A8.3 Groundwater Treatment Trial QA/QC Results

The QA/QC results for groundwater samples collected at the site are summarised in **Table A8.2** and discussed in **Section A8.4** below. Detailed laboratory QA/QC results are included in the laboratory reports in **Appendix F**.

Table 8.2 – Groundwater QA/QC Results Summary

Data Quality Indicator	Frequency	Results	DQI met?
Precision			
Groundwater Blind duplicates (intra laboratory)	0 field duplicates analysed –0% of total samples >5% acceptable	-	No[1]
Groundwater Blind replicates (inter laboratory)	1 blind replicates analysed – 9% of total samples >5% acceptable	0-13% RPD	Yes
Laboratory Duplicates	No batch specific duplicates analysed	-	Yes
Trip spike	1/1 batch (<LOR)	95-129%	Yes
Trip blank	1/1 batch (<LOR)	<LOR	Yes
Accuracy			
Surrogate spikes	All organic samples	60-140% recovery	Yes
Matrix spikes	1 sample - acceptable	95-120%	No[1]
Laboratory control samples	2 analysed – acceptable	70-130% recovery	Yes
Representativeness			
Sampling appropriate for media and analytes	All samples	All sampling conducted in accordance with JBS procedures	Yes
Laboratory blanks	1/batch	<LOR	Yes
Samples extracted and analysed within holding times.	All	All samples were extracted and analysed within holding times for the target analytes.	Yes
Comparability			
Standard operating procedures used for sample collection & handling	All	One staff member used same standard operating procedures throughout works	Yes
Standard analytical methods used	All	Standard analytical methods used	Yes
Consistent field conditions, sampling staff and laboratory analysis	All	Sampling was conducted by one staff member using standard operating procedures in the same conditions throughout the works. The primary lab and secondary labs remained consistent throughout the investigation.	Yes
Limits of reporting appropriate and consistent	All	Limits of reporting were consistent and appropriate.	Yes
Completeness			
Sample description & COCs completed	All	All field data sheets and COCs were completed appropriately.	Yes
Appropriate documentation	All	All appropriate field documentation is included in the Appendices.	Yes
Satisfactory frequency/result for QC samples	All	The QC results are considered adequate for the purposes of the investigation.	Yes
Data from critical samples is considered valid	All	Data from critical samples are considered valid.	Yes

[1] See discussion of DQI outliers below.

A8.4 Groundwater Treatment Trial QA/QC Discussion

A8.4.1 Precision

The field replicates recorded relative percentage differences (RPDs) within the acceptable range of less than 30 to 50%. It is noted that no field duplicate sample was analysed a part of the assessment, due to a shortage of sample containers on the day of the water treatment trial. Given that the data collected was used to assess treatment technologies, and is not intended to characterise the site the lack of a field duplicate is considered not to affect the precision of the treated waste data set.

A8.4.2 Accuracy

All surrogate recovery results and matrix spike results were within the acceptable range.

A8.4.3 QA/QC Conclusion

The field sampling and handling procedures produced QA/QC results which indicated that the soil and water data are of an acceptable quality and suitable for use in site characterisation.

The NATA certified laboratory Certificates of Analysis indicated that the project laboratory was generally achieving levels of performance within its recommended control limits during the period when the samples from this program were analysed.

On the basis of the results of the field and laboratory QA/QC program, the soil and groundwater data are assessed to be of an acceptable quality upon which to draw conclusions regarding the environmental condition of the site, within the limitations of this study.

A.9 Pre-Remedial Assessment Results

Results of laboratory analysis on samples collected from the site are discussed in the following section. Sample location identifiers comprise the letters 'TP' (test pit) or 'MW' (monitoring well) as a prefix and a number as a suffix. A second suffix of 'S' or 'D' has been assigned to samples collected from shallow or deep wells respectively.

A9.1 Deviations from the Sampling, Analysis, Quality Plan

A Sampling, Analysis, Quality Plan (SAQP) was prepared for the Pre-Remedial Investigations documenting the proposed strategy and methods. During completion of the site works certain changes were made based on observed conditions on site and are discussed below.

Changes to depth of bulk sample collect for cement stabilisation trial. The proposed sampling depths listed in the SAQP were based on layers of fill/soil reported to contain highly elevated contaminant concentrations in previous assessments of the site. The actual sampling depth required in the current works was assessed by comparing the previous bore logs with the field observed material until a close match was apparent. **Table A9.1** summarises the proposed and actual bulk sample collection depths.

Table A9.1: Proposed and Actual Bulk Sample Collection Depths

Proposed location		**Actual Location**	
Former Location ID / sample depth	**Layer description (CH2M Hill, 2007)**	**New testpit ID / sample depth**	**Layer description (JBS, 2010)**
MG10A/0.7m	Fill – black ash, and coke gravel	JBS TP1/0.3-0.4m	Fill- silty gravelly sand comprising coke, ash and slag, dark brown to black, dry to damp, some ballast gravel and cobble inclusions (irregular, basalt, hard)
MG02/ 1.8m	Fill – silty clay (original surface (?), spongy, wet, dark brown to black, low plasticity, black ooze, tar	JBS TP3/1.3-1.7m	Fill – silty clay dark brown, low plasticity, wet, heterogeneous with coke gravel and black tar ooze inclusions, strong PAH odours and black sheen on material
BHC (angled borehole)/ 6.0m	Fill – mixture of ironstone gravels and clays, black stains, wet sloppy, pierced through brick base annulus, free tar in bricks, saturated soil	JBS TP3/4.0 – 4.2m	Fill – silty clay yellow red with grey mottles, medium plasticity, very strong, wet PAHs odours, black ooze seepage throughout

It is noted that while co-ordinates of the original sampling locations were used to generally locate the new test pit positions, heritage restrictions prevented placement of JBS TP3 close enough to the northern gasholder such that material at the base of the brick annulus could be sampled (as described in the original BHC bore log). The material sampled at depth in JBS TP3 was, however, considered to be consistent with tar impacted material likely to have originated from material used to fill the northern gasholder.

Changes to groundwater wells to be used for pump tests and water collection for the treatment trial. The SAQP nominated that wells MW07S, MW06S, MW03S and MW31 be used for pump tests and to collect groundwater for the water treatment trial. On commencement of site works the following was noted in relation to these wells:

- MW03S was unable to be located. Site plan indicated the well was placed in the vicinity of several large soil stockpiles, and it is uncertain whether this well remains viable;
- MW06S ran dry after extraction of approximately 40 L on both 7 and 9 July 2010;
- MW07S ran dry after extraction of approximately 50 L on both 7 and 9 July 2010; and

- MW31 was unable to be located at the time of the trial and it is likely this well has been destroyed.

Given the limited time available for completion of the trial, the majority of water for the trial was pumped from MW04S and MW37S. A total of 4000 L was pumped over the trial period from these two wells.

A9.2 Field Observations

Visual and/or olfactory indicators of contamination were noted at all sampling locations on the site. At the test pit locations:

- Ash, coke and slag inclusions were observed in JBS TP1 in shallow fill between 0 and 0.6 m depth;
- Ash, coke and slag inclusions were observed in JBS TP2 in shallow fill between 0 and 0.9 m depth. Coal tar odours were noted in all material encountered at this location to the termination depth of 1.8m, and a black oily sheen/ooze was observed on material between 1.3 and 1.8 m depth;
- Coke gravels, coal tar odours and a black sheen were noted on materials JBS TP3 from 1.3 m depth to the test pit termination depth of 4.3 m;
- Ash, slag and potential ACM inclusions were observed in JBS TP4 in shallow fill between 0 and 0.6 m depth. Coal tar odours were noted in fill between 0.9 and 1.4 m depth at this location; and
- Ash, coke and slag inclusions were observed in JBS TP5 in shallow fill between 0 and 0.5 m depth. Below this depth , coal tar odours were noted in all material encountered to the termination depth of 2.1 m.

In the shallow wells pumped for the water treatment trial, groundwater on the site was noted to be black grey in colour, highly turbid and having strong coal tar odours.

Test pit logs are included in **Appendix H**. Field notes from the pump tests are provided in **Appendix I**.

A9.3 Stratigraphy

The profile encountered across the site comprised fill overlying natural clay soils. The profile encountered is summarised in **Table A9.2** below.

Table A9.2 – Summary of subsurface profile encountered during testpitting

Layer	Locations	Description	Depth Encountered (m bgl)
Fill	All boreholes	Dark brown, grey and black, gravelly silty ash, coke and slag inclusions, some materials	0 – 4.3
Free Groundwater	JBS TP2	0.9-1.0 m seepage entering pit From 1.0m onward material wet	0.9-1.8m^{+}
	JBS TP3	Materials wet from 0.4m onwards	0.4—4.3m^{+}

Notes: + wet material extended beyond test pit termination depth.

The fill encountered in all test pits excavated on the site comprised layers of heterogeneous silty sand and gravelly silty sand, generally containing ash, slag and coke inclusions. Fill present in the top metre appeared to be highly heterogeneous with the majority of this top layer comprising anthropogenic materials. Generally with depth the portion of inclusions present in fill appeared to decrease, while moisture content and the intensity of coal tar odours appeared to increase. Black sheen or ooze was only encountered in fill material at depth.

A9.4 Soil Analytical Results

The soil sampling locations are shown on **Figure A.1** and summarised laboratory results are presented in **Tables A9.3 to A9.10**. Detailed analytical laboratory reports and chain of custody documentation are provided in **Appendix E**. Results of the stabilisation trial are presented in **Appendix I**. Results of clay content analysis are presented in **Appendix J**.

Laboratory results are discussed in the following sections.

A9.4.1 Concentrations in Soil in Untreated Material

Total and leachable concentrations in selected untreated soil samples are provided in **Tables A9.3 to A9.5**. Only detected contaminants have been tabulated, with full results for all undetected compounds contained in the laboratory certificate.

Despite having similar material descriptions, the concentrations contained in the samples analysed as part of the current program (JBS TP1 and JBS TP3) were less than the concentrations detected in the original test locations samples (BHC, MG10A and MG02 from CH2M Hill 2000). While part of this difference may be attributable to variations in the contaminant profile across the site, the major factor is considered likely to be a result of the difference in testing methods adopted. Specifically that the original samples were collected from drilled boreholes, while the current samples were collected from test pits. As the original samples appear to have been collected from thin, highly impacted layers it is likely that these concentrations over state the requirements of remediation. During remediation it is likely that these thin highly impacted layers will undergo some dilution/homogenisation while being excavated and stockpiled with less impacted material. The current samples, collected from test pits cuttings, are therefore considered more likely to represent the condition of free tar impacted materials during bulk excavation.

All heavy metals concentrations were less than the remediation acceptance criteria to be applied to the site. Phenols were also below detection limit in all samples and asbestos was not identified in any soil samples.

Concentrations of Total PAHs, B(a)P and /or naphthalene exceeded the remediation acceptance criteria in samples collected from JBS TP2/0.4-0.5 m, JBS TP2/1.4-1.5 m, JBS TP3/1.7 m, JBS TP4/1.6-1.7 m and JBS TP5/0.5 m.

In general the current results indicate that B(a)P concentrations were highest at shallow depths. The highest concentration of B(a)P was detected in sample JBS TP2/0.4-0.5 m comprising shallow fill with coke and slag inclusions, containing a total concentration of B(a)P of 64 mg/kg. Despite the high total concentration the leachable B(a)P concentration in this sample was below the laboratory detection limit. Furthermore, as the leachable concentrations of B(a)P all samples were below the laboratory detection limit, the data suggests that some degree of natural immobilisation is occurring. Review of historical site data presented in the RAP (CH2M Hill, 2007) indicates that only 10 other samples collected from the site contained B(a)P concentrations in excess of 64 mg/kg.

