Status Report

Bloodtree Road, Mangrove Mountain

for Department of Trade & Investment, Regional Infrastructure and Services

Ref. SR_BloodtreeRd-rev1
May 2012

CMJA

C. M. Jewell & Associates Pty Ltd

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LIMITATIONS AND INTELLECTUAL PROPERTY

This report has been prepared by C. M. Jewell & Associates Pty Limited (CMJA) for the use of Department of Trade & Investment, Regional Infrastructure and Services (DTIRIS), for the specific purpose described in the scope of works provided to CMJA by DTIRIS on 1 July 2010. The project objectives and scope of work were developed for that purpose, taking into consideration client requirements.

The work has been carried out, and this report prepared, utilising the standards of skill and care normally expected of professional scientists practising in the fields of hydrogeology and contaminated land management in Australia. The level of confidence of the conclusions reached is governed, as in all such work, by the scope of the investigation carried out and by the availability and quality of existing data. Where limitations or uncertainties in conclusions are known, they are identified in this report. However, no liability can be accepted for failure to identify conditions or issues which arise in the future and which could not reasonably have been assessed or predicted using the adopted scope of investigation and the data derived from that investigation.

Where data collected by others have been used to support the conclusions of this report, those data have been subjected to reasonable scrutiny but have essentially, and necessarily, been used in good faith. Liability cannot be accepted for errors in data collected by others.

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1.0 INTRODUCTION

In 1999, there was an outbreak of Newcastle Disease in the Mangrove Mountain region of NSW. To prevent the disease spreading, approximately two million chickens were destroyed, and their carcasses and shed litter were buried in three landfill pits, located at:

1. Bloodtree Road;
2. George Downes Drive; and
3. Waratah Road.

At Bloodtree Road and George Downes Drive, the chicken carcasses were placed in tar-lined shipping containers, which were then placed into the pits. There were some loose carcasses buried between the containers.

At Waratah Road, poultry shed litter and manure from the chickens were buried in the pit.

Between October 1998 and June 2000, in order to obtain information about baseline water quality (specifically for drinking water) and groundwater levels, Environmental Health Officers from the Central Coast Public Health Unit sampled a number of boreholes owned and operated by the Department of Land and Water Conservation (DLWC). These boreholes were part of the DLWC's monitoring borehole network in the Kulnura/Mangrove Mountain area, and had previously been used to monitor water levels.

Additionally, in 1999, Robert Carr & Associates Pty Ltd installed three monitoring boreholes at each landfill site so that baseline groundwater quality could be assessed prior to any possible impact of the chicken and shed litter burials. The three boreholes were generally positioned so that one was upgradient of the pit and two were downgradient.

From January 2001 to August 2005, groundwater investigations were conducted by Brink & Associates at the three landfill sites to determine whether any contaminants were leaching out of the pits. Works included standing water level monitoring, assessment of groundwater flow direction, and analysis of groundwater quality. Reports for these investigations showed that some analytical results exceeded the relevant standards and concentrations of contaminants fluctuated.

In 2006, the NSW Department of Primary Industries, now trading as the NSW Department of Trade and Investment, Regional Infrastructure and Services (DTIRIS) commissioned C. M. Jewell & Associates Pty Ltd (CMJA) to conduct the monitoring program at these sites for the next five years. Four sampling events were scheduled for the twelve months between September 2006 and August 2007, and two during the following twelve-month period. While groundwater monitoring was scheduled to reduce to an annual event, more frequent monitoring (quarterly) was maintained for a selected number of boreholes. These included the defined downgradient bore at each site and any additional bores where recent results required confirmation or further investigation.

By bringing together key groundwater and landfill gas information, this Status Report establishes a baseline against which future results can be compared. Moreover, it provides an assessment to assist in the interpretation of groundwater monitoring data.

This report presents information and data specifically for the Bloodtree Road site. Separate reports have been produced for the George Downes Drive and Waratah Road landfills.

2.0 BACKGROUND

2.1 Bloodtree Road

The Bloodtree Road pit is located on zoned rural land identified as Lot 81 in Deposited Plan 664567; and lies within Gosford City Council jurisdiction, in the parish of Popran, in the county of Northumberland. It is positioned along the southern boundary of the Gosford City Council works depot, adjacent to the Mangrove Mountain Fire Station. Approximate Map Grid of Australia (MGA) Zone 56 co-ordinates for the centre of this location are 333398 m E and 6315439 m N.

2.2 Pit Excavation and Construction Details

As reported by Robert Carr & Associates Pty Ltd, the Bloodtree Road carcass disposal pit was constructed by excavating a trench 50 metres wide, 13 metres long and approximately 8 metres deep into sandstone bedrock. The excavation was lined with sand, a geocomposite clay liner (GCL) and 2.5 millimetre high-density polyethylene (HDPE) sheeting, and capped with GCL and 1 metre of clay.

An estimated one million chickens were placed in the pit, predominantly in shipping containers; some chickens were also placed between the containers. A total of 48 tar-lined, HDPE-wrapped, steel shipping containers were used.

2.3 Installation of Boreholes

As identified in Section 1.0, Robert Carr & Associates Pty Ltd installed three boreholes (BH1, BH2 and BH3) around the pit, at depths between 34 and 36 metres. Standing water levels (SWLs) in these three bores were measured by Robert Carr & Associates Pty Ltd and by Brink & Associates Pty Ltd on fifty-three occasions between May 1999 and April 2004. The reports prepared by these companies also included an assessment of groundwater flow direction based on survey and standing water level data and groundwater quality.

The locations of monitoring bores BH1 and BH2 are downgradient of the pit (but not directly in line with the direction of groundwater flow), and BH3 is positioned upgradient.

In 2007, monitoring bore BH1B was installed downgradient of the pit to assess the water quality exiting the landfill (see Section 8.1).

2.4 Geology

The site and surrounding districts lie on the Hornsby Plateau, which is underlain by flat-lying sedimentary rocks belonging to the Middle Triassic Hawkesbury Sandstone. This formation consists predominantly of medium to coarse grained quartz sandstone with numerous thin interbedded mudstone and shale units. Interbeds of very fine to medium grained sandstone also occur in some units.

2.5 Hydrogeology - Regional

Some zones that allow groundwater flow (aquifers) are present within the Hawkesbury Sandstone in the Mangrove Mountain area, mostly at depths of between 10 and 50 metres. Water quality in these aquifers is generally good, with low salinity and hardness, although the water is often slightly acidic. A natural high iron content is also often present, and there has been some diffuse regional contamination by nitrates due to agricultural land use.

2.6 Hydrogeology - Local

Local groundwater flow is largely controlled by the topography and by the location of more permeable and porous sandstone horizons, which constitute the major water storage units. Enhanced hydraulic conductivity is, however, dependent on the occurrence of both vertical and horizontal structural discontinuities such as joints and bedding plane fractures. Fracturing, which may be present on a regional scale, is a major component of the aquifer's transmissivity, and a minor component of the aquifer's storage. The occurrence of structural discontinuities suggests that variable hydrogeological conditions exist in the Mangrove Mountain area; this can make the analysis of groundwater flow more difficult. Numerous springs in the area feed the local creeks.

3.0 CONTAMINANTS OF CONCERN AND APPLICABLE CRITERIA

3.1 Contaminants of Concern

For the assessment of general water quality at Bloodtree Road, DTIRIS selected the following suite of analytes.

- pH
- total dissolved solids (TDS)
- major cations (sodium, potassium, magnesium and calcium)
- major anions (sulphate, chloride and bicarbonate)
- redox potential
- biological oxygen demand (BOD)
- dissolved oxygen
- electrical conductivity (EC)

For the assessment of nutrient load resulting from the decomposition of the carcasses and litter, the following analytes were selected:

- nitrate
- nitrite
- ammonia
- Total Kjeldahl Nitrogen (TKN)
- Total nitrogen as N
- Total phosphorus as P

In order to assess whether the metal containers containing the carcasses had corroded, the following metals were identified as suitable analytes:

- copper
- cadmium
- chromium
- lead
- nickel
- zinc
- iron

3.2 Criteria for Groundwater Quality Assessment

For the assessment of potential environmental impacts arising from the interaction of groundwater with freshwater aquatic ecosystems (a relevant issue at Mangrove Mountain), the appropriate criteria are those trigger values set for the protection of 95 per cent of species in fresh water and listed in Table 3.4.1 of ANZECC's *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (2000).

Note: The ANZECC (2000) **Trigger Values for the Protection of Freshwater Aquatic Ecosystems (95% level of protection)** were developed for surface waters, not groundwater. However, the NSW Environment Protection Authority (EPA) Guidelines for the Assessment and Management of Groundwater Contamination indicate that these triggers should be used as Groundwater Investigation Levels (GILs). The EPA guidelines also state that exceedances of GILs only indicate a need for detailed assessment. This is because natural background concentrations, diffuse regional contamination, the fate and transport of contaminants in groundwater, and potential exposure pathways must all be considered. For example, there is diffuse regional contamination by nitrates from other sources in the Mangrove Mountain area.

For the assessment of potential human health issues relating to the consumption of bore water in the area, the appropriate criteria are found within the Health Guidelines in *Australian Drinking Water Guidelines* (ADWG) (2004), prepared by the National Health and Medical Research Council (NHMRC) in collaboration with the Natural Resource Management Ministerial Council (NRMMC). These levels relate specifically to water that is to be used for human consumption, and although they do not represent mandatory standards for the quality of water for human consumption, they do offer a framework for identifying acceptable water quality.

