CH2M HILL

CH2M HILL AUSTRALIA Pty Ltd

GROUNDWATER MONITORING BORE LOG

Monitoring Bore No. **MW03S**

Sheet **1** of **1**

Project No:	**110158**	*Easting (AMG)*	317137.911	*Excavation Equip:*	Rotary Air Circulation
Project:	**Eveleigh Gasworks**	*Northing (AMG)*	1247683.304	*Contractor:*	Maquarie Drilling
Site:	**Macdonaldtown Triangle**	*Elevation (mAHD):*	18.38	*Logged By:*	Lee Moore
Date:	20-Apr-00	*Water Level (mbtc):*	2.31m	*Project Manager:*	Lee Moore
Weather:	Fine	*Final Depth (mbgl):*	3.5 m	*Checked By:*	

Depth (m)	Water Found	Sample PID	Sample No.	Graphic Log	Soil Description (soil type, colour, moisture content, plasticity, grain size, stiffness, etc.)	Observation/Comments (visual contamination, odour, side collapse, etc.)	Monitor. Bore Details
0.5					FILL, Sandy GRAVEL, gravel less than 3cm diameter, medium to coarse grained, grey/brown, dry, loose.		
1.0			MW03-1.00-1.10		Gravelly CLAY, low plasticity, soft/firm, sub-angular gravel less than 2cm diameter, light brown, moist.		
1.5							
	1.70 m						
2.0			MW03-2.00-2.10		Sandy CLAY, low plasticity, soft/firm, fine grained, grey/brown, slight organic odours.		
	2.31 mbtc						
2.5					Silty CLAY, low to medium plasticity, stiff, brown, wet, no odours.		
3.0			MW03-3.00-3.10				
3.5					EOH 3.5m		

Notes

mAHD: metres Australian Height Datum mbgl: metres below ground level mbtc: metres below top of casing

Water Found

_ Water Level | Water Inflow | Water Outflow

GNE Groundwater Not Encountered

CH2M HILL AUSTRALIA Pty Ltd

GROUNDWATER MONITORING BORE LOG

Monitoring Bore No. MW03D

Sheet 1 of 1

Project No:	**110158**	*Easting (AMG)*	317139.485	*Excavation Equip:*	Rotary Air Circulation
Project:	**Eveleigh Gasworks**	*Northing (AMG)*	1247683.339	*Contractor:*	Maquarie Drilling
Site:	**Macdonaldtown Triangle**	*Elevation (mAHD):*	18.33	*Logged By:*	Lee Moore
Date:	19-Apr-00	*Water Level (mbtc):*	4.03m	*Project Manager:*	Lee Moore
Weather:	Fine	*Final Depth (mbgl):*	13.5 m	*Checked By:*	

Depth (m)	Water Found	Sample PID	Sample No.	Graphic Log	Soil Description (soil type, colour, moisture content, plasticity, grain size, stiffness, etc.)	Observation/Comments (visual contamination, odour, side collapse etc.)	Monitor. Bore Details
0.5					FILL, Sandy GRAVEL, gravel less than 3cm diameter, medium to coarse grained, grey/brown, dry, loose.		
1.0			MW03-1.00-1.10		Gravelly CLAY, low plasticity, soft/firm, sub-angular gravel less than 2cm diameter, light brown, moist.		
1.5							
2.0			MW03-2.00-2.10		Sandy CLAY, low plasticity, soft/firm, fine grained, grey/brown, slight organic odours.		
2.5							
3.0			MW03-3.00-3.10		Silty CLAY, low to medium plasticity, stiff, brown, wet, no odours.		
3.5							
4.0	▽ 4.03 mbtc		MW03-4.00-4.10				
4.5							
5.0							
5.5							
6.0							
6.5							
7.0							
7.5							
8.0					Siltstone, low plasticity, stiff, brown/red/grey, dry, no odours		
8.5							
9.0							
9.5							
10.0							
10.5							
11.0	| 11.0 m						
11.5							
12.0					Shale, hard, grey, foliated, slight odour.		
12.5							
13.0							
13.5					EOH 13.5m		

Notes

mAHD: metres Australian Height Datum mbgl: metres below ground level mbtc: metres below top of casing