The most prominent feature of the detected PAH concentrations, are the relatively high naphthalene values, which are consistent with by-products resulting from the generation of gas from coal. Highest detected concentrations were generally associated with material observed to contain ‘black ooze’ and/or have a sheen present, and the elevated naphthalene concentrations were considered the source of the strong ‘coal tar’ odours noted during sampling. While the current dataset is limited, the results suggest the prevalence of naphthalene in soils may be linked to former use of the site. Naphthalene accounted for more than half of the total PAH concentration in samples JBS TP2/1.4-1.5 m and JBS TP3/1.7 m, collected from the anticipated tar source area in the vicinity of the

Northern Gasholder and retort area. In samples collected from the areas external to the Northern Gasholder and Retort (from TP1, TP4 and TP5), naphthalene accounted for a much lower portion of the Total PAH concentration. This appears consistent with PAH results for the site provided in Tables 1 to 8 of '*Delineation & Characterisation Sampling and review of Remedial Options, Former Macdonaldtown Gasworks - Burren Street, Erskineville*' (CH2M Hill, March 2007). Results in Tables 1 and 2 of that document (samples from the gasholder and retort area) indicate that where PAHs were detected, naphthalene was detected at much higher concentrations than any of the other PAH compounds. Results in Tables 3 to 8 of that document, providing results from the other areas of the site, show that naphthalene concentrations in these areas account for a small percentage of the Total PAH concentrations.

Additionally, it is noted that while the elevated total concentrations of naphthalene that exceeded the remediation were detected in samples JBS TP2/0.4-0.5 m, JBS TP2/1.4-1.5 m, JBS TP3/1.7 m, JBS TP4/1.6-1.7 m and JBS TP5/0.5 m, the corresponding leachable concentrations were all less than the JBS site specific leachability criteria with the exception of 2.8 mg/L in sample JBS TP2/1.4-1.5 m and 3.6 mg/L in sample JBS TP3/1.7 m.

BTEX compounds may also be generated during gas production from coal, however only low BTEX compounds were detected in the samples analysed from the site. Only one sample JBS TP2/1.4-1.5m contained a concentration above the assessment criteria, a total xylene concentration of 66 mg/kg. It is noted that the corresponding leachable concentration in this sample was below the laboratory detection limit.

A9.4.2 Conclusions Relating to Treatment Suitability

In samples exceeding the assessment criteria for B(a)P, naphthalene and/or total PAHs, the concentrations were less that the allowable limits for cement stabilisation provided in IA 2005/14. This suggests that the material present at JBS TP2/0.4-0.5 m, JBS TP2/1.4-1.5 m, JBS TP3/1.7 m, JBS TP4/1.6-1.7 m and JBS TP5/0.5 m are suitable for treatment by stabilisation and, once treated, suitable to be assessed under IA 2005/14.

The presence of total benzo(a)pyrene above the site assessment criteria in samples JBS TP2/0.4-0.5 m, JBS TP2/1.4-1.5 m, JBS TP4/1.6-1.7 m and JBS TP5/0.5 m, suggests that bioremediation is unlikely to effectively treat these materials for on site reuse. Bioremediation may however be conducted on these materials such that a reduced waste classification is achieved for off-site disposal.

The presence of elevated total xylenes in the sample JBS TP2/1.4-1.5 m is suitable for treatment by either cement stabilisation or bioremediation.

A9.4.2 Soil Treatment Trial

Following sample collection, material were delivered to Enviropacific for treatment by cement stabilisation. On receipt, the materials were processed, *i.e.* particles over 20 mm in diameter removed, with the remaining sample homogenised, subdivided and then treated with either 5, 12.5 or 20 % cement. At the request of the site Auditor, subsamples of each material were analysed after processing and subdivision, prior to the addition of cement. Samples were also analysed at the completion of the treatment trial. Contaminant concentrations in the soil through the treatment process are presented in **Appendix J.**

Mean values for each of the treated material samples are summarised in **Tables A9.6 and A9.7**. Full results are included in **Appendix J**.

Table A9.3 **PAH, Phenol and Asbestos Concentrations in Untreated Soil Samples (units as specified)**

Sample ID (summarised material description)	Total B(a)P (mg/kg)	Leachable B(a)P (mg/L)	Total Naphthalene (mg/kg)	Leachable naphthalene (mg/L)	Total PAHs (mg/kg)	Leachable PAHs (mg/L)	Total Phenols (mg/kg)	Total Phenols (mg/L)	Asbestos
JBS TP1/ 0.3-0.4m[1] Fill sandy gravel some ash, coal and slag (Material 1)	3	<0.001	0.6	<0.001	30.1	BDL	BDL	BDL	Not identified
JBS TP2/ 0.4-0.5m Fill – silty gravelly sand, coal tar odour, coke and slag inclusions	**64**	<0.001	**13**	0.022	**770.2**	0.037	BDL	BDL	Not identified
JBS TP2/1.4-1.5m Fill – silty clay, with black tar ooze inclusions coal tar odour, coke and slag inclusions	**7.7**	<0.001	**350**	**2.8**	**467.7**	2.9	BDL	BDL	Not identified
JBS TP3/1.7m[1] Fill - silty clay dark brown, s with coke gravel and black tar ooze inclusions, strong PAH odours and black sheen on material (Material 2)	0.6	<0.001	**310**	**3.6**	**330.2**	3.742	BDL	BDL	Not identified
JBS TP3/4.0-4.2m[1] Fill - very strong PAHs odours, wet, black ooze seepage throughout (Material 3)	4.5	<0.001	1.7	0.066	30.6	0.089	BDL	BDL	Not identified
JBS TP4/0.5m Fill – silty sand, ash slag and glass fragments, suspected ACM fragment	4.4	<0.001	<0.1	0.002	33.2	0.002	BDL	BDL	Not identified
JBS TP4/1.0m Fill – silty clay slight coal tar odour	<0.05	<0.001	<0.1	<0.001	BDL	BDL	BDL	BDL	Not identified
JBS TP4/1.6-1.7m Fill – silty clay	**30**	<0.001	6.3	<0.001	**349.8**	0.003	BDL	BDL	Not identified
JBS TP5/0.5m Fill – silty clay, with strong coal tar odours	**30**	<0.001	**250**	0.64	**724.3**	0.707	BDL	BDL	Not identified
JBS TP5/1.5m Fill - silty clay, with strong coal tar odours	1.5	<0.001	9.2	0.18	25.1	0.191	BDL	BDL	Not identified
JBS TP5/2.0m Fill - silty clay, with strong coal tar odours							BDL	BDL	Not identified
Assessment Criteria									
CH2M Hill RAP[2] (maximum of depth dependent values)	5	-	11.8		100	-	42 500	-	
JBS 2010 Site Specific Leachability[3]	-	1.7	-	1.162	-	-	-	6.4	

Notes:

1 Bulk sample of same material collected for benchscale immobilisation trial
2 Remediation Acceptance Criteria for Total Concentrations in soil, site specific based on exposure to vapours
3 Site Specific leachability criteria for materials to remain on site
BDL = below laboratory detection limit

Table A9.4: **VOC Concentrations in Untreated Soil Samples (units as specified)**

Sample ID	Depth (m)	Total Benzene (mg/kg)	Leachable Benzene (µg/L)	Total Toluene (mg/kg)	Leachable Toluene (µg/L)	Total Ethyl Benzene (mg/kg)	Leachable Ethyl benzene (µg/L)	Total Xylene (mg/kg)	Leachable Xylene (µg/L)	Total 1,3,5 trimethylbenzene (mg/kg)	Leachable 1,3,5 trimethylbenzene (µg/L)	Total 1,2,4 trimethylbenzene (mg/kg)	Leachable 1,2,4 trimethylbenzene (µg/L)
JBS TP1	0.3-0.4	<0.5	<1	<0.5	<1	<1.0	<1	<3.0	<1	<1	<1	<1	<1
JBS TP2	0.4-0.5	<0.5	<1	<0.5	<1	<1.0	<1	<3.0	<1	<1	1.5	<1	2.7
JBS TP2	1.4-1.5	1.4	<1	2.4	<1	26	<1	**66**	<1	25	340	15	820
JBS TP3	1.7	0.9	<1	0.72	<1	22	<1	31	<1	54	260	36	640
JBS TP3	4-4.2	<0.5	<1	<0.5	<1	<1.0	<1	<3.0	<1	<1	<1	2.2	<1
JBS TP4	0.5	<0.5	<1	<0.5	<1	<1.0	<1	<3.0	<1	<1	<1	<1	<1
JBS TP4	1	<0.5	<1	<0.5	<1	<1.0	<1	<3.0	<1	<1	<1	<1	<1
JBS TP4	1.6-1.7	<0.5	<1	<0.5	<1	<1.0	2.1	<3.0	<1	<1	<1	<1	2.8
JBS TP5	0.5	<0.5	<1	<0.5	<1	<1.0	2.0	<3	<1	<1	19	<1	5.2
JBS TP5	1.5	<0.5	<1	<0.5	35	<1.0	17	8.6	<1	4.1	170	8.5	380
JBS TP5	2.0	<0.5	3.7	<0.5	4.8	<1.0	12	<3	<1	<1	11	<1	31
Assessment Criteria													
CH2M Hill RAP (maximum of depth dependent values)		1	-	7.9	-	34.8	-	14	-	-	-	-	-
JBS Site Specific Leachability		-	8000	-	2880	-	80	-	10 000	-	-	-	-

Table A9.5: **Heavy Metal Concentrations in Untreated Soil Samples (units as specified)**

Sample ID	Depth (m)	Total Arsenic (mg/kg)	Leachable Arsenic (µg/L)	Total Cadmium (mg/kg)	Leachable Cadmium (µg/L)	Total Chromium (mg/kg)	Leachable Chromium (µg/L)	Total Copper (mg/kg)	Leachable Copper (µg/L)	Total Lead (mg/kg)	Leachable Lead (µg/L)	Total Nickel (mg/kg)	Leachable Nickel (µg/L)	Total Zinc (mg/kg)	Leachable Zinc (µg/L)
JBS TP1	0.3-0.4	30	<0.05	1.1	<0.01	26	<0.01	230	0.1	220	<0.03	20	0.02	260	1.6
JBS TP2	0.4-0.5	13	<0.05	<0.5	<0.01	19	<0.01	80	0.04	220	0.09	26	<0.02	220	1.7
JBS TP2	1.4-1.5	<4	<0.05	<0.5	<0.01	14	<0.01	**4**	0.04	58	<0.03	5	<0.02	200	0.5
JBS TP3	1.7	<4	<0.05	<0.5	<0.01	12	<0.01	1	0.02	14	<0.03	2	<0.02	3	1
JBS TP3	4-4.2	5	<0.05	<0.5	<0.01	22	<0.01	6	0.02	24	<0.03	3	<0.02	9	0.2
JBS TP4	0.5	8	<0.05	<0.5	<0.01	22	<0.01	46	0.1	260	0.05	10	<0.02	4	1.4
JBS TP4	1	9	<0.05	<0.5	<0.01	35	<0.01	51	0.06	61	0.04	3	<0.02	14	0.2
JBS TP4	1.6-1.7	6	<0.05	<0.5	<0.01	7	<0.01	65	0.4	100	0.06	4	<0.02	47	1.4
JBS TP5	0.5	6	<0.05	<0.5	<0.01	18	<0.01	18	0.02	58	0.05	5	<0.02	35	0.3
JBS TP5	1.5	5	<0.05	<0.5	<0.01	23	<0.01	16	0.02	50	<0.03	13	<0.02	93	1.3
JBS TP5	2.0	6	<0.05	<0.5	<0.01	2.5	<0.01	9	0.02	36	0.03	7	<0.02	27	0.09
Assessment Criteria															
CH2M Hill RAP (maximum of depth dependent values)		1	-	7.9	-	34.8	-	14	-	-	-	-	-		
JBS Site Specific Leachability		-	8000	-	2880	-	80	-	10 000	-	-	-	-		