The relevant criteria for both human health and environmental concerns are presented in Table 1.

Trigger values included in Table 1 are the values applying to slightly-moderately disturbed systems, and have been derived for use in assessing surface waters. In the absence of specific levels for groundwater, the surface-water trigger values have been used.

TABLE 1
Criteria for Groundwater Quality Assessment

Analyte	Drinking Water Health Guidelines ‡‡ (mg/L)	Trigger Values for the Protection of Freshwater Aquatic Ecosystems ‡ (mg/L)
pH (field + laboratory)	6.5 – 8.5	6.5 – 7.5
TDS	500+	-
Sodium	180+	-
Chloride	250+	-
Sulphate	500	-
Ammonia (as nitrogen)	0.4+#	0.9
Nitrate (as nitrogen)	11#	0.158#
Nitrite (as nitrogen)	0.9#	-
Arsenic (total)	0.007	
Arsenic (As III)	-	0.024
Arsenic (As V)	-	0.013
Cadmium	0.002	0.0002
Chromium (Cr III)	-	0.0033*
Chromium (Cr VI)	0.05	0.001^
Copper	2	0.0014
Iron	0.3+	0.3*
Lead	0.01	0.0034
Nickel	0.02	0.011
Zinc	3+	0.008

Notes:
‡‡ NHMRC 2004
‡ ANZECC 2000
* Low reliability figures which should only be used as indicative interim working levels
\+ Aesthetic value (in the absence of a human health value)
^ Figure may not protect key species from chronic toxicity
\# Trigger value calculated based on atomic weight of nitrogen
\- No criteria currently available

4.0 REVIEW OF STANDING WATER LEVELS AND GROUNDWATER FLOW DIRECTION

The standing water level (SWL) in the groundwater monitoring bores is used to calculate the direction of groundwater flow.

The landfill is located in the catchment area of Warre Warren Creek, which flows into Mangrove Creek, in the McPherson State Forest.

Table 2 presents the location, elevation and last recorded SWL (October 2011) of the groundwater monitoring bores on site.

TABLE 2
Borehole Details - October 2011

Borehole ID	Easting	Northing	Elevation of Top of Well Casing (mAHD)	SWL (mTOC)	RWL (mAHD)
BH1	319471	1315425	306.938	14.93	292.01
BH2	319495	1315360	304.944	12.96	291.98
BH3	319594	1315389	311.146	15.97	295.18
BH1B	333215	6315245	306.138	14.50	291.64

In Table 2 above, the SWL is shown as metres below the top of the well casing (mTOC), and then as a reduced water level (RWL) in metres above Australian Height Datum (mAHD). The RWL (mAHD) is calculated by subtracting the SWL (mTOC) from the elevation of the surveyed point at the top of the well casing.

Based on RWL data, BH3 is considered to be the upgradient well, while BH1B is positioned downgradient.

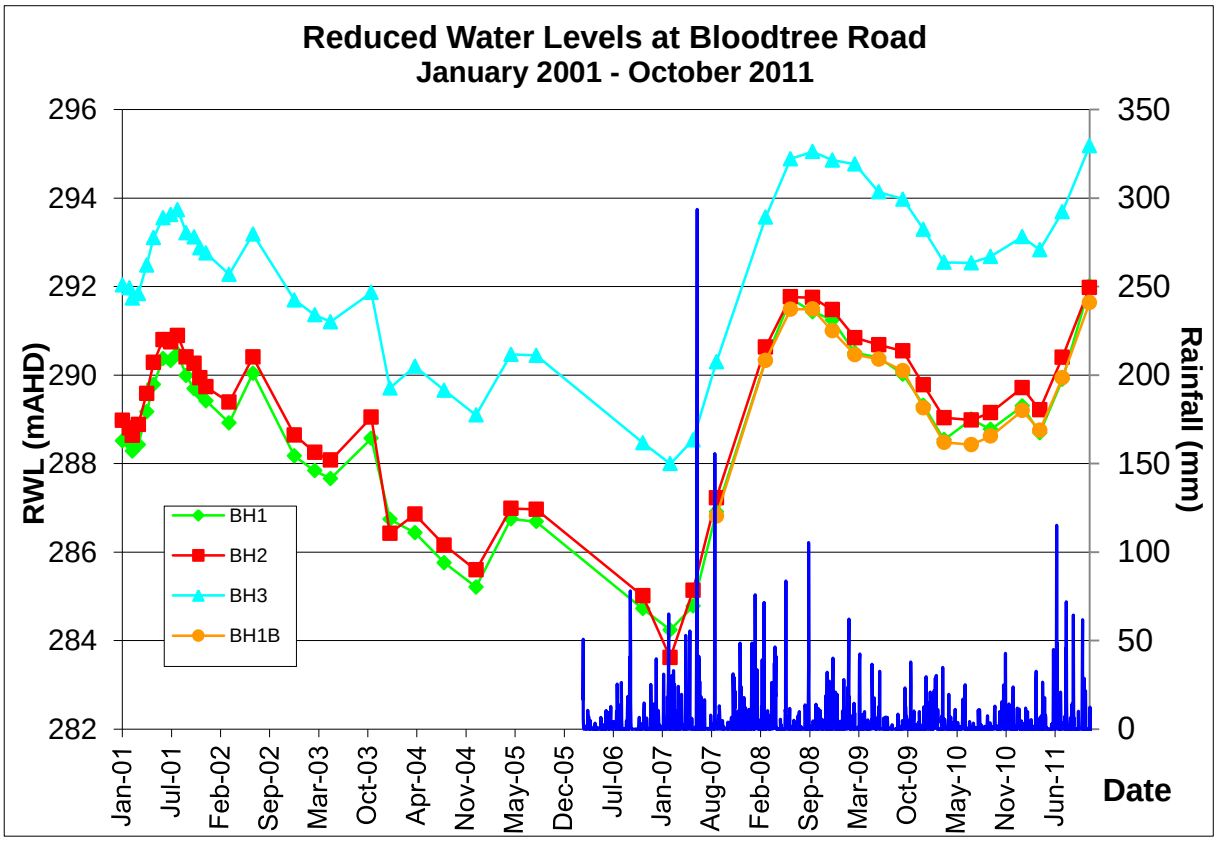

Figure 1: Reduced Water Levels - January 2001 to October 2011

Figure 1 shows long-term reduced water levels (mAHD) in the four groundwater monitoring boreholes at Bloodtree Road. It confirms that the groundwater level in the upgradient bore, BH3 (located east of the landfill), is consistently higher in elevation than groundwater levels in the three downgradient bores (BH1, BH1B and BH2), which are located to the south and west of the landfill.

As indicated by Figure 1, RWLs in each bore have followed a similar trend over time. It is also evident that groundwater elevation is heavily influenced by rainfall. After periods of heavy rainfall, the RWL in each borehole increased as groundwater recharge occurred. This response was particularly pronounced following the June 2007 and August 2007 high rainfall events.

Figure 2: Groundwater Flow Direction relative to the Burial Pit and Borehole Locations

As shown on Figure 2, the groundwater flow direction at Bloodtree Road is to the west-south-west, at a hydraulic gradient of 0.03. The hydraulic gradient on this site has been consistent throughout the monitoring period.

Note: The groundwater flow direction is perpendicular to the contour lines.

5.0 WATER QUALITY: LONG-TERM TRENDS

The following paragraphs contain a discussion of long-term trends in concentrations of key analytes, identifying concentration fluctuations and any exceedances of the criteria listed in Table 1, with a comparison between upgradient and downgradient bores from 1999 to 2011.

There is a particular focus on the downgradient bore BH1, because the quality of groundwater leaving the pit is of most concern.

Note: The calculated groundwater flow direction to the (west-south-west), meant that BH1 was not ideally located. In order to address this issue, monitoring bore BH1B was installed in 2007, and it will be discussed as part of the recent water quality trends in Section 6.0.

5.1 Total Dissolved Solids

The total dissolved solids (TDS) concentration in groundwater is a measure of the combined inorganic and organic substances dissolved in a molecular, ionised or fine colloidal form, it is not therefore directly associated with any one analyte. TDS data thus provides an indication of fluctuations in the chemical composition of groundwater.

