landfill site, Waterfall way. An archaeological investigation for the site for sites of Indigenous cultural significance was undertaken with Aboriginal Community representatives in May 2006. In accordance with 'Guidelines for Aboriginal Cultural Heritage Impact Assessment and Community Consultation', Part 6 Approvals of the National Parks and Wildlife Act 1974 (as amended) Aboriginal stakeholders with an interest in the project are invited to register their interest within 14 days, with John Appleton, Archaeological Consultant, ph 6772 6512, fax 6772 4567 mob 0428 651 789

ARMIDALE LALC Notice of General Meeting Tuesday 17th February 2009 5.30pm to 6.30pm CWA Hall Rusden Street Armidale

FOR ALL your dog grooming needs, call New England Mobile Dog Wash. 6778 5163.

Course. OHS Construction Genera Armidale. Quality +++ program. Nex 30th Janurary 2009, Friday 27th Fe Tuesday 17th March. PRICING: $12 0418 113 301 or 0428 221 929

WORKCOVER ACCREDITED Course. OHS Construction Genera Armidale. Quality +++ program. Nex 30th Janurary 2009, Friday 27th Fe Tuesday 17th March. PRICING: $12 0418 113 301 or 0428 221 929

BEAUTY THERAPY AND NAIL C
Correspondence courses start
29 yrs experience AQF No 0012
Contact Gail Hands on 0439 7

Tuition

TUTORING MATHS (yrs 7-10 general), Business Studies, Geo levels), Economics. Pairs welcome teacher Call Tim on 67720164

Garage Sale

230 MANN Street, 8am-3pm, Sat sale, beds, blinds, furniture, car g more

85A DOUGLAS st, Sat 7th fro books, toys, furniture, garden, tools more

GARAGE SALE – HELD DECEASED ESTATE. QUALIT /ANTIQUE WARDROBES/BOOK ETC. FRIDGE/WASHING /MICROWAVE/BLENDERS/CROCK POT PLANTS/GARDEN HOUSEHOLD ITEMS, KNICKNA COLLECTABLES. SAT 7TH + SUN 9AM. 178 ALLINGHAM ST.

Real Estate

BEN LOMOND. Century Cottage or Titles. Walk to Primary School. 3B roof. 2 open fires; fuel stove. Origin Cypress - lined rooms. Peaceful, P location. Will Exchange for house All offers considered. Phone 6733 2