Table A9.6 **Mean Results of Soil Treatment Trial (units as specified) – Assessment of Compliance to IA 2005/14**

Sample ID (JBS/Enviropacific)		Cement ratio	Total B(a)P (mg/kg)	Leachable B(a)P (mg/L)[1]	Total PAHs (mg/kg)	Leachable PAHs (mg/L)[1]	Total TPH C_{10}-C_{36} (mg/kg)	Leachable TPH C_{10}-C_{36} (µg/L)[1]	Mean UCS 7-day curing (MPa)	Compliant with IA 2005/14	Waste Classification under IA 2005/14
Control Sample		untreated	1.7	<0.001	51	0.083	500	680	ND	-	-
JBS TP1/ 0.3-0.4m	Material 1 Post 5%	1:20	4.7	<0.001	44	<0.001	360	400	2.18	Y	General Solid
	Material 1 Post 12.5%	1:8	3.8	<0.001	34	<0.001	320	280	3.10	Y	General Solid
	Material 1 Post 20%	1: 5	3.9	<0.001	43	<0.001	300	290	5.85	Y	General Solid
JBS TP3/1.7m	Material 2 Post 5%	1:20	2.0	<0.001	171	2.6	810	6700	**0.35**	N	-
	Material 2 Post 12.5%	1:8	1.6	<0.001	117	1.9	450	5700	1.00	Y	General Solid
	Material 2 Post 20%	1: 5	1.6	<0.001	101	1.5	420	4900	1.55	Y	General Solid
JBS TP3/4.0-4.2m	Material 3 Post 5%	1:20	0.8	<0.001	17	0.26	<250	1420	**0.13**	N	-
	Material 3 Post 12.5%	1:8	0.8	<0.001	20	0.33	<280	1300	**0.43**	N	-
	Material 3 Post 20%	1: 5	1.7	<0.001	48	0.48	460	1950	**0.60**	N	-
Assessment Criteria											
IA 2005/14, NSW EPA[2]		2:1	500	-	13 000	-	-	-	1	-	-
General Solid Waste (DECC 2009)		-	10	40	200	-	10 000	-	-	-	-
Restricted Solid Waste (DECC 2009)		-	23	160	800	-	40 000	-	-	-	-
Site Specific Leachability (JBS 2010)		-	-	1.6							

Notes 1. Leachability testing by ASLP, unless otherwise specified

2. NSW EPA '*General Immobilisation of Contaminants in Waste – Coal tar Contaminated Waste From Former Gasworks Sites*' approval number 2005/14 (IA 2005/14).

Table A9.7: **Mean Results of Soil Treatment Trial (units as specified) – Assessment of Additional Compound Results**

Sample ID (JBS/Enviropacific)		**Cement ratio**	**Total Naphthalene (mg/kg)**	**Leachable naphthalene (mg/L)[1]**	**Total Toluene (mg/kg)**	**Leachable Toluene (µg/L)[1]**	**Total Ethyl Benzene (mg/kg)**	**Leachable Ethyl benzene (µg/L)[1]**	**Total Benzene (mg/kg)**	**Leachable Benzene (µg/L)[1]**	**Total Xylene (mg/kg)**	**Leachable Xylene (µg/L)[1]**
Control Sample		untreated	18	0.059	<0.5	0.083	<0.5	1.5	<0.5	<1	<3	<3
JBS TP1/ 0.3-0.4m	Material 1 Post 5%	1:20	0.6	0.001	<0.5	<0.001	<0.5	<1	<0.5	<1	<3	<3
	Material 1 Post 12.5%	1:8	0.5	<0.001	<0.5	<0.001	<0.5	<1	<0.5	<1	<3	<3
	Material 1 Post 20%	1: 5	0.4	<0.001	<0.5	<0.001	<0.5	<1	<0.5	<1	<3	<3
JBS TP3/1.7m	Material 2 Post 5%	1:20	120	**2.4**	<0.5	<1	2.8	70	<0.5	<1	4.7	121
	Material 2 Post 12.5%	1:8	74	**1.7**	<0.5	<1	1.4	44	<0.5	<1	1.2	80
	Material 2 Post 20%	1: 5	60	1.3	<0.5	<1	<1	30	<0.5	<1	<3	52
JBS TP3/4.0-4.2m	Material 3 Post 5%	1:20	2.7	0.2	<0.5	0.26	<0.5	4.4	<0.5	<1	<3	2.3
	Material 3 Post 12.5%	1:8	5.0	0.27	<0.5	0.33	<0.5	<1	<0.5	<1	<3	<3
	Material 3 Post 20%	1: 5	16	0.42	<0.5	0.48	<0.5	2.6	<0.5	<1	<3	<3
Assessment Criteria												
IA 2005/14, NSW EPA[2]		2:1	-	-	-	-	-	-	-	-	-	-
General Solid Waste (DECC 2009)		-	-	-	-	-	-	-	-	-	-	-
Restricted Solid Waste (DECC 2009)		-	-	-	-	-	-	-	-	-	-	-
Site Specific Leachability (JBS 2010)		-	-	1.16	-	2880	-	80	-	8000	-	10 000

Notes 1. Leachability testing by ASLP, unless otherwise specified
2. NSW EPA '*General Immobilisation of Contaminants in Waste – Coal tar Contaminated Waste From Former Gasworks Sites*' approval number 2005/14 (IA 2005/14).

The results in **Table A9.6** indicate that two of the three materials tested are suitable for treatment by cement stabilisation with the addition of at least 12.5% cement. Material 3, collected from JBS TP3/ 4.0 – 4.3 m, failed to meet the required UCS value, which is likely to be related to the clay content of this material. The results for this material however show that the UCS value increased as the percentage of cement added increased, which suggests that cement stabilisation may be possible using a higher percentage of cement.

Results for the remaining two samples after treatment show full compliance with the requirements of IA 2005/14, and under this order would be suitable for off site disposal to landfill as General Solid Waste at a landfill licenced to receive immobilised material.

With regards to on site reuse, the treated material must be compliant with all the requirements of IA/2005 (to demonstrate contaminants have been stabilised) and the leachable concentrations must be less the site specific leachability criteria. The results in **Table A9.6** indicate that only Material 1 complies with all these requirements. As discussed previously Material 3, collected from JBS TP3/ 4.0 – 4.3 m, failed to meet the required UCS value, however this may be rectified using a higher portion of cement. Leachable concentrations of naphthalene in the Material 3 treated samples exceeded site specific leachability criteria, and would therefore be considered unsuitable for reuse on the site. We note that the methods currently accepted for determining leachable concentrations will greatly overestimate leachable concentrations in stabilised material. The Enviropacific report (Appendix I) for the stabilisation trial notes that '*...current leachate methods (TCLP, ASLP and MEP are the only leachate tests currently used by regulatory authorities in Australia) have important limitations. For example, each of these methods require particle size reduction to either 9.5 mm (TCLP and MEP) or 2.4 mm (ASLP), which effectively contravenes the assessment of encapsulated wastes as the integrity of the monolithic structure is compromised, and each of these methods employ vigorous end-over-end agitation of the sample. In fact in AS4439.3- 1997 (ASLP) the Scope states that "The procedure is not applicable to encapsulated wastes which cannot be reduced to the specified maximum particle size without breaking the integrity of encapsulation". For this reason, in the General IA, the DECCW is in effect relying on the UCS measurement as an indicator of the stability of cement stabilised waste, whilst still requiring B(a)P leachability (TCLP) for cement stabilised samples to be below the Waste Classification Guidelines criteria (and from previous EPS experience with other gasworks projects B(a)P leachability has typically been non-detectable in both the untreated and cement stabilised samples using TCLP).*

If a more appropriate leach test (e.g. a diffusion-based or column leach test on a moulded/monolithic sample) was adopted for assessing the leachability of cement stabilised materials destined for on-site placement, the optimum UCS required to minimise contaminant leachability could be more accurately determined, and a different leachability data set may result, that might be more appropriately applied to acceptance criteria for on-site placement of cement stabilised material.'

The results of the treatment trial suggest that some cement stabilised soils may be suitable for on-site reuse. The limited sample size suggests that material containing total naphthalene concentrations over 50 mg/kg may not be suitable for on site reuse following stabilisation, or use of column leach tests in addition to ASLP testing may be required to determine the leachable concentrations in cement stabilised material. A column leach test, although not an approved method, would avoid grinding of the treated material and be more representative of leaching conditions that may occur on site. TCLP testing would still likely be required for assessment of the material against IA 2005/14, and determining the waste classification of the treated material if off site disposal is required.

At the request of the Site Auditor samples of untreated material were also analysed after the materials had been sorted (*i.e.* oversize particles removed) and prior to the addition of water and/or cement. Full tabulated pre and post treatment analytical results are presented in **Appendix J.**

As expected, for each of the bulk samples supplied, the range of total concentrations in the subsampled material shows minor variation. Generally the total concentrations in the three subsample prepared from each bulk material were within 20 percent of each other.

With the exception of B(a)P, total concentrations generally showed only minor reductions between the pre and post treatment samples. The slight reduction is considered to be the result of the addition of cement to the material, essentially diluting the original concentrations. Contaminant reductions above those noted were not expected as the trialled treatment method is not intended to remove contamination only reduce its mobility.

To assess the ability of the treatment method to reduce mobility the leachable concentrations were compared in the pre and post treatment samples. It is noted that pre treatment leachable concentrations were determined using the TCLP method to assess the likely waste classification of these materials assuming no treatment occurs. Leachable concentrations in the post treatment samples were determined using the ASLP method, to assess the suitability of cement stabilised material to be reinstated on site. The following paragraphs generally discuss the variation in leachable concentrations between pre and post treatment samples as an indication of the likely performance of the material, although readers should be aware of the different leachability methods used in determining these results.

BTEX compounds and naphthalene were noted as the main contaminants of concern in groundwater migrating off site. The following was noted in relation to leachable concentrations in the samples untreated and treated from the trial.

In general the leachable concentrations of all BTEX compounds, where detected, were reduced by an order of magnitude in the treated material samples. It is however noted that all leachable BTEX concentrations in the samples of untreated material were less than the site specific leachability criteria.

For naphthalene mixed results were obtained, the leachable concentrations in Material 1 (JBS TP1/0.3-0.4m) were less than the laboratory detection limit in both the untreated and treated material. For Material 2 (JBS TP1.7 m), naphthalene concentrations on average reduced by only 1 mg/L between the pre and post treatment samples. This may be due to a number of factors including the elevated total concentrations of naphthalene, the use of the ASLP method (rather than column leach tests) as discussed above. In Material 3 (JBS TP3/4.0-4.2 m) the leachable concentrations in the treated material were an order of magnitude less than concentrations detected in the untreated material. It is noted that leachable naphthalene concentrations in all Material 3 samples, both untreated and treated exceeded the site specific leachability criteria. These results suggest that where material is being treated by cement stabilisation for on site reuse additional refinement of the treatment process is required to reduce the ASLP determined leachable concentration. Alternately consideration should be given to use of method to determine the leachable concentration that does not require crushing or grinding of the stabilised material.