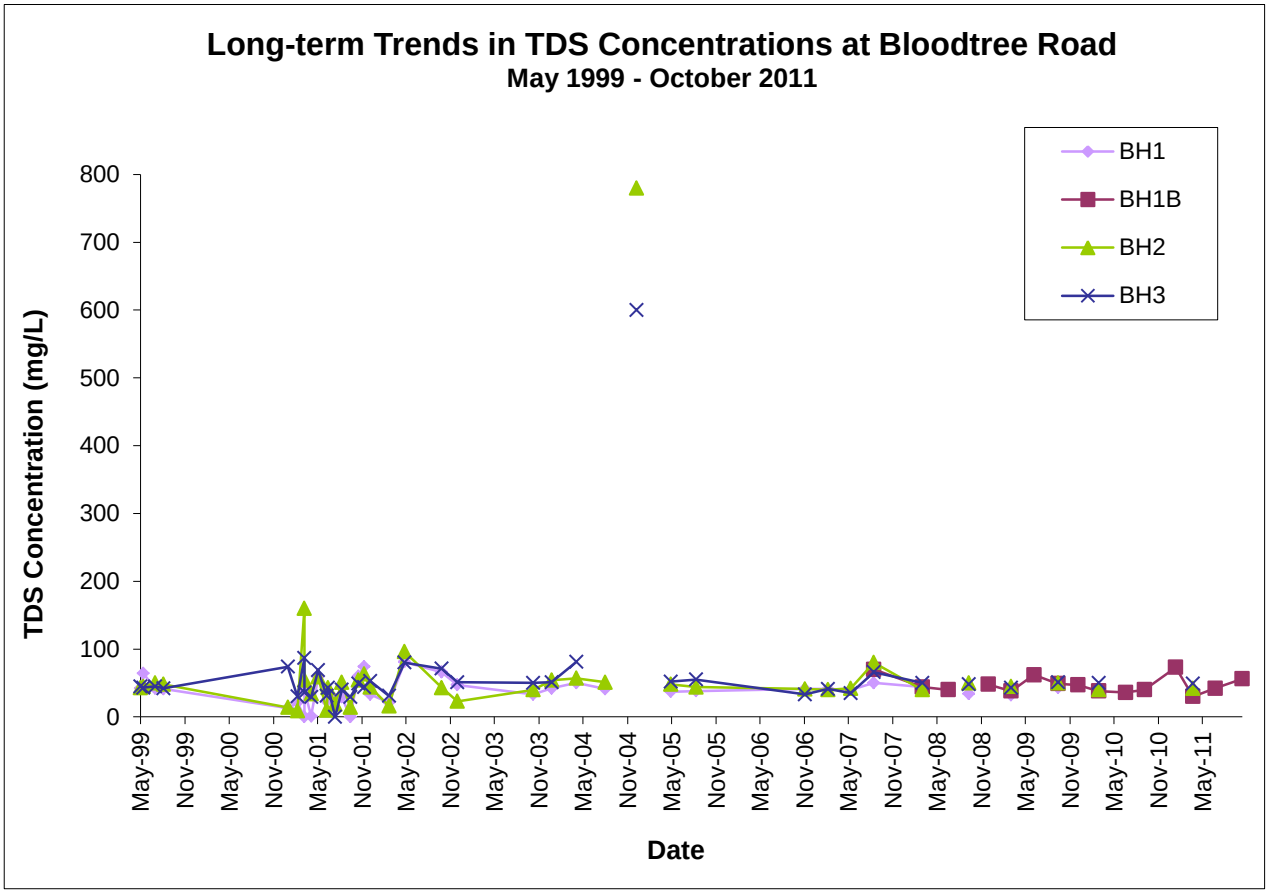

Figure 3: Long-term Trends of TDS - May 1999 to October 2011

As shown on Figure 3, TDS concentrations in groundwater throughout the monitoring period were typically below the ADWG (2004) of 500 mg/L, and generally very consistent.

TDS concentrations of 780 mg/L and 600 mg/L were reported during the December 2004 monitoring event in BH2 and BH3 respectively. These high concentrations of TDS did not appear to be associated with a significant change in any other analyte, and may reflect an error. *Note:* These anomalous results were reported by Brink & Associates.

5.2 Nutrients

Nitrogen and phosphorus concentrations at Bloodtree Road have been analysed since groundwater monitoring commenced in 1999. An assessment of these concentrations in groundwater is important because nitrogen and phosphorus are released during the decomposition of carcasses; their presence in groundwater could indicate migration of leachate.

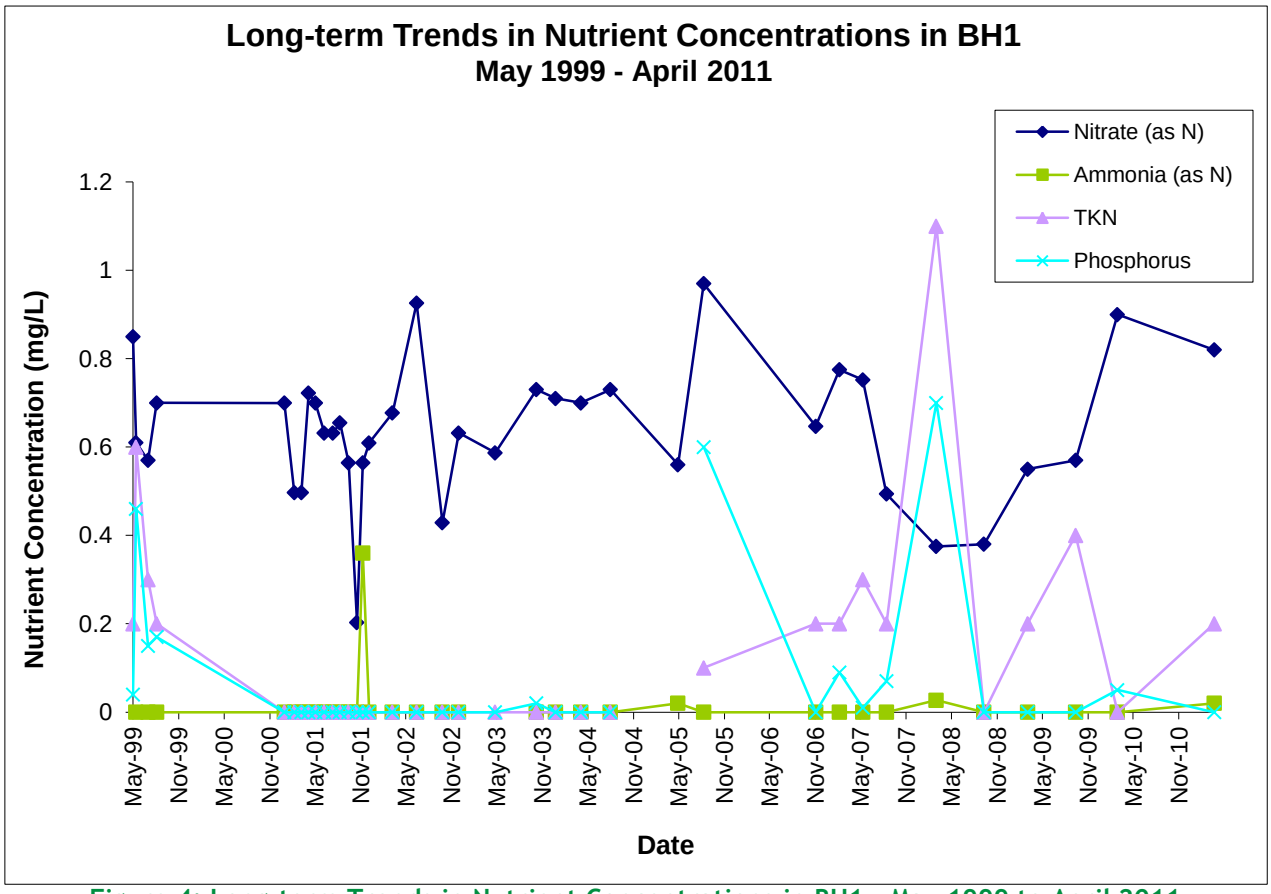

Figure 4: Long-term Trends in Nutrient Concentrations in BH1 - May 1999 to April 2011

Nitrate

Nitrate is a water-soluble molecule made up of nitrogen and oxygen.

Common sources of nitrate in the environment include fertilizers, animal wastes, septic tanks, municipal sewage treatment systems and decaying plant debris. Excess nitrogen within the environment can contribute to eutrophication and algal blooms, leading to oxygen depletion in water.

Note: Samples taken between January 2001 and August 2005 were analysed for nitrate concentration using Ion Chromatography, while analysis carried out from November 2006 to 2011 was conducted using a Discrete Analyser. When analysing groundwater, most laboratories report nitrate as nitrogen (nitrate as N) because this allows easy comparison with other forms of nitrogen. However, the reporting units from January 2001 to May 2003 are presumed to be nitrate (as nitrate), whilst the units in 1999 and from October 2003 to 2011 are nitrate (as nitrogen). The closure of the laboratory that analysed samples from 2001 to 2003 means that this assumption cannot be confirmed.

To assess the long-term nitrate (as nitrogen) concentration trends, those concentrations reported in samples obtained from January 2001 to May 2003 have been converted to nitrate (as nitrogen), and results presented in Figure 4.

Nitrate concentrations in BH1 ranged from 0.2 mg/L to 0.97 mg/L. The concentration of nitrate appears to fluctuate over time; however, concentrations continue to remain above the adopted criterion.

The concentration of nitrate in all other groundwater monitoring bores at Bloodtree Road ranged from 0.01 mg/L (BH1B) to 2.76 mg/L (BH3). The trend in nitrate concentrations is consistent across all borehole locations, with peaks and troughs occurring at similar intervals.

Concentrations of nitrate continue to slightly exceed the ANZECC trigger value for the protection of freshwater aquatic ecosystems (95% level of protection) in all four boreholes at Bloodtree Road. However, these results are indicative of a regional problem, most probably due to the intensive agricultural land use around Mangrove Mountain. If nitrate were originating from the pit, nitrate concentrations are expected to be higher in those boreholes downgradient of the pit given the likely high nitrogen content of material in the pit.

Ammonia

Ammonia is a molecule made up of nitrogen and hydrogen. When analysing groundwater, most laboratories report ammonia as nitrogen (ammonia as N) to allow easy comparison with other forms of nitrogen.