Water Found

▽ Water Level | Water Inflow | Water Outflow

GNE Groundwater Not Encountered

CH2M HILL AUSTRALIA Pty Ltd

GROUNDWATER MONITORING BORE LOG

Monitoring Bore No. MW04S

Sheet 1 of 1

Project No:	**110158**	*Easting (AMG)*	317159.418	*Excavation Equip:*	Rotary Air Circulation
Project:	**Eveleigh Gasworks**	*Northing (AMG)*	1247704.764	*Contractor:*	Maquarie Drilling
Site:	**Macdonaldtown Triangle**	*Elevation (mAHD):*	18.4	*Logged By:*	Lee Moore
Date:	20-Apr-00	*Water Level (mbtc):*	2.29m	*Project Manager:*	Lee Moore
Weather:	Fine	*Final Depth (mbgl):*	3.5 m	*Checked By:*	

Depth (m)	Water Found	Sample PID	Sample No.	Graphic Log	Soil Description (soil type, colour, moisture content, plasticity, grain size, stiffness, etc.)	Observation/Comments (visual contamination, odour, side collapse, etc.)	Monitor. Bore Details
0.5					FILL, Sandy GRAVEL, angular gravel less than 5cm diameter, coarse grained, grey/black, dry, loose, no odours.		
1.0			MW04-1.00-1.10		Sandy CLAY, low plasticity, soft/firm, medium grained, red/brown, moist.		
1.5							
	1.80 m						
2.0			MW04-2.00-2.10		Silty CLAY, low plasticity, soft, grey/brown, wet, slight organics odour.		
	2.29 mbtc						
2.5					Sandy CLAY, low plasticity, firm/stiff, medium grained, red/brown, wet.		
3.0			MW04-3.00-3.10				
3.5					EOH 3.5m		

Notes

mAHD: metres Australian Height Datum mbgl: metres below ground level mbtc: metres below top of casing

Water Found

_ Water Level | Water Inflow | Water Outflow

GNE Groundwater Not Encountered

CH2M HILL AUSTRALIA Pty Ltd

GROUNDWATER MONITORING BORE LOG

Monitoring Bore No. MW04D

Sheet 1 of 1

Project No:	**110158**	*Easting (AMG)*	317158.641	*Excavation Equip:*	Rotary Air Circulation
Project:	**Eveleigh Gasworks**	*Northing (AMG)*	1247703.451	*Contractor:*	Maquarie Drilling
Site:	**Macdonaldtown Triangle**	*Elevation (mAHD):*	18.37	*Logged By:*	Lee Moore
Date:	19-Apr-00	*Water Level (mbtc):*	3.78m	*Project Manager:*	Lee Moore
Weather:	Fine	*Final Depth (mbgl):*	11.5 m	*Checked By:*	

Depth (m)	Water Found	Sample PID	Sample No.	Graphic Log	Soil Description (soil type, colour, moisture content, plasticity, grain size, stiffness, etc.)	Observation/Comments (visual contamination, odour, side collapse etc.)	Monitor. Bore Details
0.5					FILL, Sandy GRAVEL, angular gravel less than 5cm diameter, coarse grained, grey/black, dry, loose, no odours.		
1.0			MW04-1.00-1.10		Sandy CLAY, low plasticity, soft/firm, medium grained, red/brown, moist.		
1.5							
2.0			MW04-2.00-2.10		Silty CLAY, low plasticity, soft, grey/brown, wet, slight organics odour.		
2.5							
3.0			MW04-3.00-3.10		Sandy CLAY, low plasticity, firm/stiff, medium grained, red/brown, wet.		
3.5							
4.0	3.78 mbtc						
4.5							
5.0							
5.5							
6.0							
6.5							
7.0							
7.5					Siltstone, low plasticity, stiff, red/brown/grey, dry.		
8.0							
8.5							
9.0							
9.5							
10.0	10 m						
10.5					Shale, hard, grey, foliated, wet, no odours.		
11.0							
11.5					EOH 11.5m		
12.0							
12.5							
13.0							
13.5							

Notes

mAHD: metres Australian Height Datum mbgl: metres below ground level mbtc: metres below top of casing