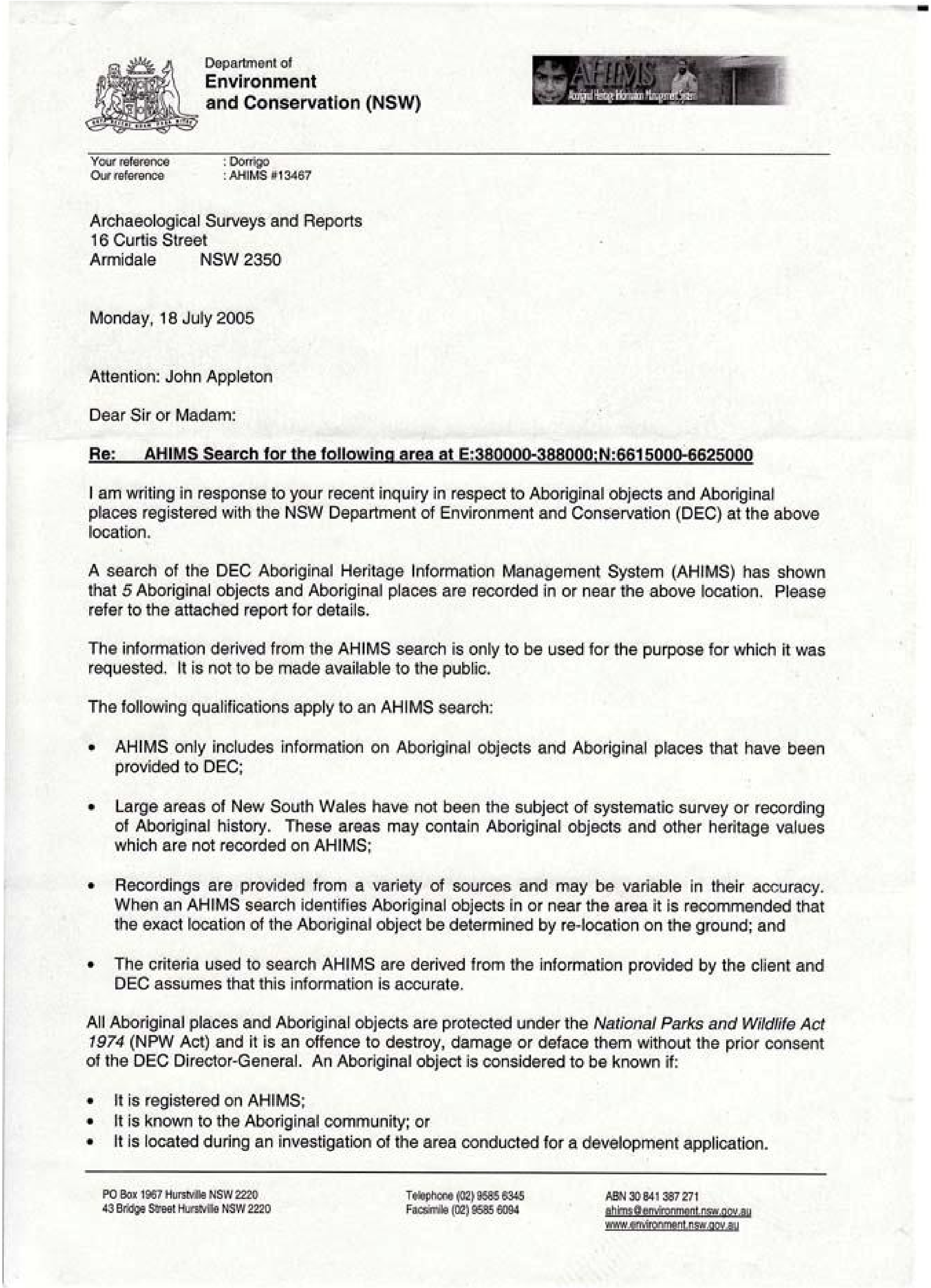
To Let

2 RMS AVLIABLE in 4 rm house, c and buses, partly furnished, from 0435123351

4 BED HOUSE, close to UNE, s $300p/w, refs required ph 67 0412304315

ROOM TO rent in fully furnished ho UNE $110 a week + expenses ph 67

Appendix iv – Results of AHIMS search.



Department of
**Environment
and Conservation (NSW)**

Your reference : Dorrigo
Our reference : AHIMS #13467

Archaeological Surveys and Reports
16 Curtis Street
Armidale NSW 2350

Monday, 18 July 2005

Attention: John Appleton

Dear Sir or Madam:

Re: AHIMS Search for the following area at E:380000-388000;N:6615000-6625000

I am writing in response to your recent inquiry in respect to Aboriginal objects and Aboriginal places registered with the NSW Department of Environment and Conservation (DEC) at the above location.

A search of the DEC Aboriginal Heritage Information Management System (AHIMS) has shown that *5* Aboriginal objects and Aboriginal places are recorded in or near the above location. Please refer to the attached report for details.

The information derived from the AHIMS search is only to be used for the purpose for which it was requested. It is not to be made available to the public.