Ammonia is naturally occurring, being produced through the decay processes of animal and vegetable matter. Other sources of ammonia can be anthropogenic e.g. livestock farming practices, sewage (including septic systems). Ammonia can be very toxic to aquatic organisms; this toxicity is pH dependent. Ammonia is also a nutrient and oxidises to nitrate in surface water. Its presence can contribute to eutrophication of natural waters.

As shown in Figure 4, ammonia (as nitrogen) concentrations in BH1 ranged from below the limit of reporting (LOR) to 0.36 mg/L. Ammonia is not considered to be of concern at Bloodtree Road, remaining below the appropriate criteria in all groundwater monitoring boreholes.

Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) is a sum of all organic nitrogen and ammonia in a given groundwater sample.

Throughout the monitoring period, TKN concentrations in BH1 have ranged from below the LOR to 1.1 mg/L.

Phosphorus

Phosphorus is a non-metal that is a vital plant nutrient and its main use, as phosphate compounds, is in the production of fertilizers.

As it is a plant nutrient, excess phosphorus in surface water can result in excessive algal and water weed growth, and in eutrophication. Phosphorus does tend to bind strongly to iron compounds in soil, and is not generally as mobile as nitrogen in groundwater.

Phosphorus is commonly analysed as soluble reactive phosphorus (which is predominantly orthophosphate) or total phosphorus, which includes organic phosphorus and particulate phosphorus as well as soluble reactive phosphorus. Total phosphorus has been analysed during this monitoring program.

The concentration of total phosphorus in BH1 throughout the monitoring period, varied from below the LOR to 0.7 mg/L.

5.3 Heavy Metals

To assess the condition of the metal containers containing the chicken carcasses, heavy metals were incorporated into the suite of analytes. Although some heavy metals are necessary in small amounts for normal biological processes, many become toxic at high concentrations. Heavy metals can enter the environment both naturally (e.g. through rock weathering processes) and anthropogenically (e.g. agricultural practices, transport, industrial activities and waste disposal). Unlike organic wastes, heavy

metals are not biodegradable, and some have the ability to accumulate in the environment and in living tissue.

Heavy metals generally occur in very low concentrations and are reported in micrograms per litre (µg/L) as opposed to milligrams per litre (mg/L).

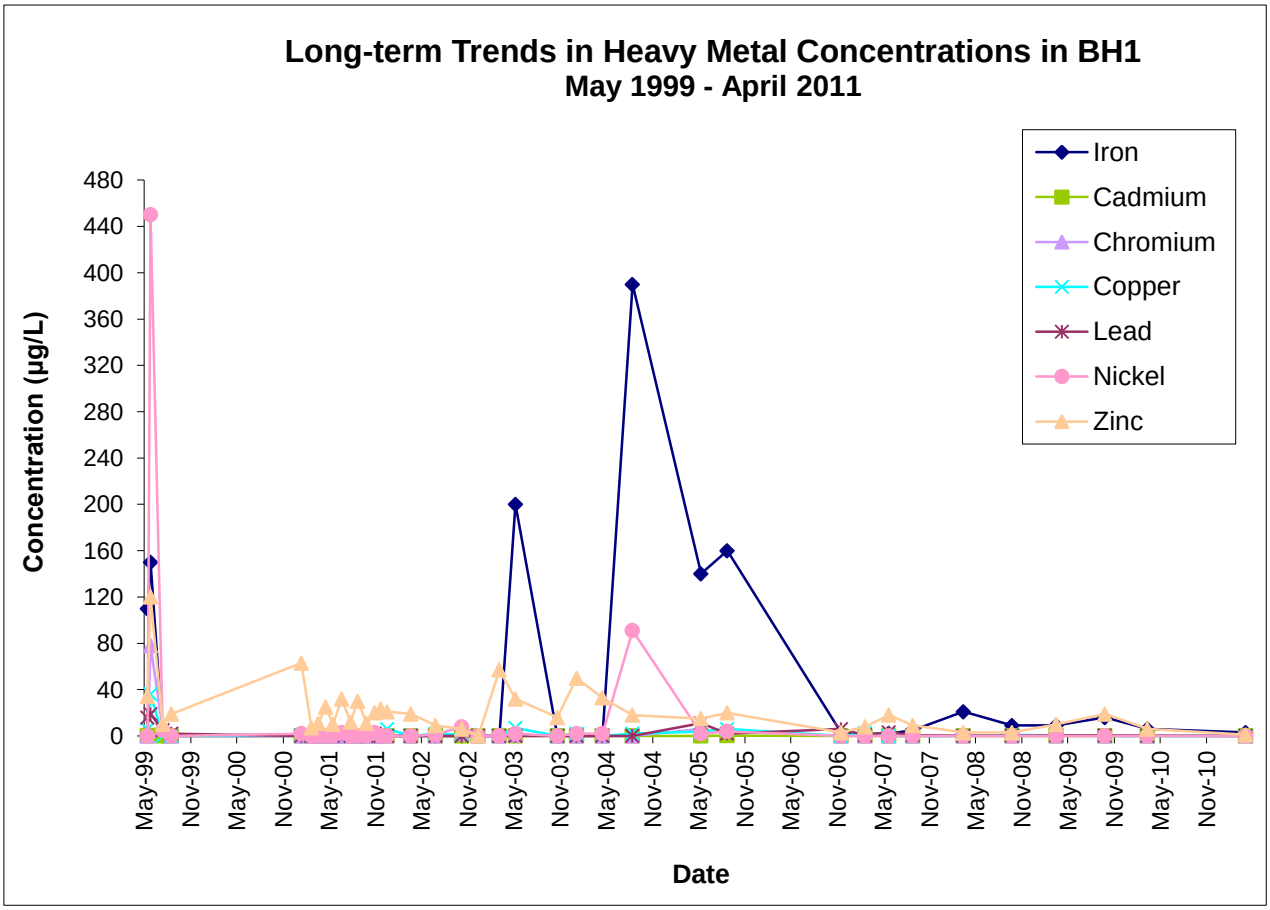

Figure 5: Long-term Trends in Heavy Metals in BH1 - May 1999 to April 2011

As shown in Figure 5, concentrations of zinc in BH1 range from below the LOR to 120 µg/L. However, the concentration of zinc in groundwater at Bloodtree Road typically fluctuate slightly above and below the ANZECC trigger value for the protection of freshwater aquatic ecosystems (95% level of protection).

Concentrations of iron in BH1 range from below the LOR to 390 µg/L, although for the most part, concentrations remain well below the ANZECC trigger value. Similar concentrations of iron have been detected in all other wells at the Bloodtree Road site.

Note: The LOR for iron between 1999 and 2005 was either 50 µg/L or 100 µg/L. If a concentration of iron was reported below the LOR, the value could not be graphed on Figure 5.

The peaks and troughs of iron and zinc concentrations experienced at BH1 are generally consistent with trends seen at BH2 and BH3, with peaks often occurring following periods of heavy rainfall.

The relatively high nickel, chromium and copper concentrations in May 1999 (450 µg/L, 78 µg/L and 36 µg/L, respectively) appears to be an anomalous event, with concentrations typically below the LOR.

Overall, heavy metals in groundwater are not considered to be of concern at the Bloodtree Road site.

6.0 WATER QUALITY: RECENT TRENDS

The following paragraphs contain a discussion of recent trends in concentrations of key analytes, identifying concentration fluctuations and exceedances of the criteria listed in Table 1, with a comparison between upgradient and downgradient bores from 2006 to 2011.

There is a particular focus on the downgradient bore BH1B, as this is most likely to reflect the influence of the burial pit.