Water Found

Water Level | Water Inflow | Water Outflow

GNE Groundwater Not Encountered

CH2M HILL

CH2M HILL AUSTRALIA Pty Ltd

GROUNDWATER MONITORING BORE LOG

Monitoring Bore No. **MW06S**

Sheet **1** of **1**

Project No:	**110158**	*Easting (AMG)*	317103.196	*Excavation Equip:*	Rotary Air Circulation
Project:	**Eveleigh Gasworks**	*Northing (AMG)*	1247719.155	*Contractor:*	Maquarie Drilling
Site:	**Macdonaldtown Triangle**	*Elevation (mAHD):*	18.96	*Logged By:*	Lee Moore
Date:	20-Apr-00	*Water Level (mbtc):*	2.33m	*Project Manager:*	Lee Moore
Weather:	Fine	*Final Depth (mbgl):*	3.5m	*Checked By:*	

Depth (m)	Water Found	Sample PID	Sample No.	Graphic Log	Soil Description (soil type, colour, moisture content, plasticity, grain size, stiffness, etc.)	Observation/Comments (visual contamination, odour, side collapse, etc.)	Monitor. Bore Details
					FILL, Bitumen		
			6-0.2-0.3		FILL, Brown/black, coke fill, dry, crumbly, light, minor coarse black sand.		
			6-0.3-0.4				
0.5					FILL, Red/grey, sandy clay, red weathered shale.		
1.0			6-1.0-1.1				
1.5					Dark grey plastic silty clay, roots.		
	1.80 m						
2.0			6-2.0-2.1				
	2.33 mbtc						
2.5					Red, clay, compacted, dry, weathered shale red.		
3.0			6-3.0-3.1				
3.5					EOH @ 3.5m		

Notes

mAHD: metres Australian Height Datum mbgl: metres below ground level mbtc: metres below top of casing

Water Found

Water Level | Water Inflow | Water Outflow

GNE Groundwater Not Encountered

CH2M HILL

CH2M HILL AUSTRALIA Pty Ltd

GROUNDWATER MONITORING BORE LOG

Monitoring Bore No. **MW06D**

Sheet **1** of **1**

Project No:	**110158**	*Easting (AMG)*	317102.514	*Excavation Equip:*	Rotary Air Circulation
Project:	**Eveleigh Gasworks**	*Northing (AMG)*	1247720.496	*Contractor:*	Maquarie Drilling
Site:	**Macdonaldtown Triangle**	*Elevation (mAHD):*	18.97	*Logged By:*	Lee Moore
Date:	19-Apr-00	*Water Level (mbtc):*	2.29m	*Project Manager:*	Lee Moore
Weather:	Fine	*Final Depth (mbgl):*	15.0 m	*Checked By:*	

Depth (m)	Water Found	Sample PID	Sample No.	Graphic Log	Soil Description (soil type, colour, moisture content, plasticity, grain size, stiffness, etc.)	Observation/Comments (visual contamination, odour, side collapse, etc.)	Monitor. Bore Details
0					FILL, Brown/black, coke fill, dry, crumbly, light, minor coarse black sand		
0.5			6-0.2-0.3				
			6-0.3-0.4		FILL, Red/grey, sandy clay, red weathered shale.		
1.0			6-1.0-1.1				
1.5					Dark grey plastic silty clay, roots.		
2.0			6-2.0-2.1				
2.5	2.29 mbtc						
3.0			6-3.0-3.1				
3.5							
4.0							
4.5					Red, clay, compacted, dry, weathered shale red.		
5.0							
5.5							
6.0							
6.5							
7.0							
7.5							
8.0							
8.5							
9.0							
9.5							
10.0							
10.5							
11.0	11.0 m				Shale, hard, grey, foliated, slight odour.		
11.5							
12.0							
12.5							
13.0							
13.5							
14.0							
14.5							
15.0					EOH @ 15.0m		

Notes

mAHD: metres Australian Height Datum mbgl: metres below ground level mbtc: metres below top of casing

Water Found

Water Level | Water Inflow | Water Outflow

GNE Groundwater Not Encountered

APPENDIX F

LABORATORY ANALYTICAL RESULTS AND CHAIN OF CUSTODY

APPENDIX F HAS BEEN PROVIDED AS VOLUME TWO

APPENDIX G

NATURAL ATTENUATION BACKGROUND INFORMATION

It must be noted that to obtain an indication as to whether natural attenuation of organic contaminants is occurring in the aquifer, multiple groundwater sampling events and analysis are required. It is not possible to determine whether natural attenuation is occurring from one monitoring round. The following information indicates whether there is a potential for natural attenuation in the surficial and Ashfield Shale aquifers at the Macdonaldtown Triangle.