While B(a)P was not listed as a contaminant of concern in groundwater it is noted that the leachable concentrations in all untreated and treated samples were less than the laboratory detection limit, consistent with the results discussed in **Section A9.3**.

A9.5 Water Treatment Trial

The methods and results of the water treatment trial conducted on the site were documented in the JBS Letter Report '*Groundwater Treatment Trial, Former Macdonaldtown Gasworks*', dated 05 August 2010 Reference 40913 - 15534. A copy of that letter is included as **Appendix C**.

The results of the water treatment trial are summarised in **Tables A9.8** and **A9.9** below. Overall it is noted that samples of the treatment system effluent (*i.e.* all 'Sample 4' results, collected post GAC filter) were reported to contain very low concentrations of all contaminants of concern at the site. Based on these results it appears that a water treatment plant could be used as part of the remediation process to enable discharge of collected groundwater as follows:

- To stormwater following receipt of relevant approvals from City of Sydney Council; or
- To sewer should a 'trade waste agreement' be entered into with Sydney Water.

Additionally the results indicate that the treated effluent was of a suitable quality for reinjection into the subsurface. The feasibility of this option, is however, uncertain, given the required discharge rates during remediation are likely to exceed the infiltration potential of the clay soils underlying the site. This option would also require licensing by the NSW Office of Water.

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Table A9.8: **Summary of Water Treatment Trial Results – VOCs, TPH and Heavy Metals**

Sample ID	pH	Analyte												
		VOCs			TPH		Heavy Metals							
		Chloroform	Bromodichloromethane	Dibromochloromethane	C_6-C_9	C_{10}-C_{36}	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn
MW04S	Pumped groundwater holding tank	21	25	18	<10	6,200	<1	<0.1	<1	<1	<1	<0.5	1	110
Sample 1 – Run 1	Influent (15 mins)	14	8.9	2.7	<10	1,100	<1	<0.1	<1	<1	<1	<0.5	1	110
Sample 2 – Run 1	Post oil-water separator / pre sand filter (15 mins)	9.8	5.8	1.7	<10	170	<1	<0.1	<1	1	<1	<0.5	2	100
Sample 3 – Run 1	Post sand filter/ pre GAC (15 mins)	12	7.6	2.2	<10	3,210	<1	<0.1	<1	10	<1	<0.5	8	63
Sample 4 – Run 1	**Post GAC Effluent (15 mins)**	**<1**	**<1**	**<1**	**<10**	**<250**	**16**	**<0.1**	**<1**	**<1**	**<1**	**<0.5**	**<1**	**1**
Sample 1 – Run 2	Influent (30 mins)	12	2.1	2.1	<10	3,600	<1	<0.1	<1	3	<1	<0.5	7	170
Sample 2 – Run 2	Post oil-water separator / pre sand filter (30 mins)	11	6.6	2.0	<10	322	<1	<0.1	<1	4	<1	<0.5	9	91
Sample 3 – Run 2	Post sand filter/ pre GAC (30 mins)	9.7	6.3	2.0	<10	190	<1	<0.1	<1	7	<1	<0.5	8	48
Sample 4 – Run 2	**Post GAC Effluent (30 mins)**	**<1**	**<1**	**<1**	**<10**	**<250**	**17**	**<0.1**	**<1**	**<1**	**<1**	**<0.5**	**<1**	**<1**
Sample 1 – Run 3	Influent (40 mins)	9.6	5.9	1.8	<10	5,700	<1	<0.1	<1	<1	<1	<0.5	2	160
Sample 2 – Run 3	Post oil-water separator / pre sand filter (40 mins)	10	5.5	1.7	<10	<250	<1	<0.1	<1	<1	<1	<0.5	2	140
Sample 3 – Run 3	Post sand filter/ pre GAC (40 mins)	11	5.2	1.6	<10	1230	<1	<0.1	<1	4	1	<0.5	2	49
Sample 4 – Run 3	**Post GAC Effluent (40 mins)**	**<1**	**<1**	**<1**	**<10**	**<250**	**24**	**<0.1**	**<1**	**<1**	**<1**	**<0.5**	**<1**	**<1**

Table A9.9: Summary of Water Treatment Trial Results - PAHs

Sample ID	Component or sampling stage (time after system commencement)	Analyte - PAHs														
		Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene	Benzo(b+k)fluoranthene	Benzo(a)pyrene	Indeno(1,2,3-c,d)pyrene	Dibenzo(a,h)anthracene	Benzo(g,h,i)perylene
MW04S	Pumped groundwater holding tank	5.6	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sample 1 – Run 1	Influent (15 mins)	2.2	<0.1	0.7	0.5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
Sample 2 – Run 1	Post oil-water separator / pre sand filter (15 mins)	0.3	<0.1	0.4	0.4	0.4	<0.1	0.2	0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
Sample 3 – Run 1	Post sand filter/ pre GAC (15 mins)	0.2	<0.1	0.3	0.2	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
Sample 4 – Run 1	**Post GAC (15 mins)**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.02**	**<0.01**	**<0.01**	**<0.01**	**<0.01**
Sample 1 – Run 2	Influent (30 mins)	3.4	<0.1	0.5	0.4	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
Sample 2 – Run 2	Post oil-water separator / pre sand filter (30 mins)	0.2	<0.1	0.5	0.5	1	0.2	0.7	0.4	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
Sample 3 – Run 2	Post sand filter/ pre GAC (30 mins)	0.2	<0.1	0.4	0.4	0.5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
Sample 4 – Run 2	**Post GAC (30 mins)**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.02**	**<0.01**	**<0.01**	**<0.01**	**<0.01**
Sample 1 – Run 3	Influent (45 mins)	3.8	<0.1	0.8	0.6	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
Sample 2 – Run 3	Post oil-water separator / pre sand filter (40 mins)	0.2	<0.1	0.6	0.5	0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
Sample 3 – Run 3	Post sand filter/ pre GAC (40 mins)	0.2	<0.1	0.6	0.5	0.6	0.1	0.1	0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
Sample 4 – Run 3	**Post GAC (40 mins)**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.02**	**<0.01**	**<0.01**	**<0.01**	**<0.01**

A9.6 Pump Tests

The groundwater wells pumped to generate water for the treatment trials were also subject to small scale pump tests, conducted in line with the method provided in MacDonald A, Barker J and Davies J (September 2008) '*The bailer test: a simple effective pumping test for assessing borehole success*' in Hydrogeology Journal.

The following locations were subject to pump tests:

- MW04S;
- MW07S;
- MW37S; and
- MW42S.

Data loggers were used to record the drawdown in these wells during the pumping and recovery phases of the tests. Line graphs of the raw data collected from each well over the duration of the pump test are presented in **Figures A2** to **A3**, as time versus height of water above the logger.

Based on this inspection of the raw data, no further analysis was conducted on the results from MW04S and MW07S. The plots from these two locations show that both wells were unable to sustain pumping rates of 1 - 2.4 Litres per minute (L/min), with both running dry over the duration of pumping. While these results reflect the spatial variability in the volume of perched groundwater present under the site, and permeability of the formation, they were considered to not provide meaningful data for remediation planning.

The results from MW37S and MW42S were used to estimate the hydrologic properties of fill material underlying the site. The pump test data from both locations were used to estimate the transmissivity of the screened formation using three methods of analysis as follows:

- Papodopulos and Copper (1967) –using the active pumping data only;
- Cooper and Jacob (1946) – using the active pumping data only; and
- Theis Recovery Method (1946) – using the well recovery data only.

The methods selected have been assessed as suitable for analysis of constant discharge, single well tests (*i.e.* no use of observation wells during the pump test) in unconfined aquifers (Kruseman & De Ridder, 2000). Kruseman & De Ridder (2000) also indicates that as storage in the well may influence drawdown at the commencement of pumping and recovery phases of the test, then only the latter stages of data should be used for curve matching.

Curve matching and data analysis were undertaken using the AquiferWin32 software package. The transmissivity values calculated using all three tests are summarised in **Table A9.10** below, with the corresponding AquiferWin32 output files and curve matching analysis provided in **Appendix I**.

The hydraulic conductivity of the formation surrounding the pumped wells was estimated from the calculated transmissivity values using the following equation:

$K = T/b$ Where T = aquifer transmissivity

b = aquifer thickness (assumed to be the length of the saturated screen interval in the well);

K = hydraulic conductivity of the formation.

Table A9.10 – Summary of Hydraulic Conductivity Testing Results

Well ID	SWL* (m below TOC$^{\alpha}$)	Screen Interval (m below TOC)	Transmittivity ($m^2.s^{-1}$)			Mean transmissivity ($m^2.s^{-1}$)	Hydraulic conductivity ($m.s^{-1}$)
			Papodopulos & Copper (1967)	Cooper & Jacob (1946)	Theis Recovery Method (1946)		
MW37S	0.931	1.5-4.5	9.89×10^{-6}	1.23×10^{-6}	3.47×10^{-5}	1.55×10^{-5}	5.09×10^{-6}
MW42S	1.19	1.5-4.5	9.70×10^{-6}	1.32×10^{-6}	4.88×10^{-5}	1.99×10^{-5}	6.65×10^{-6}

Notes: * Standing Water Level

From the values estimated in **Table A9.10**, hydraulic conductivity values for the screened intervals within the wells tested range between 5.09×10^{-6} $m.s^{-1}$ and 6.65×10^{-6} $m.s^{-1}$.

Very few published values are available for fill layers, given the inherent variability of groundwater flow characteristics in these materials, it is, however, noted that the estimated values of hydraulic conductivity are in the range of values listed in Freeze and Cherry (1979), for silts, sand and fine grained sand.