6.1 Total Dissolved Solids

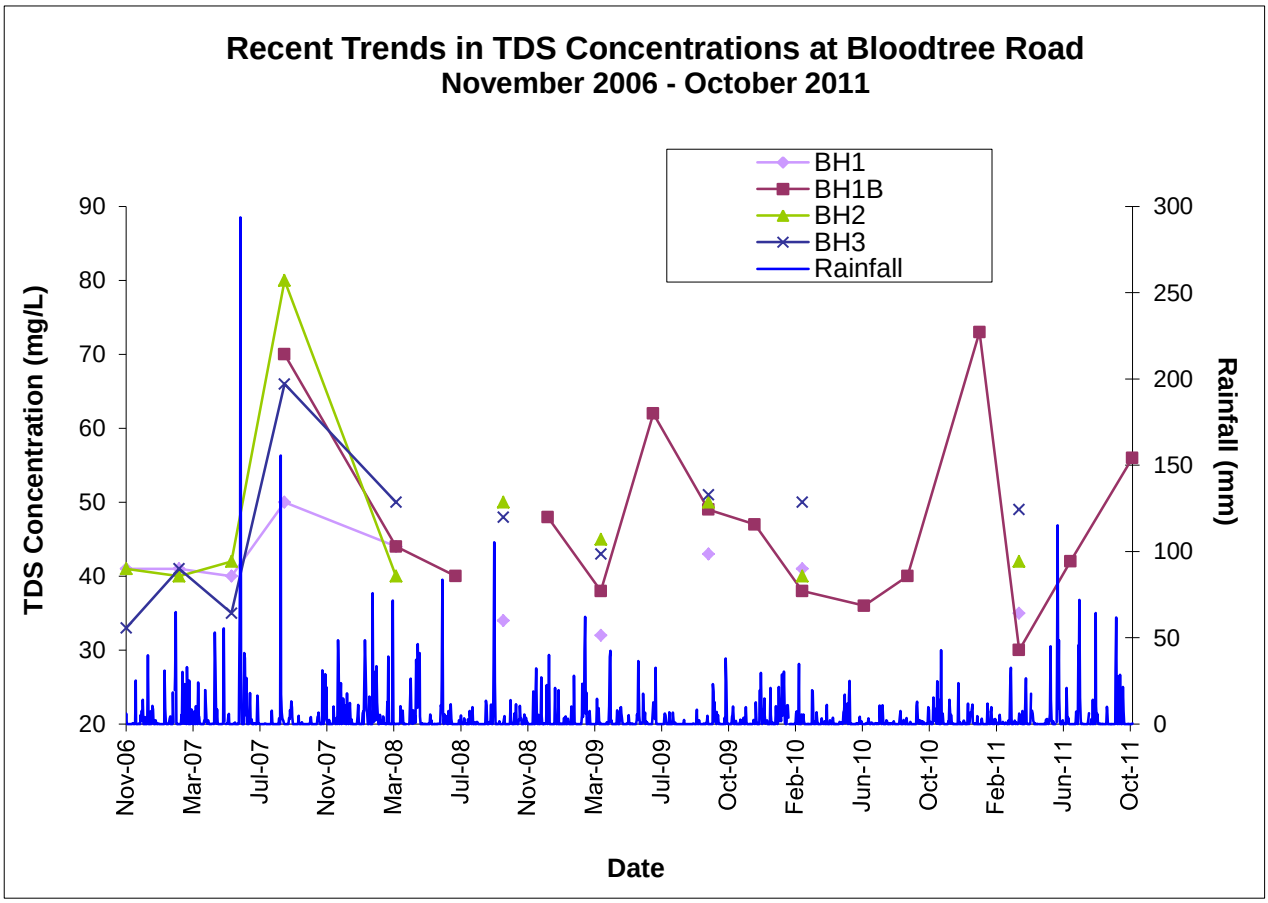

Figure 6: Recent Trends in TDS - November 2006 to October 2011

As presented in Figure 6, TDS concentrations in groundwater from all four boreholes on site have been below the ADWG (2004) from November 2006 to October 2011.

Recent TDS concentrations ranged from 33 mg/L to 66 mg/L in BH3 (upgradient well) and 30 mg/L to 73 mg/L in BH1B (downgradient well). From these analytical results, it is considered that there is no correlation between borehole location and TDS concentration, but a relationship exists between TDS fluctuations and groundwater level fluctuations (increase following heavy rainfall event).

6.2 Nutrients

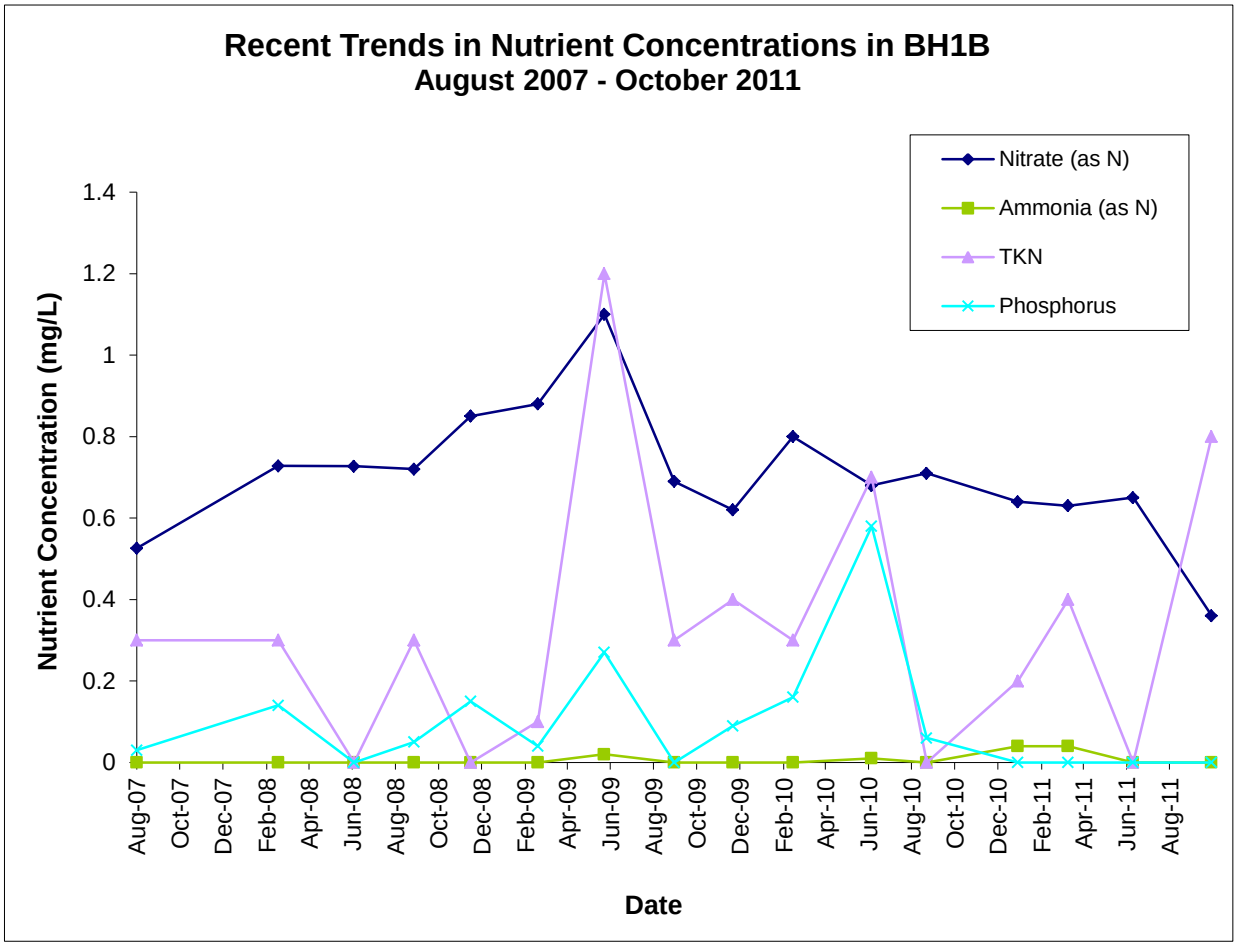

Figure 7: Recent Trends in Nutrient Concentrations in BH1B - August 2007 to October 2011

As a result of regional land use, nitrate concentrations in all groundwater monitoring boreholes continue to slightly exceed the ANZECC trigger value for the protection of freshwater aquatic ecosystems (95% level of protection). Recent concentrations of nitrate in BH1B range from 0.36 mg/L to 1.1 mg/L.

Ammonia in groundwater is largely undetected at Bloodtree Road; when it was detected, concentrations were within the adopted criteria.

Recent concentrations of TKN ranged from below the LOR to 1.2 mg/L, while concentrations of phosphorus ranged from below the LOR to 0.58 mg/L.