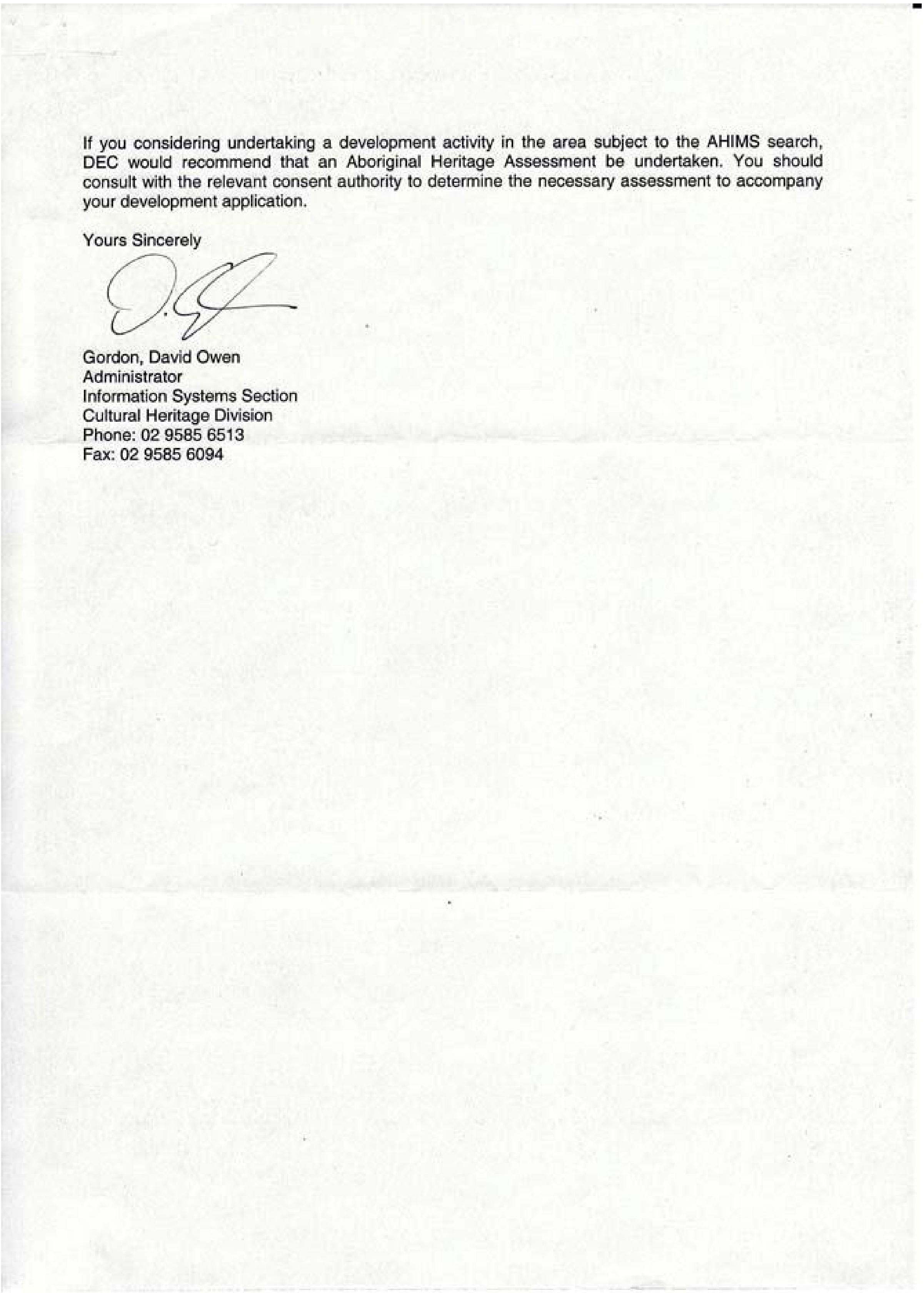
The following qualifications apply to an AHIMS search:

- AHIMS only includes information on Aboriginal objects and Aboriginal places that have been provided to DEC;
- Large areas of New South Wales have not been the subject of systematic survey or recording of Aboriginal history. These areas may contain Aboriginal objects and other heritage values which are not recorded on AHIMS;
- Recordings are provided from a variety of sources and may be variable in their accuracy. When an AHIMS search identifies Aboriginal objects in or near the area it is recommended that the exact location of the Aboriginal object be determined by re-location on the ground; and
- The criteria used to search AHIMS are derived from the information provided by the client and DEC assumes that this information is accurate.

All Aboriginal places and Aboriginal objects are protected under the *National Parks and Wildlife Act 1974* (NPW Act) and it is an offence to destroy, damage or deface them without the prior consent of the DEC Director-General. An Aboriginal object is considered to be known if:

- It is registered on AHIMS;
- It is known to the Aboriginal community; or
- It is located during an investigation of the area conducted for a development application.