Natural attenuation of hydrocarbon contamination in groundwater can occur by the natural replacement of hydrogen ions by either aerobic or anaerobic processes. In order to quantify this potential, electron acceptor analysis has been undertaken on the surficial groundwater present beneath the site. The natural attenuation parameters analysed from the groundwater during the groundwater sampling event includes sulphate, nitrate, dissolved oxygen and ferrous iron.

The table below presents the analytical and field measured natural attenuation parameters for the groundwater collected from the surficial and Ashfield Shale aquifers.

Summary of Natural Attenuation Data				
Well	SO_4	NO_3	Diss O_2	Ferrous Fe
Surficial Aquifer				
MW03S	240	nd	1.1	55.6
MW04S	41	nd	1.1	35.3
MW06S	130	1.42	3.9	1.5
Ashfield Shale Aquifer				
MW03D	580	0.01	3.1	36.5
MW04D	610	0.02	2.2	12.8
MW06D*	650	nd	3.1	6.8

NOTE:
* - Background Monitoring Well
nd – not reported above laboratory PQL
All results in mg/L

There are two main processes by which natural attenuation of hydrocarbon contamination can occur in groundwater, aerobic and anaerobic biodegradation. For the purposes of discussion benzene has been used as an example of a hydrocarbon contaminant.

Aerobic biodegradation can occur when oxygenated groundwater intersects a hydrocarbon contaminant plume. Dissolved oxygen concentrations in groundwater measured during the purging and sampling process indicates the amount of oxygen present within the aquifer. The chemical reaction for the aerobic degradation of benzene is described as:

$$C_6H_6 + 7.5O_2 \rightarrow 6CO_2 + 3H_20$$

Based on this process, approximately 3 mg of oxygen is required to degrade 1 mg of benzene. Using a stochiometric approach, the amount of oxygen required to degrade hydrocarbons in the $C_{15} – C_{28}$ chainlength can be estimated to be approximately three times greater than for a C_6 chainlength hydrocarbon. Therefore, approximately 9 mg of oxygen would be required to

degrade 1 mg of C_{18} chainlength hydrocarbon. This calculation provides a conservative overestimate of the potential biodegradation of hydrocarbon compounds.

The average dissolved oxygen concentration recorded in the surficial aquifer at the site was 2.03 mg/L. Therefore, based on the above equation, at this dissolved oxygen concentration the surficial aquifer has the potential to degrade approximately 0.225 mg/L of C_{18} chainlength hydrocarbon.

The average dissolved oxygen concentration recorded in the Ashfield Shale aquifer at the site was 2.8 mg/L. Therefore, based on the above equation, at this dissolved oxygen concentration the Ashfield Shale aquifer has the potential to degrade approximately 0.311 mg/L of C_{18} chainlength hydrocarbon.

The process for anaerobic biodegradation requires a lack of oxygen, carbon, electron acceptors, nutrients and appropriate geochemical conditions for the bacteria to thrive. The presence of dissolved oxygen hinders the anaerobic biodegradation of hydrocarbon compounds. Anaerobic biodegradation will not occur until all of the dissolved oxygen has been removed from the system.

Common anaerobic degradation processes include denitrification, ferric iron reduction, sulfagenesis and methanogensis (Wiedemeier, 1994).

The anaerobic biodegradation process for benzene by denitrification occurs through the following process:

$$6NO_3^- + 6H^+ + C_6H_6 \rightarrow 6CO_{2(g)} + 6H_20 + 3N_{2(g)}$$

Using the same principles outlined for the aerobic degradation of hydrocarbon chainlengths, approximately 14.34 mg of nitrate would be required to degrade 1 mg of C_{18} chainlength hydrocarbon. The average concentration of NO_3 in the surficial groundwater recorded at the site is 0.476 mg/L. Therefore, there the surficial aquifer has the potential to degrade approximately 0.033 mg/L of of C_{18} chainlength hydrocarbon.

The average nitrate concentration recorded in the Ashfield Shale aquifer at the site was 0.012 mg/L. Therefore, based on the above equation, at this nitrate concentration the Ashfield Shale aquifer has the potential to degrade approximately 0.00084 mg/L of C_{18} chainlength hydrocarbon.