6.3 Heavy Metals

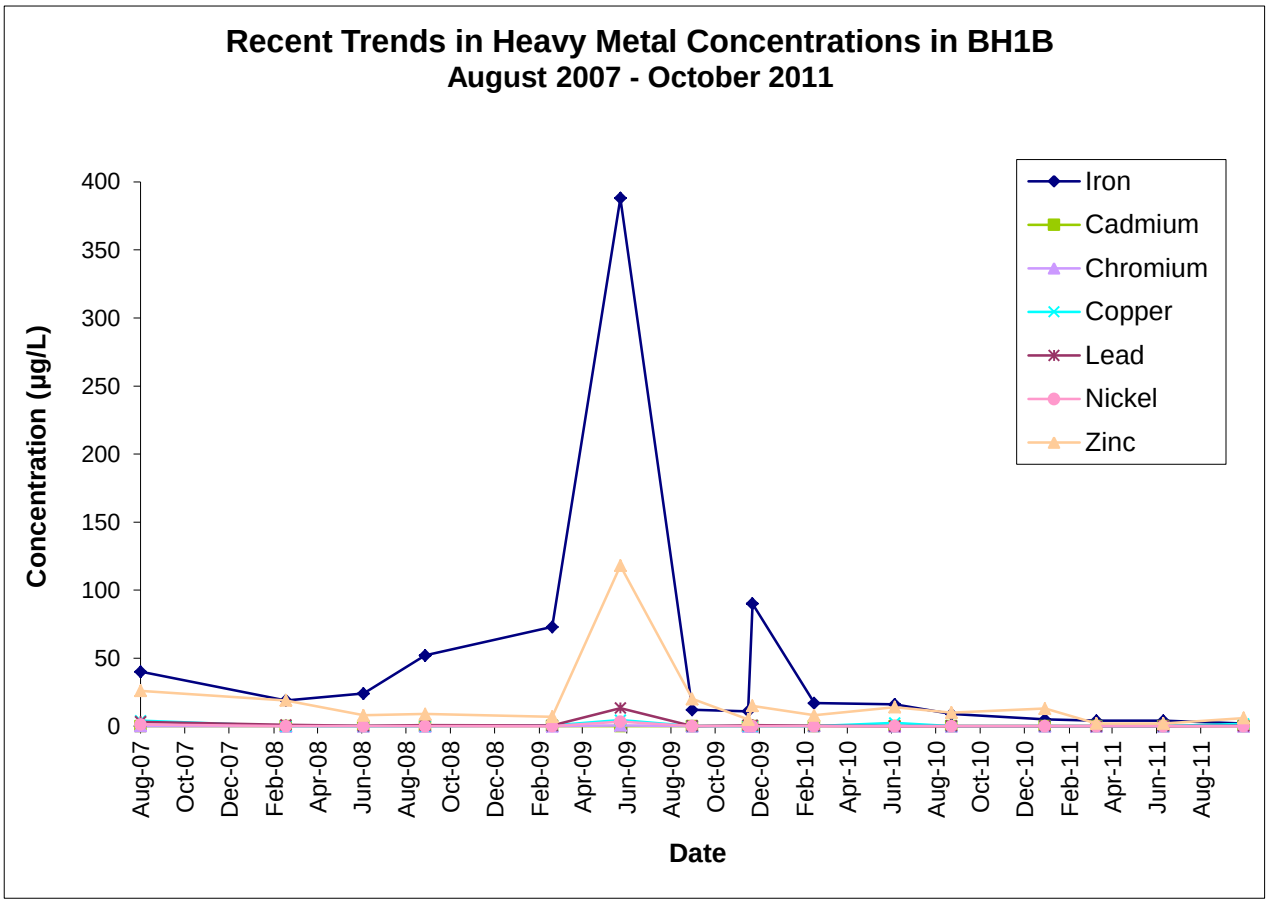

Figure 8: Recent Trends of Heavy Metals in BH1B - August 2007 to October 2011

As shown on Figure 8, there was a 'spike' in metal concentrations, particularly iron, copper, lead and zinc, in the June 2009 monitoring event. The concentration increases are correlated to each other, are comparable to the other wells at Bloodtree Road, and appear to be influenced by the rise in groundwater levels that occurred in mid 2007.

Zinc concentrations in BH1B have frequently exceeded the ANZECC trigger value for the protection of freshwater aquatic ecosystems (95% level of protection). However, for the most part, these concentrations only slightly exceed the criterion.

Analytical results indicate that concentrations of iron in BH1B have been below the adopted criteria from August 2007 to October 2011 (excluding the June 2009 monitoring event).

In most sampling events, cadmium, chromium and nickel were not detected in downgradient boreholes BH1 and BH2, but these metals were detected in BH1B. This suggests that groundwater is transporting dissolved metals from the landfill area, possibly a result of the local geology (i.e. ironstone banding), previous site use as a quarry, the unconsolidated fill applied to the landfill, and/or the large waste soil, organic waste and road-base stockpiles of the adjacent Council depot. However, concentrations of these metals in BH1B have not exceeded the ANZECC trigger value.

7.0 SUMMARY OF EXCEEDANCES IN RECENT AND LONG-TERM MONITORING EVENTS

As previously discussed in Section 3.0, all analytical results are compared to relevant criteria to assess groundwater quality. Specifically, the ANZECC Guidelines are used as a decision-making tool to guide further sampling, while the ADWG are used to assess risk to down-gradient human receptors.

Although the ANZECC (2000) Trigger Values for the Protection of Freshwater Aquatic Ecosystems were developed for surface waters, not groundwater, they are used as a benchmark in the analysis of groundwater quality, because groundwater discharges to surface water systems.

7.1 pH

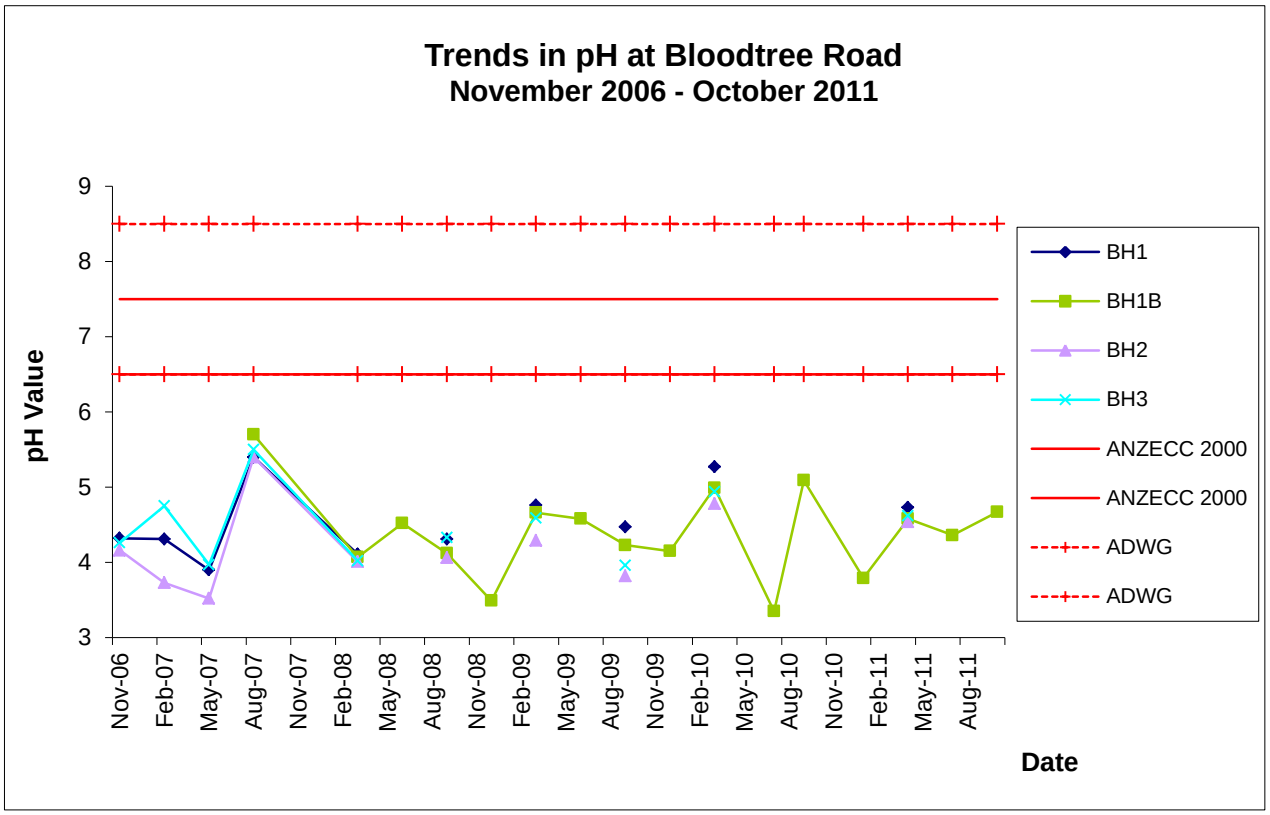

Figure 9: Trends in pH - November 2006 to October 2011

Groundwater at Bloodtree Road and around Mangrove Mountain is generally considered to be slightly acidic, which is common in groundwater associated with the Hawkesbury Sandstone formation.

As seen in Figure 9, in all four groundwater monitoring boreholes, pH values have continuously remained outside the guideline values set by the ADWG (2004) and the ANZECC 2000 Fresh Water Guidelines at the 95% species protection level. The pH of groundwater between 2006 and 2011 has ranged from 3.97 to 5.5 in BH3 (upgradient well) and 3.35 to 5.7 in BH1B (downgradient well).

The pH values at Bloodtree Road are natural background values, unrelated to the burial pit.

It has been noted that pH increases slightly following periods of heavy rainfall, as an influx of fresh water mixes with the groundwater.