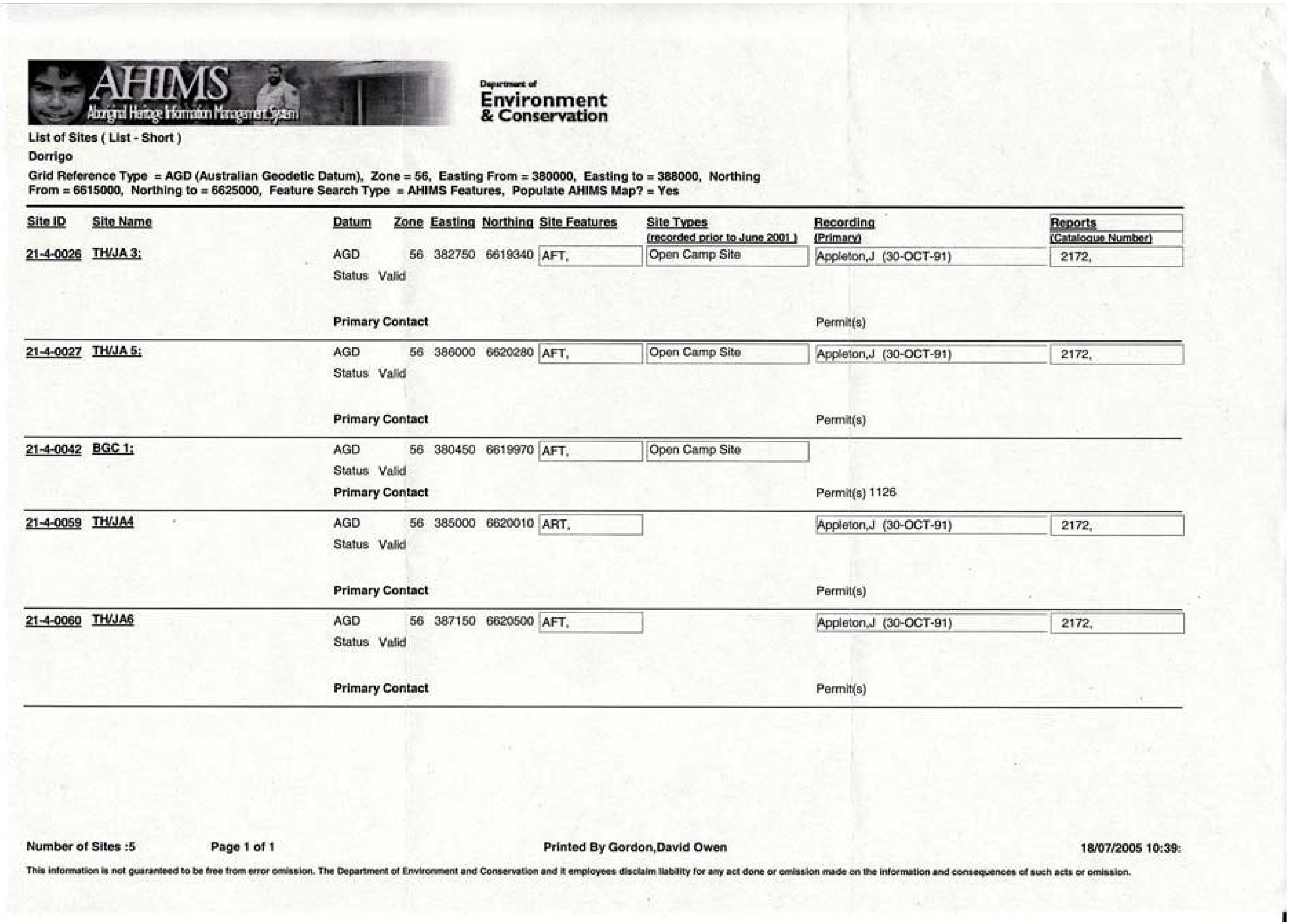
PO Box 1967 Hurstville NSW 2220
43 Bridge Street Hurstville NSW 2220
Telephone (02) 9585 6345
Facsimile (02) 9585 6094
ABN 30 841 387 271
ahims@environment.nsw.gov.au
www.environment.nsw.gov.au



If you considering undertaking a development activity in the area subject to the AHIMS search, DEC would recommend that an Aboriginal Heritage Assessment be undertaken. You should consult with the relevant consent authority to determine the necessary assessment to accompany your development application.