The biodegradation of benzene through iron reduction occurs following the chemical reaction:

$$6OH^+ + 30Fe(OH)_3 + C_6H_6 \rightarrow 6CO_2 + 30Fe^{2+} + 78H_2O$$

Under this process, and using the same approach as described above, approximately 63 mg of Fe would be required to degrade 1 mg of C_{18} chainlength hydrocarbon. Using the average concentration of ferrous iron reported by the laboratory for the surficial aquifer, 30.8 mg/L,

approximately 0.489 mg/L of C_{18} chainlength hydrocarbon would be able to be degraded through iron reduction.

Using the average concentration of ferrous iron reported by the laboratory for the Ashfield Shale aquifer, 18.7 mg/L, approximately 0.296 mg/L of C_{18} chainlength hydrocarbon would be able to be degraded through iron reduction.

Natural attenuation of benzene by sulphate reduction occurs through the following chemical reaction:

$$7.5H^+ + 3.75SO_4^- + C_6H_6 \rightarrow 6CO_{2(g)} + 3.75H_2S^o + 3H_2O$$

Using the same approach as described above, approximately 13.8 mg of SO_4 would be required to degrade 1 mg of C_{18} chainlength hydrocarbon. The average concentration of SO_4 reported in the surficial groundwater is 151 mg/L. Therefore, approximately 10.94 mg/L of C_{18} chainlength hydrocarbon could be degraded through sulphate reduction.

The average sulphate concentration recorded in the Ashfield Shale aquifer at the site was 613.3 mg/L. Therefore, based on the above equation, at this sulphate concentration the Ashfield Shale aquifer has the potential to degrade approximately 44.4 mg/L of C_{18} chainlength hydrocarbon.

Co-metabolite

Methane is an *in situ* product of the natural attenuation of hydrocarbons via the process of methanogenesis. The amount of dissolved methane present in the groundwater is a direct indicator as to the degree of hydrocarbon biodegradation.

The reported analytical results for both the surficial and Ashfield Shale aquifers are presented in the table below.

Summary of Dissolved Methane Data	
Well	Dissolved Methane
Surficial Aquifer	
MW03S	230
MW04S	2500
MW06S	100
Ashfield Shale Aquifer	
MW03D	83
MW04D	22
MW06D	47

NOTE:
All results in µg/L @25°C

The biodegradation of benzene by methanogenesis occurs by the following reaction:

$$C_6H_6 + 4.5H_2O \rightarrow 2.25CO_2 + 3.75CH_4$$

Based on the approaches described above, approximately 2.3 mg of methane is produced as a result of the biodegradation of the of C_{18} chainlength hydrocarbon.

The average concentration of dissolved methane reported in the surficial groundwater is 943.3 mg/L. Therefore, it can be estimated that approximately 410.14 mg/L of C_{18} chainlength hydrocarbon has been degraded through methanogenesis.

The average concentration of dissolved methane reported in the Ashfield Shale aquifer is 50.67 mg/L. Therefore, it can be estimated that approximately 22.02 mg/L of C_{18} chainlength hydrocarbon has been degraded through methanogenesis.

The various metabolic processes listed above are not mutually exclusive. As liable organic matter enters an oxygenated aquifer, microbial metabolism will likely degrade the contaminating substrate. That is, the indigenous microorganisms utilise the pollutant, as an electron donor to support heterotrophic microbial respiration. The aquifer microbiota use oxygen as a co-substrate and as an electron acceptor to support their respiratory activities. When oxygen becomes limiting, aerobic respiration slows, but other groups of microorganisms may then come into play and continue to degrade the contaminating organic matter. Under conditions of anoxia, anaerobic bacteria can use organic chemicals or several inorganic chemicals or several inorganic chemicals or several inorganic anions as alternate electron acceptors.

These concentrations suggest that the surficial aquifer has a potential assimilative capacity of 1.6 mg/L of hydrocarbons, which indicates a moderate potential for hydrocarbon degradation in the aquifer.

Using both aerobic and anaerobic pathways these concentrations suggest that the Ashfield Shale aquifer has a potential assimilative capacity of 44.7 mg/L of hydrocarbons, which indicates a good potential for hydrocarbon degradation in the aquifer.

In addition, the presence of co-metabolite methane in both the surficial and Ashfield Shale aquifers suggests that the natural attenuation of hydrocarbons is actively occurring in the aquifers.