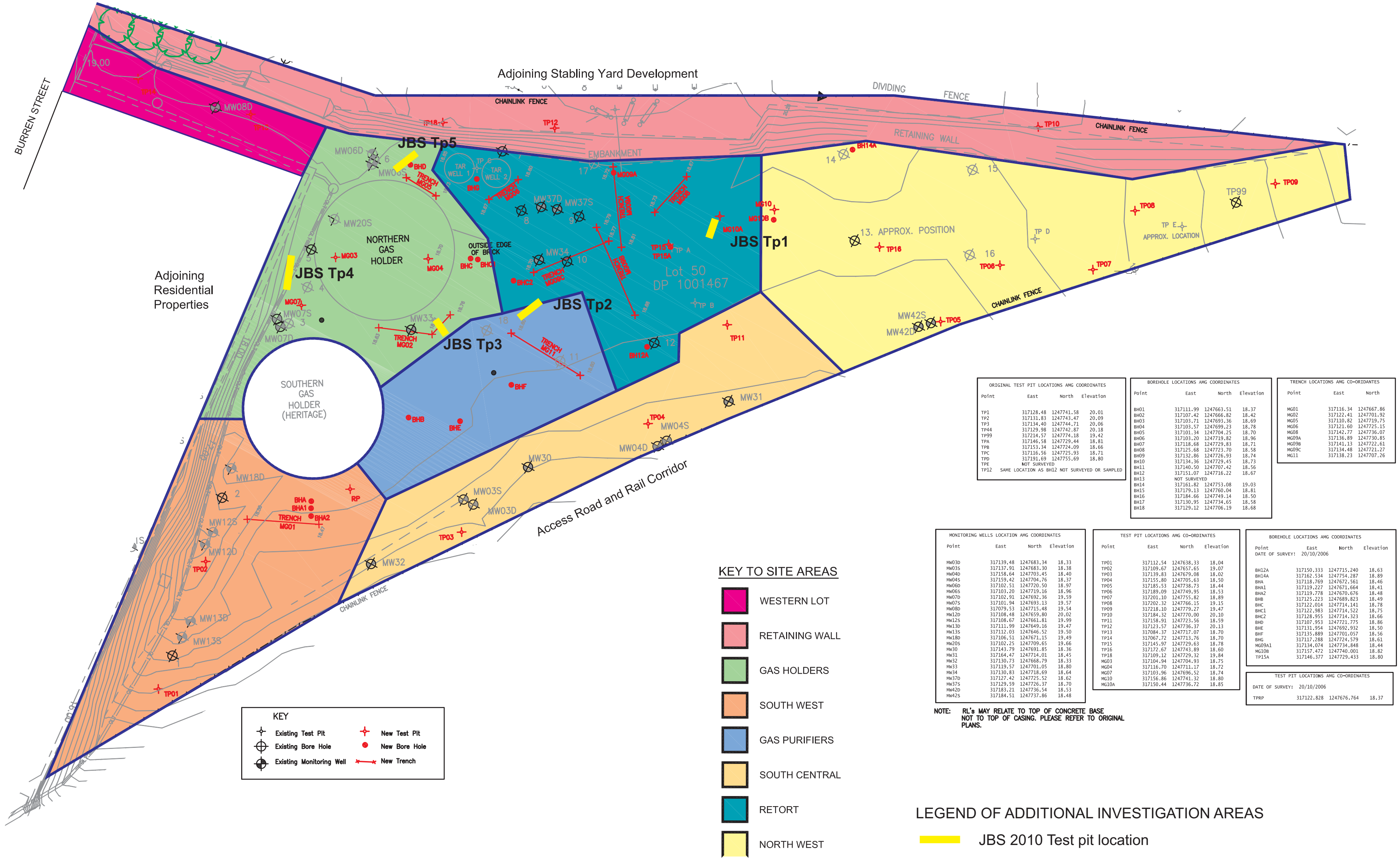
The hydraulic conductivities reported in **Table A9.10** are equivalent to an order of magnitude less than the average value of 1.4×10^{-5} $m.s^{-1}$ reported for clay soils in (SKM 2006). In relation to the slug test determined conductivity value, it is noted that the SKM report noted that '…*based on the measured extent of the shallow and deep groundwater plumes migrating from the site, the permeability rates estimated from the slug tests appear to be an order of magnitude greater than actual rates*'. The JBS calculated conductivity values therefore, appear to be consistent with rate of off-site migration of contaminated groundwater.

Adopting a maximum hydraulic gradient of 3.1×10^{-2} the SKM report estimated flow velocities in shallow groundwater to be on the order of 6.2 and 13.7 metres per year. Using the same hydraulic gradient value, the conductivities reported in **Table A9.10** equate to flow velocities between 5 and 6.5 metres per year.

The difference in estimated hydraulic conductivities may be attributable to the use of a pump test in the recent work by JBS, compared to slug tests by SKM in 2006. The pump test undertaken by JBS enabled estimates of conductivity to be made from both the pumping and recovery periods, while the slug test only allows for assessment of recovery.

Given that two of the four shallow wells ran dry over the duration of pumping, it is considered that the values provided in **Table A9.10** are likely to represent the upper end of hydraulic conductivities in fill on the site.

Figures A1 to A3



ORIGINAL TEST PIT LOCATIONS AMG COORDINATES

Point	East	North	Elevation
TP1	317128.48	1247741.58	20.01
TP2	317131.83	1247743.47	20.09
TP3	317134.40	1247744.71	20.06
TP44	317129.98	1247742.87	20.18
TP99	317214.57	1247774.18	19.42
TPA	317146.58	1247729.44	18.81
TPB	317153.34	1247724.09	18.66
TPC	317116.56	1247725.93	18.71
TPD	317191.69	1247755.69	18.80
TPE	NOT SURVEYED		
TP12	SAME LOCATION AS BH12 NOT SURVEYED OR SAMPLED		

BOREHOLE LOCATIONS AMG COORDINATES

Point	East	North	Elevation
BH01	317111.99	1247663.51	18.37
BH02	317107.42	1247666.82	18.42
BH03	317103.71	1247693.36	18.69
BH04	317103.57	1247699.23	18.78
BH05	317101.34	1247704.25	18.70
BH06	317103.20	1247719.82	18.96
BH07	317118.68	1247729.83	18.71
BH08	317125.68	1247723.70	18.58
BH09	317132.86	1247726.93	18.74
BH10	317134.36	1247729.45	18.73
BH11	317140.50	1247707.42	18.56
BH12	317151.07	1247716.22	18.67
BH13	NOT SURVEYED		
BH14	317161.82	1247753.08	19.03
BH15	317179.13	1247760.04	18.81
BH16	317184.66	1247749.14	18.50
BH17	317130.95	1247734.65	18.58
BH18	317129.12	1247706.19	18.68

TRENCH LOCATIONS AMG CO-ORIDANTES

Point	East	North
MG01	317116.34	1247667.86
MG02	317122.41	1247701.92
MG05	317110.82	1247719.75
MG06	317121.60	1247725.15
MG08	317142.77	1247736.07
MG09A	317136.89	1247730.85
MG09B	317141.13	1247722.61
MG09C	317134.48	1247721.27
MG11	317138.23	1247707.26

MONITORING WELLS LOCATION AMG COORDINATES

Point	East	North	Elevation
MW03D	317139.48	1247683.34	18.33
MW03S	317137.91	1247683.30	18.38
MW04D	317158.64	1247703.45	18.40
MW04S	317159.42	1247704.76	18.37
MW06D	317102.51	1247720.50	18.97
MW06S	317103.20	1247719.16	18.96
MW07D	317102.91	1247692.36	19.59
MW07S	317101.94	1247693.13	19.57
MW08D	317079.53	1247715.48	19.54
MW12D	317108.48	1247659.80	20.02
MW12S	317108.67	1247661.81	19.99
MW13D	317111.99	1247649.16	19.47
MW13S	317112.03	1247646.52	19.50
MW18D	317106.51	1247671.15	19.49
MW20S	317102.25	1247709.65	19.66
MW30	317143.79	1247691.85	18.36
MW31	317164.47	1247714.01	18.45
MW32	317130.73	1247668.79	18.33
MW33	317119.57	1247701.05	18.80
MW34	317130.83	1247718.69	18.64
MW37D	317127.42	1247725.52	18.62
MW37S	317129.59	1247726.37	18.70
MW42D	317183.21	1247736.54	18.53
MW42S	317184.51	1247737.86	18.48

TEST PIT LOCATIONS AMG CO-ORDINATES

Point	East	North	Elevation
TP01	317112.54	1247638.33	18.04
TP02	317109.67	1247657.65	19.07
TP03	317139.83	1247679.08	18.02
TP04	317155.80	1247705.63	18.50
TP05	317185.53	1247738.73	18.44
TP06	317189.09	1247749.95	18.53
TP07	317201.10	1247755.82	18.89
TP08	317202.32	1247766.15	19.15
TP09	317218.10	1247779.27	19.47
TP10	317184.32	1247770.00	20.10
TP11	317158.91	1247723.56	18.59
TP12	317123.57	1247736.37	20.13
TP13	317084.37	1247717.07	18.70
TP14	317067.72	1247713.76	18.70
TP15	317145.97	1247729.63	18.78
TP16	317172.67	1247743.89	18.60
TP18	317109.12	1247729.32	19.84
MG03	317104.94	1247704.93	18.75
MG04	317116.70	1247711.17	18.72
MG07	317103.96	1247696.52	18.74
MG10	317156.86	1247741.32	18.80
MG10A	317150.44	1247736.72	18.85

BOREHOLE LOCATIONS AMG COORDINATES

DATE OF SURVEY: 20/10/2006

Point	East	North	Elevation
BH12A	317150.333	1247715.240	18.63
BH14A	317162.534	1247754.287	18.89
BHA	317118.769	1247672.561	18.46
BHA1	317119.227	1247671.664	18.41
BHA2	317119.778	1247670.676	18.48
BHB	317125.223	1247689.823	18.49
BHC	317122.014	1247714.141	18.78
BHC1	317122.983	1247714.522	18.75
BHC2	317128.955	1247714.323	18.66
BHD	317107.953	1247721.775	18.86
BHE	317131.954	1247692.932	18.50
BHF	317135.889	1247701.057	18.56
BHG	317117.288	1247724.579	18.61
MG09A1	317134.074	1247734.848	18.44
MG10B	317157.472	1247740.001	18.82
TP15A	317146.377	1247729.433	18.80

TEST PIT LOCATIONS AMG CO-ORDINATES

DATE OF SURVEY: 20/10/2006

TPRP	317122.828	1247676.764	18.37

NOTE: RL's MAY RELATE TO TOP OF CONCRETE BASE NOT TO TOP OF CASING. PLEASE REFER TO ORIGINAL PLANS.

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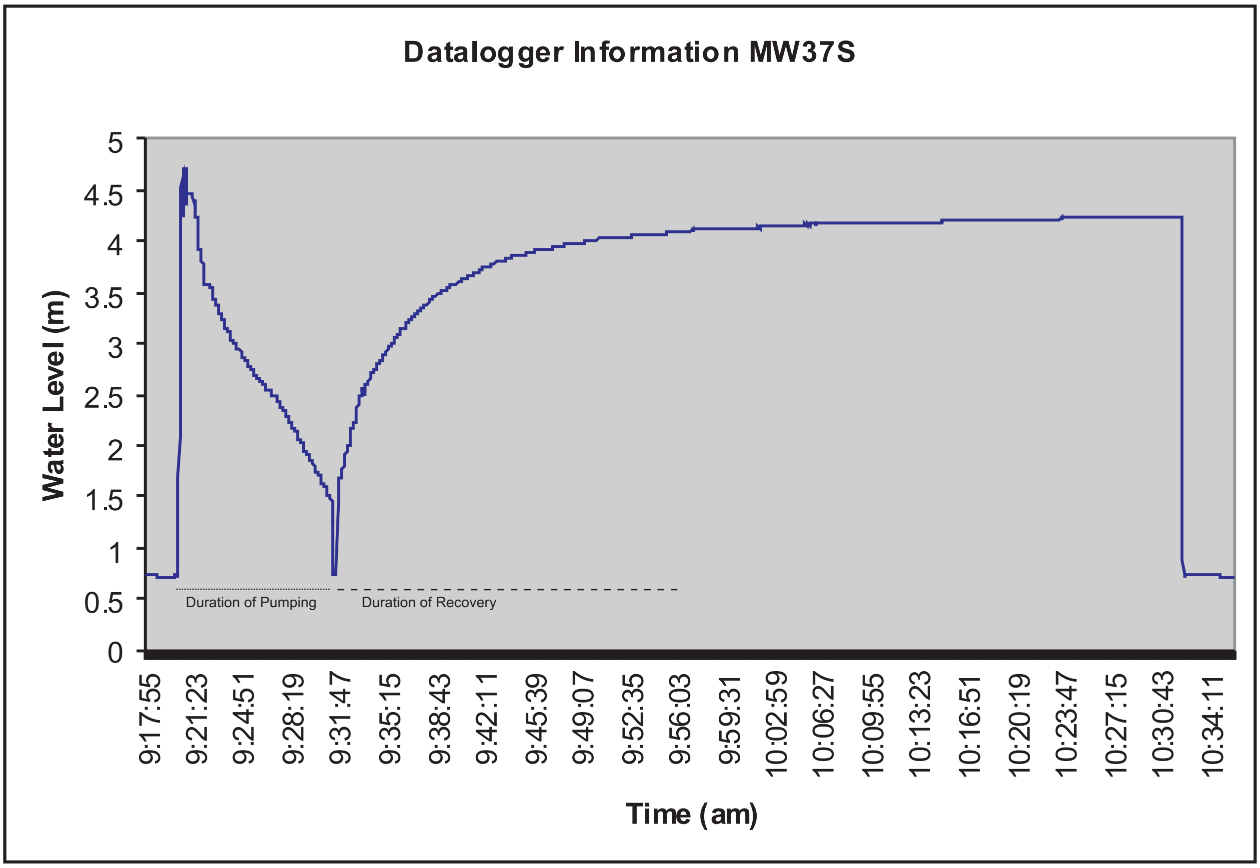
0 50m
Approximate scale