Yours Sincerely

Gordon, David Owen
Administrator
Information Systems Section
Cultural Heritage Division
Phone: 02 9585 6513
Fax: 02 9585 6094



AHIMS
Aboriginal Heritage Information Management System

Department of
Environment
& Conservation

List of Sites (List - Short)

Dorrigo

Grid Reference Type = AGD (Australian Geodetic Datum), Zone = 56, Easting From = 380000, Easting to = 388000, Northing From = 6615000, Northing to = 6625000, Feature Search Type = AHIMS Features, Populate AHIMS Map? = Yes

Site ID	Site Name	Datum	Zone	Easting	Northing	Site Features	Site Types (recorded prior to June 2001)	Recording (Primary)	Reports (Catalogue Number)
21-4-0026	TH/JA 3;	AGD	56	382750	6619340	AFT,	Open Camp Site	Appleton,J (30-OCT-91)	2172,
		Status	Valid						
		Primary Contact						Permit(s)	
21-4-0027	TH/JA 5;	AGD	56	386000	6620280	AFT,	Open Camp Site	Appleton,J (30-OCT-91)	2172,
		Status	Valid						
		Primary Contact						Permit(s)	
21-4-0042	BGC 1;	AGD	56	380450	6619970	AFT,	Open Camp Site		
		Status	Valid						
		Primary Contact						Permit(s) 1126	
21-4-0059	TH/JA4	AGD	56	385000	6620010	ART,		Appleton,J (30-OCT-91)	2172,
		Status	Valid						
		Primary Contact						Permit(s)	
21-4-0060	TH/JA6	AGD	56	387150	6620500	AFT,		Appleton,J (30-OCT-91)	2172,
		Status	Valid						
		Primary Contact						Permit(s)	

Number of Sites :5 Page 1 of 1 Printed By Gordon,David Owen 18/07/2005 10:39:

This information is not guaranteed to be free from error omission. The Department of Environment and Conservation and it employees disclaim liability for any act done or omission made on the information and consequences of such acts or omission.

Appendix v – Site Types

Site types associated with Indigenous activities and culture

The definitions that follow are for terms used in this report, and do not necessarily apply to their use in different contexts.

Art sites are defined as places where any medium has been applied to a rock surface either as symbols, characters, drawings, paintings, or any other rendition, recognisable as not being a natural discolouration or feature. They also include markings to a rock surface, either by engraving, abrading, or pecking, and which cannot be identified as being a natural feature.

Bora rings are circles of 2-30 metres diameter of compressed earth (from repeated treading or dancing), or stone arrangements, at which men performed initiation ceremonies, and are the most frequently recorded ceremonial sites. Sometimes they occur as two rings joined by a central track in a barbel configuration. They usually occur on level or low-lying country, which is usually the first topographical unit to be cultivated, or utilised for highways and roads, but they may also occur as circular stone arrangements on elevated rock platforms and hilltops. If they are or were present then they are usually either already known and have been recorded, or they have long since been destroyed.

Carved trees are readily recognised by even the untrained observer. The carving is incised either into the outer bark, or more commonly, into the living wood after removal of a section of the bark. The designs frequently consist of 'diamond cross-cuts', but may also consist of stylised animal motifs. Previously unrecorded carved trees are still discovered in relatively remote or inaccessible areas. Carved trees frequently occur near burial sites and/or Bora rings, but in some regions they may have been tribal boundary markers.

Fish traps may occur either in rivers or on seashores. They are recognisable as unnaturally formed stone arrangements that were constructed to trap fish (or eels or turtles) carried into the enclosure in deep water, and which are left stranded within the enclosure as the water level drops. The fish were then caught by nets, hand, or by spear.

Grinding grooves are usually observed on the surfaces of large sedimentary boulders or exposed shelves and outcrops of sedimentary rock along creek banks and beds, or near water. They have been produced by Aborigines using the rock surface to shape and sharpen the edges of stone to produce ground-edged axes, or to sharpen wooden spears (the latter tend to be narrow and deep). Water was used to lubricate the surface of the rock. The grooves frequently occur as linear abraded depressions in the rock, and may each be between 10 and 50 centimetres long, up to 15 centimetres wide, and 2 to 5 centimetres deep. Some sedimentary rock surfaces may exhibit shallow ground depressions of roughly round or elliptical shape, and these are more likely to be associated with seed grinding, root crushing, or other food preparation.