7.2 Nitrate as Nitrogen

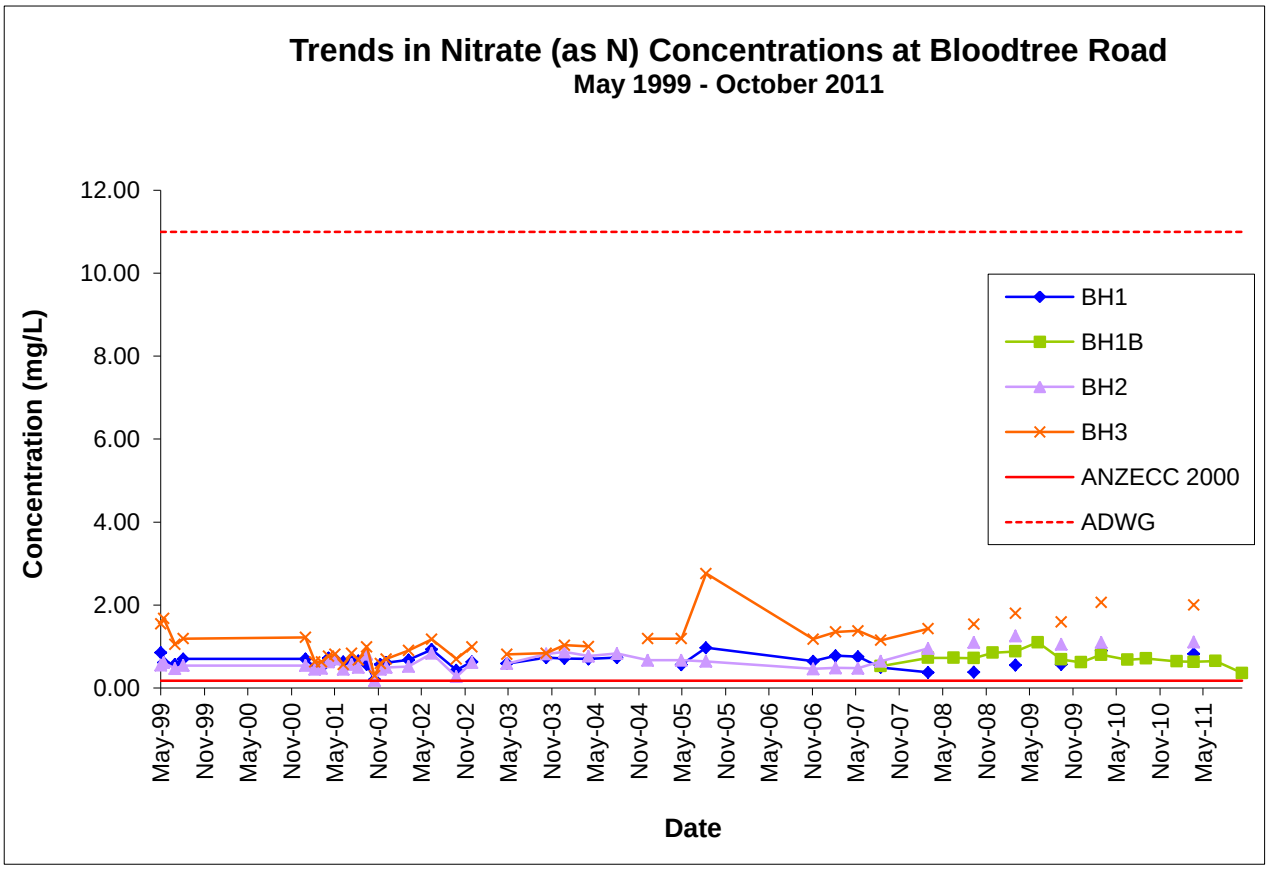

Figure 10: Trends in Nitrate (as N) Concentrations - May 1999 to October 2011

Since monitoring began in 1999, detected concentrations of nitrate in groundwater have remained below the ADWG (2004) value of 11 mg/L in all four monitoring boreholes at Bloodtree Road.

However, the recorded concentrations of nitrate in all boreholes at Bloodtree Road have consistently exceeded the ANZECC trigger value of 0.158 mg/L (as nitrogen). The highest concentration of nitrate reported throughout the monitoring period is 2.76 mg/L in the upgradient well BH3. Additionally, concentrations of nitrate in groundwater at BH3 are typically higher than those boreholes downgradient (specifically, BH1 and BH1B).

These results are indicative of regional levels, and not associated with the landfill. The elevated nitrate concentration is likely due to the intensive agricultural land use around Mangrove Mountain.

7.3 Zinc

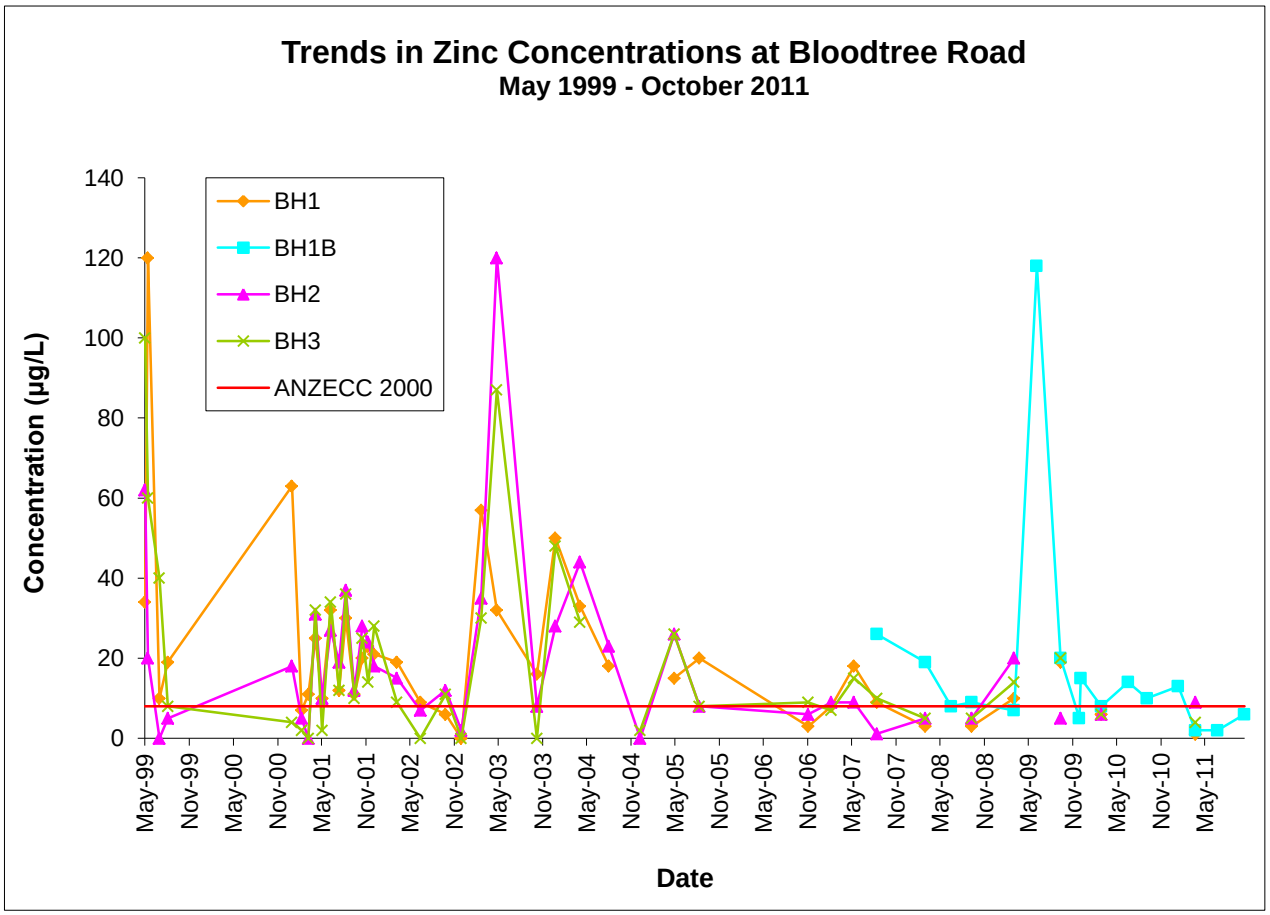

Figure 11: Trends in Zinc Concentrations - May 1999 to October 2011

Exceedances of the ANZECC trigger value for zinc (8 µg/L) have recently been reported in all groundwater monitoring bores at Bloodtree Road, as shown on Figure 11. The highest recorded concentrations of zinc reported in each well are 120 µg/L at BH1 (May 1999), 120 µg/L at BH2 (May 2003), and 118 µg/L at BH1B (June 2009).

Note: BH1 and BH2 are not located immediately downgradient of the landfill, unlike BH1B.

Although in recent events, the concentrations of zinc only slightly exceed or are below the adopted criterion, and therefore, it is not considered to negatively impact the environment or any downgradient receptors i.e. neighbouring landholder bore located 300 metres downgradient of the landfill.

The toxicity of zinc to plants and animals varies with hardness and pH; the acute toxicity of zinc is lower in water with higher hardness and lower pH.

Acute toxicity for Australian species range from 140 to 9600 µg/L (Bacher and O'Brien (1990), Skidmore and Firth (1983)).

8.0 MAINTENANCE WORK AND RESPONSES TO SITE ISSUES

8.1 Installation of New Groundwater Monitoring Bore

Monitoring Bore – BH1B

As boreholes BH1 and BH2 are not directly in line with the calculated direction of groundwater flow (west-south-west), they are not well-located to monitor the impact of the landfill. In order to address this issue, monitoring bore BH1B was installed in August 2007 at a suitable location between the landfill and the nearest potential 'receptor' (a downgradient borehole owned by a neighbouring landholder).

The borehole was advanced using the air-percussion hammer technique. The upper 6 metres were drilled with a solid flight auger, and the air-hammer was used below that depth. Once the borehole had been drilled to the depth of the water table, a claw drill bit was used (as wet sand caused the air-hammer to clog). All drill bits were 100 millimetres in diameter.

The well was completed with class 18 PVC casing and a 3-metre 0.4-millimetre machine-slotted screen, with a short sump at the base. The annulus around the screened zone was filled with 2-millimetre clean quartz gravel, and a bentonite seal was formed above the gravel pack. The upper portion of the annulus was backfilled with crushed sandstone from the drilling, and a surface cement seal was installed.

8.2 Landfill Gas Monitoring

Detection of landfill gases at Mangrove Mountain would be expected given the volume of organic material that has been buried in the landfills. Landfill gases are produced by the decomposition of organic waste in a landfill. Waste is broken down by bacteria that are naturally present both in the waste itself, and also in the soil that has been used to cover the landfill. The major components of landfill gas are methane, carbon dioxide and nitrogen, but many other gases may be present at trace concentrations.

Landfill gas (LFG) monitoring was conducted at Bloodtree Road on 21 August 2007 using a GA2000 infrared gas analyser.