Figure A1 **Location of Additional Investigation Areas**

CH2M Hill (2007)
Note- All locations shown are approximate only



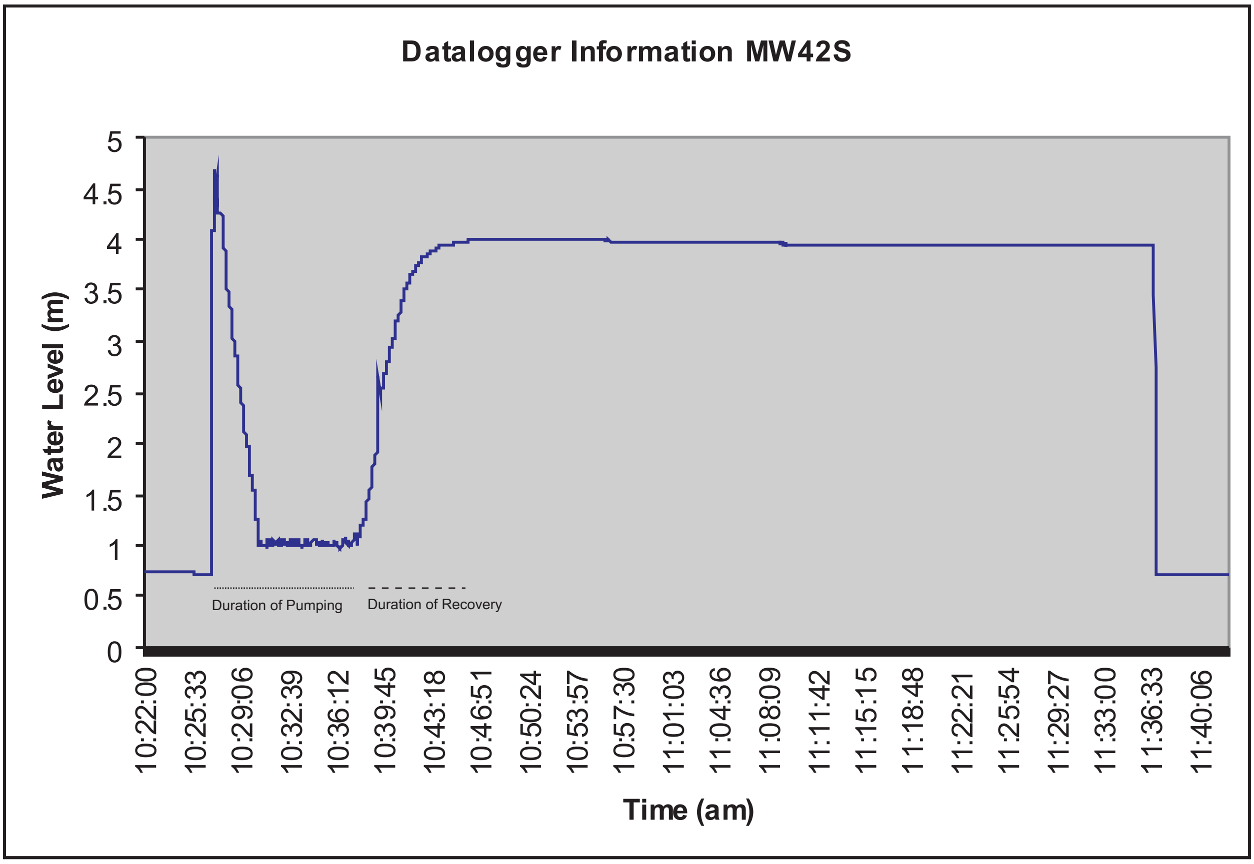


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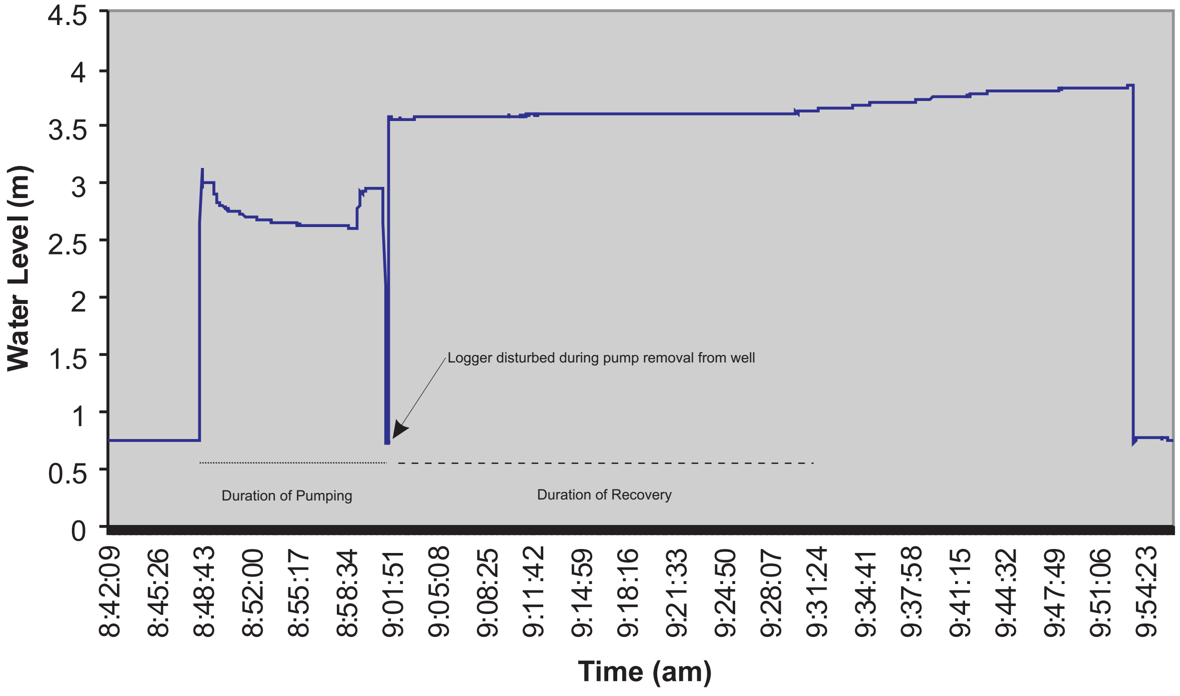
Figure **A3 Raw Pump Test Data MW37S and MW42S**

Former Macdonaldtown Gasworks
Burren Street, Erskineville
Job Reference: 40913 R08

Datalogger Information MW04S



Datalogger Information MW06S

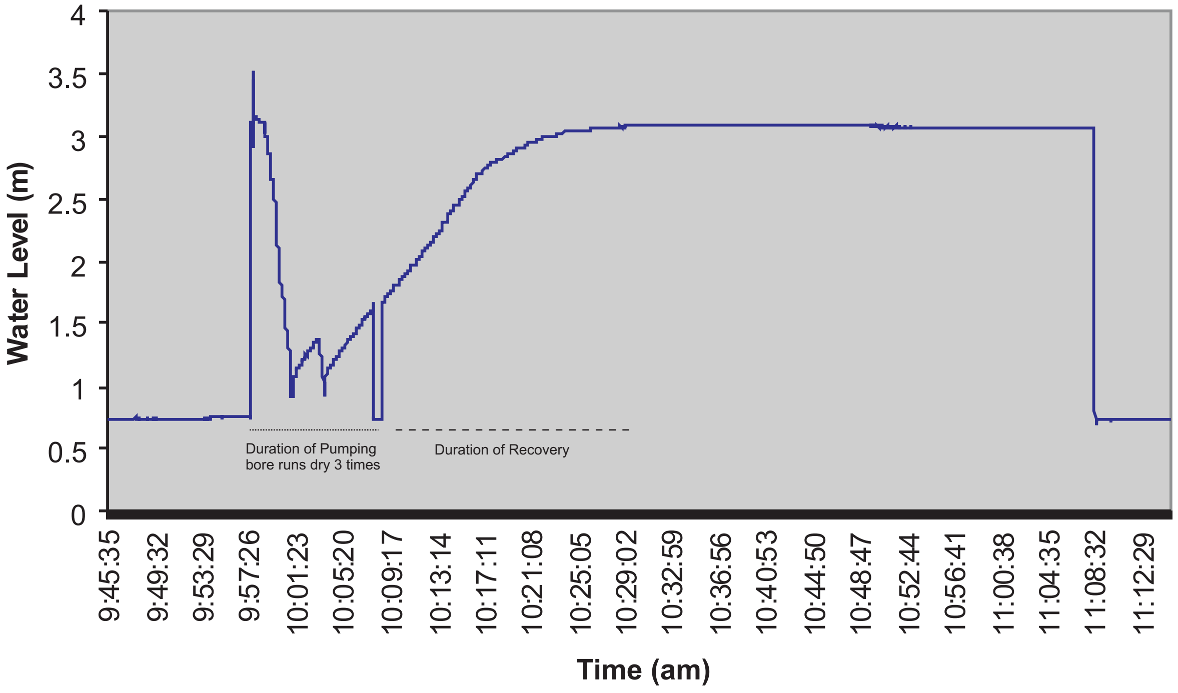


Figure **A2 Raw Pump Test Data MW04S and MW06S**

Former Macdonaldtown Gasworks
Burren Street, Erskineville
Job Reference: 40913 R08

Appendix B

'Site Specific Leachability Criteria, former Macdonaldtown Gasworks, Burren Street Erskineville' JBS Environmental Pty Ltd (2010a)

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JBS40913-15507

23 August 2010

John Dawson
Project Director
Incoll Management Pty Ltd
Level 1, 73 Miller Street
North Sydney NSW 2060
(Sent Via email: jdawson@incoll.com.au)

Development of Site Specific Soil Leachability Criteria – Former Macdonaldtown Gasworks, Burren Street, Erskineville, NSW

Dear John,

JBS Environmental Pty Ltd (JBS) was commissioned by Incoll Management Pty Ltd (Incoll), to undertake additional environmental assessment works to inform the revision of the remedial strategy prepared for the former Macdonaldtown Gasworks site, on behalf of the site owner, Rail Corporation NSW Environment Projects Unit (RailCorp). This letter has been prepared as part of those works and documents the derivation of site specific criteria for leachable concentrations of contaminants in soil. These are proposed to be used for the proposed remediation of the site.

The site is located between Erskineville and Macdonaldtown railway stations. The site is roughly triangular in shape, being part of the area commonly referred to as the Macdonaldtown Triangle. The site location is shown in **Figure 1**.

A Remedial Action Plan (RAP) has been prepared for the site and is documented in CH2M Hill (December 2007) '*Remedial Action Plan, Former Macdonaldtown Gasworks – Burren Street, Erskineville, NSW*'. Based on review of the RAP it is considered that while a range of technologies may be applicable to the site, the remedial program is likely to be a combination of the following methods:

- Dewatering of impacted areas to enable excavation of fill / soil as required;
- On-site treatment of water generated during dewatering for groundwater recharge, discharge to stormwater or discharge to sewer, as appropriate;
- Removal / excavation of free tar as required for disposal off site to an appropriately licenced landfill or treatment facility;
- Excavation of impacted soil and for treatment by stabilisation, thermal desorption or other appropriate method; and
- Reuse of stabilised material on the Macdonaldtown site, if suitable, otherwise disposal off site to an appropriately licenced landfill.