Middens may be identified variously as beach, lagoon, lacustrine, or estuarine, and are most likely to be observed at or above the water line where erosion, topsoil removal, or mining has exposed the shell. The size of the midden can vary enormously, with the smallest comprising a 'one off', "dinner-time camp" (Meehan. 1982), with as few as two or three shells, or a shallow lens of only a few centimetres. The largest middens may extend for many kilometres and may comprise of a number of lenses and layers of shell and ash up to several metres deep. These large middens may be evidence of continuous exploitation of the resource over many thousands of years. Middens of fresh water mussel shell may be found in eroding creek banks or in eroding terraces, particularly near both existing and defunct water holes.

Isolated shell or fragments may occur on any surface and in any situation. A single shell may have been discarded by a bird, but the presence of use-wear would indicate Aboriginal use of the shell as a tool, which was discarded after use. Such occurrence is likely to be where there is no immediate source of stone material suitable for tool manufacture.

Natural Mythological sites are places of significance to Aborigines, either because they are described in mythological stories or songlines, or because they were used in religious ceremonies. They may occur anywhere and while some are more predictable than others – as for example, permanent water holes, waterfalls, rock promontories, etc., others may have no particularly remarkable features. Seldom is there any recognisable artefactual evidence or anything to distinguish it from similar features in the vicinity. These sites must of necessity be identified by Aboriginal people with an association with the place.

Open sites, campsites, knapping floors, scatters, and isolated artefacts, are most likely to occur on eroded and exposed creek banks, particularly where slope wash or stock trails has removed the humic layer, or on eroded ridges and spurs, particularly near the junctions in watercourses.

Open sites are most likely to be present in greatest numbers near a source of either raw stone material, or potential food resources, or in a natural corridor between two differentially preferred environmental zones, or at the contact between two environmental zones containing different resources.

Artefacts in open scatters are likely to be manufactured from the dominant raw material available; i.e. Greywacke on greywacke-sourced soils, quartz on granite-sourced soils, silcrete and chert on relict sedimentary soils.

Artefact assemblages in open scatters are likely to consist predominantly of discard material, i.e., cores, flakes, flaked pieces, and debitage.

Artefacts exhibiting retouch scars and backing are most likely to occur in sites where secondary activity took place peripheral to the central camp site, although this is a generality and can only be observed where there is sufficient surface visibility to identify peripheral sites. Fragments of flakes with retouch or backing may occur on knapping floors indicating breakage occurring during manufacture, or maintenance areas in which damaged tools have been replaced and discarded.

Isolated artefacts are likely to be most frequently observed where the groundcover obscures all but the larger artefacts, such as cores, and large flakes, or where there is little contrast between the texture of artefactual material and the surface upon which it lies. Artefacts of materials contrasting with the matrix may be visible regardless of size; eg. quartz artefacts may be far more visible than much larger basalt artefacts against a background of dark humic terrace soils.

PADs or Potential Archaeological Deposits are deposits, usually in shelters (but they may also be identified where there are intact deposits in open areas), which although not containing any visible archaeological material, are considered likely to contain archaeological material below the surface. These ‘sites’ are not recorded as sites on the Aboriginal Site Register, but are identified as places that require subsurface testing to establish whether a site exists or not.

Rock shelters with art or occupation deposits, are most likely to occur where the character of the parent rock is sufficiently massive or consolidated for it to retain a structure that weathers differentially to form shelters and overhangs.

Scarred trees are perhaps the most difficult site type to determine as having been caused by deliberate removal of the bark by humans and not as a consequence of natural events; such as abrasion from falling trees or branches, natural branch attrition, fire damage, or contact from vehicles or stock. They may occur in places wherever there are tree species that produce bark suitable for tool and implement manufacture. While some scars are clearly the consequence of deliberate bark removal by Aborigines (either evidenced by stone axe marks, or identified by Knowledge Holders), some scars were made by settlers, and stockmen, and surveyors who frequently blazed trails and property boundaries by scarring the trees, and by timber men who removed a strip of bark to test the suitability of a tree for logging.