The monitoring work targeted:

- cracks in the pit surface,
- cracks within the monitoring well casing, and
- potential gas pockets beneath the cap.

A LFG port (BT1) was advanced 2.5 metres into the Bloodtree Road pit cap to investigate the potential gas pockets beneath the cap. The subsurface was investigated by hand-augering into the cap, and then the PVC port was installed within the borehole and the annulus backfilled, sealing off the borehole so that the gas could accumulate.

Note: Methane concentrations are expected to be highest below the geosynthetic clay and HDPE liner.

Results from the August 2007 LFG monitoring event are provided below in Table 3.

TABLE 3 Landfill Gas Monitoring				
Location Details		**Peak Concentration (as a %)**		
ID	**Description**	**Methane**	**Carbon Dioxide**	**Oxygen**
BT1	Port 2.5 m	**17.9**	**16.1**	3.3
BH1	Monitoring Well	0	0.1	20.3
BH1B	Monitoring Well	0	0.1	20.4
BH2	Monitoring Well	0	0.1	20.3
BH3	Monitoring Well	0	0.1	20.4
X	Surface	0	0	20.5

A methane concentration of 17.9% was recorded in the soil above the pit liners, indicating that significantly higher concentrations may be present at greater depth.

Additional methane monitoring at Bloodtree Road was conducted in 2008 and results are presented in Table 4.

TABLE 4 Methane Monitoring Results June and July 2008		
Date	**Monitoring Locations**	**Methane Concentration**
27 Jun 2008	*Outdoor*: across surface surrounding landfill *Indoor*: inside Rural Fire Service Depot shed	0% 0%
4 Jul 2008	*Outdoor*: subsurface port BT 1 in landfill cap	37.4%
31 Jul 2008	*Outdoor*: subsurface port BT 1 in landfill cap	37.5%

Because the location of the landfill is isolated, and public access is restricted by locked gates and a 2-metre-high barbed-wire and mesh fence, the potential risk to human health posed by landfill gas production is significantly reduced.

However, as methane was detected within the cap of the Bloodtree Road landfill, landfill gas vents were installed at the Bloodtree Road landfill (see below).

8.3 Installation of Landfill Vents

In August 2008, three landfill gas vents (V1, V2 and V3, as indicated on Figure 12) were installed in the pits, between the shipping containers that contain the decomposed chicken carcases.

This work was done for the following reasons:

- to reduce the potential for lateral migration of landfill gas from the Bloodtree Road landfill;
- to avoid the need for regular and ongoing assessments of landfill gas accumulation at the Rural Fire Service depot; and
- to minimise risks to future maintenance works.

Figure 12: Approximate Locations of LFG Vents at Bloodtree Road

The vents were constructed using 150-millimetre PVC piping and extended 6 to 7 metres into the pit and also aboveground, with a T-piece fitted at the top of each vent to prevent rain from entering. The vents were constructed in a similar manner as the sampling port, with a gravel pack around the screened portion of the vent and a bentonite seal above the screen to prevent water from entering the vent.

During the vent installation process, inspection of the pit contents indicated that the integrity of the landfill had not been compromised, with no evidence to suggest that rainfall had entered the landfill.

8.4 Site Maintenance Work

Vegetation Maintenance

In April 2009, landfill maintenance work was conducted at the Bloodtree Road landfill site.

Development Application 35015/2008, submitted to Gosford City Council, requested approval to remove vegetation from the Bloodtree Road landfill site and to conduct ancillary works (re-capping and sediment control fencing) to mitigate the risk posed by landfill gas and nutrient contamination. The development application was approved in June 2008.

The work consisted of clearing (stump-grinding) woody vegetation across the landfill, particularly along the edges where juvenile Eucalypts and shrubs were sprouting. This was a precautionary measure conducted to ensure that tree roots do not penetrate the geo-synthetic clay and HDPE liners and thus provides a direct pathway for water to access the pit. A sediment control fence was also installed on site.

Throughout the monitoring period, similar maintenance work has been conducted on site, with all woody re-growth vegetation removed.

Landfill Cap Maintenance

Subsidence was not considered a significant issue at the site because the landfill cap was generally mounded, preventing the pooling of water across most of the surface. However, some slight subsidence was identified in the north-eastern corner of the landfill cap.

Accordingly, throughout the vegetation maintenance work conducted in November 2010, Gosford City Council filled the subsided area with 2 to 3 cubic metres of topsoil covered by 2 to 3 cubic metres of woodchips (see Photograph 1).

Photograph 1: Woodchips underlain by imported soil used to fill the subsided corner

However, in October and November 2011, water level measurements from within the landfill gas vents in the pit (specifically V1 and V2) indicated that water was present at the base of the pit. *Note:* The landfill gas vents extend (approximately 6 to 7 metres) between the shipping containers, and do not reach the base of the pit.

Additionally, the ground surface at the western end of the pit appeared to have subsided.

As a short-term solution to reduce the infiltration potential of rainwater, DTIRIS constructed a system of shallow trenches that help to direct (some) water away from the surface of the landfill. Longer-term remedial options were recommended by CMJA, and they included:

- A bund or drain positioned along the northern end of the landfill to divert run-on away from the landfill.
- Recapping of the landfill by removing the top layer of sand until the compacted clay layer is intercepted and importing additional clay to build a contour that will encourage run-off to be shed radially and thus significantly reduce infiltration.
- Construct a leachate monitoring/pumping well in the centre of the landfill to monitor leachate levels at the base of the landfill and to allow for leachate to be removed from the base of the pit.

In November and December 2011, DTIRIS implemented Option 1 and Option 2. As provided by DTIRIS, the following works were undertaken for Option 2.

Eastern end of the landfill
The surface of the pit was excavated until a grey/blue clayey material was intercepted at depths between 0.3 metre (southern edge) and 0.55 metre (northern edge). *Note:* Depths are provided below the benchmark relative level of 0 metre (concrete footing at base of south-east corner post of compound fence. The clayey material was considered to be the upper surface of the clay cap given its colour and texture. The layer appeared to subside from south to north, similar to the shape of the pre-works surface.

The excavation continued until a colour and texture change was encountered, which was presumed to be the low permeability level.

The eastern end was then filled to a level above RL 0 metre with 390 tonnes of heavy block fill clay (a green-coloured shale or mudstone based material) to direct and prevent infiltration of rainfall. The damp clay was placed into the excavation by the excavator and packed into place with the excavator bucket. The clay layer was keyed in along the edges to about 100 to 200 mm below RL 0 metre, depending on the level of the edge. This was completed by trimming the upper surface of the pit border, compacting it with the excavator track, applying additional clay, and then re-compacting to seal the edges of the pit. Clay was then added and compacted, tapering away from the pit until it was level with the natural surface.

A thin layer of wet <50 mm screened blue shale clay was then spread over the block fill clay layer with the excavator bucket at 200 to 100 mm depth. Approximately 81 tonnes of blue shale clay was spread across the block fill clay surface.

A layer of dry <40 mm ripped sandstone was then placed over the blue shale clay using a D5 bulldozer to spread sandstone and to shape the surface landform. The surface was then rolled using a small roller on the Cat-tracked skid-steer loader. A total of around 450 tonnes of imported <40 mm ripped sandstone was spread across the landfill surface and adjacent land to produce a run-off landform.

Western end of the landfill
The surface of the south-western corner was excavated to the grey/blue clayey material, revealing a slumped existing clay cap.

The slumped area was filled with approximately 50 to 60 tonnes of block fill clay to restore sub-surface drainage and to improve the integrity of the south-western corner.

The block fill clay was then covered with the ripped sandstone/shale material removed from the excavation of the eastern end. This stockpiled material was spread with the D5 bulldozer and rolled with the skid-steer loader to produce a mounded landform consistent with the eastern end of the landfill.

Final stages of landfill capping
Once a mounded landform was established across the entire pit surface, the topsoil stockpiled from the surface stripping was distributed with the D5 bulldozer and then spread with the power rake/levelling bar fitted to the skid-steer loader across the entire landfill surface. This thin layer was then rolled with the small skid-steer-mounted roller to stabilise the surface (see Photograph 2).

Photograph 2: Landfill following cap maintenance work

Approximately 130 square metres of kikuyu turf was sporadically placed on and around the landfill:

- to stabilise the pit surface,
- to promote further vegetation growth, and
- to control run-off away from the landfill.

Additional topsoil and turf was added to the surface of the pit in late December 2011 and early January 2012 (see Photograph 3).

Photograph 3: Additional topsoil and turf being added to the surface of the pit in late January 2012

9.0 ADDITIONAL WORKS REQUIRED

Recent and long-term groundwater analytical results from the Bloodtree Road site indicate that the groundwater continues to be of relatively good quality.

Depending on the effectiveness of the recent landfill cap maintenance work, it may be necessary to construct a leachate monitoring well in the centre of the landfill to monitor leachate levels and to allow for leachate to be removed from the base of the pit.

To maintain the integrity of the landfill liners and cap, vegetation growth must be controlled (through lawn mowing and removal of deep rooted vegetation).

The chicken carcasses within the Bloodtree Road landfill will continue to decompose and the landfill liner may weaken over time. As a result, DTIRIS intends to continually monitor groundwater quality and conduct maintenance works on site, as required. However, the site itself is not owned by DTIRIS and therefore, long-term management options will be developed in consultation with the site owner.

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