In order to implement such a remedial approach, in addition to health based assessment criteria for protection of future site users, it will also be necessary to derive site specific acceptance criteria for leachable concentrations in soil that are considered suitable for protection of the environment. Once derived it is considered these site specific criteria can then be applied (in combination with human health based soil criteria as total concentrations) at two levels;

- Initially on *in-situ* impacted materials - to assess whether excavation / remediation is required for protection of environmental values; and
- Secondly on treated materials – to assess whether they are suitable for reuse on the site.

This letter has been prepared to document the derivation of the site specific criteria for leachable concentrations in treated material for use during remediation of the site.

1. Site Background

Calculation of site specific leachability criteria requires the input of site specific data relating to the hydrogeological conditions and contamination present. This Section provides a summary of this information and is based on a review of the following documents prepared for the site:

- Rail Services Australia (November 1999) '*Eveleigh Gasworks – Site History'*;
- CH2M Hill (December 2001) '*Soil and Groundwater Investigations of the former Gasworks Area and Offsite*';
- Sinclair Knight Merz (April 2006) '*Macdonaldtown Triangle (Former Gasworks Site) – Human Health and Ecological Risk Assessment*';
- CH2M Hill (March 2007) '*Delineation & Characterisation Sampling and review of Remedial Options*'; and
- CH2M Hill (December 2007) '*Remedial Action Plan*'.

A summary of the subsurface profile encountered on the site is provided in **Table 1**.

2. Hydrogeology

The review of the hydrogeological conditions at the site included in the RAP (CH2M Hill, 2007) states that the groundwater exists as a shallow perched groundwater 'layer ' and a deep bedrock 'layer'. The shallow groundwater, encountered as shallow as 1m below ground level in some areas, was reported to be present within fill materials and silty clay overlying the mottled clay layer as describes in **Table 1**, while the deeper groundwater was reported to exist within the Ashfield Shale bedrock under semi-confined conditions.

A summary of estimates of the hydrogeological properties of the subsurface is provided in **Table 2,** and is based on data provided in SKM (2006).

All previous reports acknowledge that while shallow groundwater underlying the site appears to be restricted to the fill and clay layers, and deep groundwater to the shale bedrock, it is possible there may be some interconnectivity between the two water bearing zones given the apparent similar direction of flow gradient.

Table 1: Summary of Subsurface Profile and Contamination Impacts

Layer	Observed Depth (m below ground level)	Nature of Material	Nature of Impact		
			Free Tar[1]	**Tarry Soils[2]**	**Dark stained impacts[3]**
Fill	0 to 3.5	Ash and coke gravels to 0.5m depth across much of the site	✓ Limited to immediate vicinity of tar wells and gas works pipes	✓ Limited to areas of former gasworks footprints	-
		Reworked clay 0.5m to 1.5m depth across the majority of the site	✓ Limited to immediate vicinity of tar wells and gas works pipes	✓ Limited to areas of former gasworks footprints	-
		Sands and gravels 0.5m to 1.5m depth in north-east, south central and gas purifier areas	✓ Limited to immediate vicinity of tar wells and gas works pipes	✓ Limited to areas of former gasworks footprints	-
		Gravelly Sand and Clay with minor ash to depths of 3.5m in the south west area of the site	-	✓ Limited to areas of former gasworks footprints	-
		Gravelly sand and demolition waste in the northern retaining wall and inside annulus of northern gas holder	-	✓ Limited to areas of former gasworks footprints	-
Silty clay	1.5-2.5	Saturated silty clay layer present underlying fill across the majority of the site	✓ near tar wells and northern gasholder	✓ near tar wells and northern gasholder	-
Red/grey mottled clay	2.5 to 4.0-6.0	Highly plastic, stiff to very stiff, moist and consistent with red podzolic soil	✓ near tar wells and northern gasholder	✓	✓ under southern gasholder
Shale	4 m onwards	Underlies natural clays and grades from extremely weathered to moderately weathered at 10 m depth. Fractures assessed to be common beyond depths of 6m.	✓ near tar wells and northern gasholder	-	✓ under southern gasholder

Notes:

1. 'Free tar' as defined in RAP (CH2M Hill, 2007) is *'soil impacted by free tar, consisting of soil and fill material impacted to a high degree with black ooze, highly odourous, liquor type material*';
2. 'Tarry soils' as defined in RAP (CH2M Hill, 2007) is '*soil and fill materials with minor tar impacts and moderate odours*'
3. 'Dark Stained impacts' as defined in RAP (CH2M Hill, 2007) is '*dark brown to black staining in the deep soils and Weathered Shale within the soil pores and shale fracture zones underneath the Southern Gasholder. The material as moderately odourous*';

✓ = present in layer

\- = not present in layer

Table 2: Summary of Hydrogeolgical Data Available for the site

Parameter	Value	Details	Sources
Flow direction	South to south-easterly	noting significant variation in shallow groundwater flow due to subsurface obstructions	
Permeability	1.4 x 10^{-5} ms^{-1}	Shallow well	Slug test conducted by SKM in 2005
	1.0 x 10^{-5} to 3.0 x 10^{-5} ms^{-1}	Deep wells	
Hydraulic Gradient	3.1 x 10^{-2}	Between shallow wells MW17S and MW12S	Groundwater gauging by SKM in 2005
	1.3 x 10^{-2}	Between shallow wells MW20S and MW03S	
Flow velocities	6.2 to 13.7 m/yr	Shallow wells	Determined by SKM from gradient and permeability data
Averaging Time – Threshold[1]	12.2 to 36.5 m/yr	Deeper wells	

3. Groundwater Quality

The most recent round of groundwater sampling completed at the site was conducted by SKM in 2005 (SKM, 2006). The maximum concentrations of contaminants exceeding the assessment criteria in the 'on site' wells is summarised in **Table 3**. In general the maximum concentrations in samples collected from the shallow wells were less than concentrations in samples collected from the deeper wells.

Table 3: Summary of Groundwater Contamination

	Criteria	Shallow Groundwater			Deep Groundwater		
Analyte	**ANZECC 2000**	**Concentration Range**	**Well ID - highest concentration**	**Site Area**	**Concentration Range**	**Well ID - highest concentration**	**Site Area**
Cd	0.2	nd - 2.6	MW13s	Southwest	nd - 1.5	MW06d	Gasholders
Cr(total)	-	nd - 15	MW04s	South Central	nd - 7	MW04d	South Central
Cu	1.4	nd - 220	MW42s		0.001 - 208	MW42d	Northeast
Pb	3.4	nd - 174	MW42s	Northeast	nd - 140	MW03d	South Central
Ni	11	nd - 10	MW04s	South Central	nd - 92	MW36d	Offsite
Zn	8	0.033 - 1,570	MW13s	Southwest	0.015 - 869	MW42d	Northeast
Cyanide (total)	7	0.02 - 0.479	MW20s	Gasholders	nd - 14.9	MW03d	South Central
Benzene	950	nd - 704	MW07s	Gasholders	nd - 14,000	MW03d	South Central
Toluene	-	nd - 117	MW07s	Gasholders	nd - 792	MW03d	South Central
Ethylbenzene	-	nd - 213	MW07s	Gasholders	nd - 317	MW03d	South Central
Total Xylenes	550 (o & p)	nd - 417	MW07s	Gasholders	nd - 5,010	MW03d	South Central
Total PAHs	16 (naphthalene)	nd - 1,677 (naphthalene 1,460)	MW07s	Gasholders	nd - 4,208 (naphthalene 3,840)	MW07d	Gasholders

Note: "nd" is 'Non Detect', or less than the laboratory Limit of Reporting (<LOR).
All concentrations in µg/L

Water quality parameters measured in samples from the site in 2005 indicated that groundwater underlying the site was of low salinity, 'slightly variable' pH and highly oxygenated (SKM, 2006) which was considered to be indicative of recharge occurring primarily through rainfall infiltration.

With respect to heavy metals, elevated concentrations of cadmium, copper, nickel and lead and zinc were detected in both the deep and shallow wells located along the northern site boundary. The discussion provided in the SKM report indicated that elevated heavy metals concentrations were representative of background conditions. The only exception noted was a zinc concentration of 1570 µg/L in the sample from MW13S, which is located in the south-western portion of the site and was the highest zinc concentration detected in the available dataset.

The highest concentrations of Total Petroleum Hydrocarbons (TPH) C_6 –C_9, benzene, toluene, ethylbenzene and xylene (BTEX) and volatile organic carbons (VOCs) on site were detected in the deep wells located in the vicinity of the southern gasholder and central southern site boundary at wells MW03D, MW04D, MW07D and MW12D.

Elevated concentrations of TPH C_{10} –C_{36}, polycyclic aromatic hydrocarbons (PAHs), primarily being naphthalene, were generally detected in the deep wells located in the vicinity of the southern gasholder and central southern site boundary at wells MW03D, MW04D and MW07D. It is noted that speciated 'indicator' compounds have been identified in each sample where significant levels of TPH have been reported.

Phase separated hydrocarbons were not observed in any wells forming the monitoring well network.

Based on the available data it is considered that the primary levels of contaminants of concern in groundwater at the site are BTEX and naphthalene. Elevated TPH concentrations are consequent of elevated concentrations of BTEX and PAH compounds.

4. Contaminant Hydrogeology

Based on the results of laboratory analysis of groundwater samples collected from on site and off site wells, the SKM (2006) report stated that:

'*The shallow plume appears to begin near the northern boundary of the Former Cleaning Shed and Gasworks areas and extend in a south-west direction of some 75m. The data indicate that the down-gradient edge of the plume is located at the East Hills Line at the southern edge of the site boundary. The lateral extent of plume appears to be confined in the west to the sewer main located adjacent to the rear boundary of the residential properties, while to* [sic] *the plume is estimated to extent 50m to the east of the former tank area.*

The extent of the middle to heavy-end hydrocarbon plume in the deeper aquifer appears to be larger than the shallow aquifer. While the northern, eastern and western boundaries of the plume are similar to the shallow plume, the down-gradient extent of the plume appears to cover a distance of some 160m from the former tar tank area, with its edge near the southern boundary of railway land along Railway Parade. The data indicate that the deep aquifer plume is located entirely on railway owned [sic] *land.'*

In relation to the estimated flow velocities for the site, as summarised in **Table 2**, the RAP CH2M Hill, 2007) notes that the flow velocity values provided in SKM 2006, do not correlate with the measured lateral extent of the plume, based on gasworks operations commencing more than 100 years prior. It is also noted that the SKM report states that, based on the measured extent of the shallow and deep groundwater plumes migrating from the site, the permeability rates estimated from the slug tests appear to be an order of magnitude greater than actual rates.

5. Site Specific Environmental Investigations for Leachable Soils Concentrations

In preparing the revised remediation strategy for the site, it is proposed that both the total and leachable concentrations of the contaminants of concern are assessed.

Acceptable total concentrations of contaminants in site soils have been set on human health based criteria in SKM (2006).

The principal potential main environmental exposure pathway for the site is groundwater. Assessment criteria for leachable concentrations of contaminants in soil should be consistent with groundwater ecological criteria. These criteria are considered not appropriate for direct comparison to laboratory measurement of soil leachability. The laboratory testing method for leachable concentrations of soil constituents involves an extended period of tumbling the sample in the media to be analysed. This is highly unlikely to ever be replicated in the environment. Additional correction factors need to be considered to allow comparison of soil leachabilities to groundwater based ecological protection criteria.