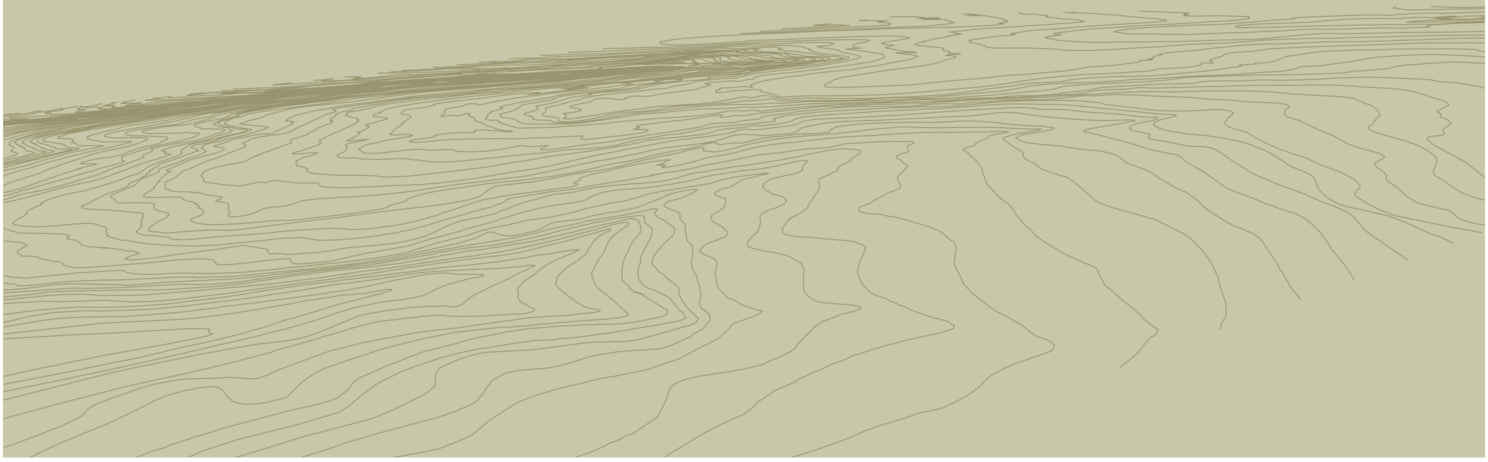
Other site types such as hearths, burials, etc., are less easily predicted, although burials are frequently associated with carved trees, and Bora rings, and hearths with campsites, shelters, and shell middens.

AECOM

MORE SPECIALISTS,
PARTNERING MORE POWERFULLY
THINKING MORE INNOVATIVELY,
DESIGNING MORE INTELLIGENTLY,
DELIVERING MORE RELIABLY.

ARMIDALE REGIONAL LANDFILL

Environmental Assessment



ARMIDALE REGIONAL LANDFILL

Environmental Assessment Publications

Volume 1

Main Document

Volume 2

Appendix A Director-General’s Requirements, 2005 and 2008; and Government Consultation
Appendix B AECOM, 2006: Armidale Regional Landfill Environmental Management Plan (Draft)
Appendix C Maunsell AECOM, 2004: Regional Landfill Siting Study Final Report
Appendix D EA Systems, 2006: Hydrogeological Study

Volume 3

Appendix E EA Systems, 2009: Flora and Fauna Assessment
Appendix F RCA Australia, 2007: Hydrogeological Investigation
Appendix G AECOM, 2010: Landfill Concept Design Drawings
Appendix H EA Systems, 2009: Biodiversity Offset Management Plan

Volume 4

Appendix I AECOM, 2010: Landfill Liner Literature Review and Hydrogeological (Leachate) Assessment
Appendix J NSW Department of Public Works and Services, 2002: Landfill Siting Study, Aerial Photographic Survey
Appendix K EA Systems, 2006: Preliminary Contaminated Site Investigations
Appendix L EA Systems, 2006: Salinity Assessment
Appendix M PM Ashley, 2006: Geological Report on proposed Armidale Dumaresq Council landfill site, with emphasis on investigation of a possible geological fault
Appendix N PM Ashley, 2005: Report on Geological Logging of Diamond Drill Core from the Proposed Armidale Landfill Site
Appendix O Holmes Air Sciences, 2009: Air Quality Assessment Report
Appendix P AECOM, 2010: Greenhouse Gas Inventory
Appendix Q AECOM, 2010: Armidale Regional Landfill Noise Impact Assessment
Appendix R Archaeological Surveys & Reports Pty Ltd, 2009: The Archaeological Investigation For Sites Of Indigenous Cultural Significance For Part 3A Approval New England Regional Landfill Waterfall Way, East of Armidale, Northern Tablelands NSW