Leachability criteria determined for the site should be based on the available criteria used for protection of groundwater resources and incorporate a dilution attenuation factor (DAF). A range of DAF calculation methods currently exist and account for either:

- The dilution of contaminated leachate that occurs as it reaches a water bearing zone which is assumed to be unimpacted, as per methods published by the United States Environmental Protection Agency (USEPA, 1996) and the Center for Research in Water Resources (CRWR, 2003); or
- The dilution of contaminated groundwater that occurs within the overall catchment prior to discharge at the receiving water body. Dilution occurs by mixing with groundwater present across the remainder of the catchment. The basis and calculation of this factor is detailed in the method published by the Commonwealth Scientific and Industrial Research Organisation (CSISO, 2009).

6. Background

The method used to determine the site specific leaching criteria is as follows:

1. Review of the site and surrounding area to identify the nearest potentially sensitive ecological receptor as associated environmental values, as described in **Section 6.1**;
2. Determine Groundwater Investigation Levels (GILs) for the site by consideration of the environmental values of the surrounding catchment / nearest potentially sensitive receptor, as described in **Section 6.1**;
3. Estimate an approximate DAF value based on the likely discharge of groundwater sourced from beneath the site to the nearest potentially impacted environmental receptor, as described in **Section 6.3**;
4. Calculate the site specific criteria for leachable concentrations in treated material by multiplying the GIL by the DAF for each of the groundwater contaminants of concern, as described in **Section 6.4**.

6.1. Nearest Potential Sensitive Ecological Receptor

The NSW DEC (2007) '*Guidelines for the Assessment and Management of Groundwater Contamination*' requires groundwater investigation levels to be developed to protect environmental values of the surrounding catchment area. This includes consideration of current and potential future uses of groundwater and related ecosystems.

The site lies within the Alexandra Canal sub-catchment of the Cooks River catchment boundary as established by DECCW. The interim water quality objectives established by DECCW for tributaries within the Cooks River catchment[1] include:

- Aquatic ecosystem;
- Visual amenity;
- Secondary contact recreation;
- Primary contact recreation (for achievement in 10 years or more); and
- Aquatic foods to be cooked before eating (for achievement in 5-10 years).

Groundwater discharges from the site need to be protective of these water quality objectives. These beneficial uses will occur at groundwater discharge point nearest to the site, which is most likely the Munni Street Creek which discharges into Alexandra Canal. Shallow groundwater migrating off site may flow directly into the Munni Street Creek or enter piped stormwater drains that flow into the Creek, located approximately 50 m from the site, along Railway Parade to the south.

Of the water quality objectives listed for the overall Cooks River catchment, only 'protection of aquatic ecosystems' are considered applicable to the nearest surface water discharge point (i.e. Munni Street Creek then Alexandra Canal), noting that:

- Visual amenity has been severely degraded below the 'pristine' condition of this waterway;
- Secondary contact recreation is unlikely to occur given the degraded visual amenity; and
- Primary contact activities and consumption of aquatic foods are also unlikely to occur.

Aquatic ecosystems at the discharge point have been adopted as the environmental values requiring protection from groundwater discharging from the site. The GILs applicable to this value are summarised in **Table 3** and are based on ANZECC/ARMCANZ (2000) water quality trigger values for protection of 95 % of species in marine water.

6.2. Determination of DAF Values

When leachate from soil reaches a water bearing zone, it is mixed with the existing water present in that saturated layer and is diluted as it becomes groundwater. Once part of the groundwater system, it is again diluted at the discharge point, where it becomes mixed with the groundwater discharge from the remainder of the catchment.

In the derivation of soil clean-up criteria for a site that allows for protection of ecological values a DAF is used to account for these processes.

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[1] Source: http://www.dec.nsw.gov.au/ieo/CooksRiver/caag.htm

Several methods exist for calculation of the DAF value. A review of the various methods was undertaken as part of this assessment. DAF calculation methods described in the following documents are the most widely used and/or most appropriate methods for use at the site:

- USEPA Soil Screening Level (SSL) Method (USEPA 1996);
- Center for Research in Water Resources, University of Austin Texas (2003); and
- Method described in CSIRO (2009).

DAF values calculated for the site using each of the listed methods are discussed in the following sections.

USEPA Soil Screening Level (SSL) Method (USEPA 1996)

USEPA *Soil Screening Level* (USEPA, 1996) provides a default DAF value of 20 for sites occupying an area greater than 0.5 acres, however states that site specific DAF can be used in various options for calculating impact to groundwater soil cleanup criteria, including calculation of the Leachate Criterion (LC). A site specific DAF is calculated using Equation 1 below (taken from the USEPA 1996 guidance document Equation 37). Equation 1 requires a value for the mixing zone depth in the aquifer, which is calculated using Equation 2 (taken from the USEPA 1996 guidance document Equation 45).

$$DAF = 1 + (Kid/IL) \qquad \text{(Equation 1)}$$

Where i = gradient (m/m)

d = mixing zone depth (m), calculated below (Equation 2)

I = infiltration rate (m/yr)

L = length of area of concern parallel to ground water flow (m)

K = aquifer hydraulic conductivity (m/yr)

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

Where da = aquifer thickness (m) – (USEPA, 1996) notes that if the calculated aquifer mixing zone depth is greater than the aquifer thickness, then the mixing zone depth should be set to equal to the aquifer thickness

It is noted that this method provides a DAF value that applies to leachate as it enters water bearing zones on the site, rather than at the discharge point, given the absence of any parameters that incorporate the overall catchment size or distance to the ultimate discharge point.

Major assumptions inherent to this method include:

- Dilution of the contaminant due to transport through the unsaturated soil zone is not included, the chemical in soil is assumed to be immediately adjacent to the water table; and
- Chemical degradation is also not included in this model at the soil contaminant source zone or in the resulting impacted groundwater, the calculations assume that the groundwater quality requirements must be achieved in the short term.

The above equations have been used to determine a DAF value for the site, based on site specific values for gradient, length of area parallel to groundwater flow direction and hydraulic conductivity. The calculated DAF value for the site using Equation 1 is presented in **Table 4**, along with the values used for determination.

Table 4: Summary of DAF Calculation – USEPA 1996

Parameter	**Value**	**Reference**
i, hydraulic gradient (m/m)	3.1×10^2	SKM 2006, highest gradient value reported for shallow wells
da, aquifer thickness (m)	5	Estimated thickness of shallow water bearing zone based on SKM 2006 observations that groundwater in fill occurs as shallow as 1 m bgl, and that clay extends to approximately 6 m depth
d, mixing zone depth (m)	5	Using equation 2 a value of 8.2 m was calculated for d. The aquifer thickness was therefore set as 5, adopting the recommendation in the method

Parameter	Value	Reference
I, infiltration rate (m/yr)	1.214	Bureau of Meteorology – Historical Annual Average Rainfall for Sydney (bom website on 28/07/10)- worst case scenario that 100% of rainfall infiltrates subsurface
L, length of area of concern parallel to groundwater flow (m)	68	Maximum length of site running south-east
K, aquifer conductivity (m/yr)	441.5	Based on maximum value of 1.4 x 10^{-5} ms^{-1}reported in SKM 2006 for shallow wells
Calculated DAF	**1.8**	**Using Equation 1 adopting the values listed above**

Given the low DAF calculated and the range of input data available for the site, DAFs were calculated for a range of scenarios, the results of which are summarised **Table 5** below. These values also provided as assessment of the sensitivity of the method.

Table 5: Alternate DAF Calculations – adopting USEPA 1996

Calculated DAF	% change	Scenarios
3.76	109	Assuming only 30% of all rainfall on site infiltrates soil profile. Using a value of 0.3642 for I with all other values as per **Table 4**.
1.08	40	Assumes conductivity values are 1 order of magnitude below slug test calculated value, based on SKM 2006 report. Using a value of 44.15 m/yr for K with all other values as per **Table 4**.
1.01	44	Using a hydraulic gradient value of 4.41 x 10^5 in the direction of groundwater flow. Based on the water levels reported in SKM 2006, at two shallow wells (17.57 m AHD at MW07S and 17.54 m AHD at MW03s) placed 68m apart

Variation of the input values used in Equation 1 suggests that of all the parameters estimated for the site, the DAF calculated is most sensitive to the value adopted for infiltration.

The two main limitations of the USEPA (1996) method for the current application include:

- The method is intended to estimate the magnitude of dilution that occurs as soil leachate enters a water bearing zone on the site, rather than at the discharge point. Application of such a DAF to produce site specific criteria, is intended to result in GIL compliant groundwater migrating off site. Any parameters that incorporate the second stage of dilution that occurs between the site and the final discharge point, such as the overall catchment size or distance to the ultimate discharge point, are notably absent. For the current project this absence is considered to result in overly conservative DAF values. The site is located in an area where groundwater is unlikely to be utilised for primary contact, secondary contact or irrigation purposes. Under these circumstances, the environmental values of the catchment, or health impacts to future site users, will not be impacted if compliance with the GILs occurs at the site boundary or further along at the ultimate discharge point; and
- The limited sensitivity analysis conducted on the method focused on the parameters with the greatest potential for variation. The results indicated that the calculated DAF showed the greatest change as the value for the infiltration rate was altered (the DAF increased by 108% when the infiltration rate was reduced to 30% of the original input value, as opposed to only 40-44% change in the calculated DAF when values for hydraulic conductivity and hydraulic gradient were varied). As infiltration rate is governed by soil properties which are likely to be highly variable in shallow soils on the site, the approach of using literature review sourced values for input is also considered to be insufficiently robust for the current purpose.

Center for Research in Water Resources, University of Austin Texas (CRWR, 2003)

A report prepared by the Center for Research in Water Resources, University of Austin Texas (CRWR, 2003) describes the DAF calculation method used in the groundwater assessment component of the Texas Source Water Assessment Program. The Texas Source Water Assessment Program, was undertaken to determine the susceptibility of individual water sources to contamination.

The DAF applied to each water source was determined using the following series of equations:

$$DAF = DF \times AF \qquad \text{(Equation 3)}$$

Where DF = Dilution Factor, as calculated by Equation 4 below
AF = Attenuation Factor, as calculated by Equation 6 below

$$DF = C_w/C_{soil} = \{[\rho_{b/} (\theta_{ws}+K_d\rho_b+H'\theta_{as})] / LDF\} \text{ x } (L1/L2) \qquad (Equation\ 4)$$

Where C_w = Contaminant concentration in groundwater (g/cm^3)
C_{soil} = Contaminant concentration in soil (g/g-soil)
ρ_b = Soil bulk density (kg/L)
θ_{ws} = *the volumetric water content in the vadose zone (cm^3-water/cm^3-soil)*
k_d = *the soil water partitioning coefficient (cm^3-water/g-soil)*
H' = *Henrys Law constant*
θ_{as} = *the volumetric air content in the vadose zone (cm^3-air/cm^3-soil)*
LDF = the Lateral Dilution Factor, as calculated by Equation 5 below
L1 = thickness of affected soil
L2 = Depth from the top of the affected soil to the groundwater table

$$LDF = 1 + \{(U_{gw}\ \delta_{gw})/(I_f W_s)\} \qquad (Equation\ 5)$$

Where U_{gw} = groundwater Darcy velocity (cm/year)
δ_{gw} = groundwater mixing zone thickness (m)
I_f = net infiltration rate (cm/year)
W_s = *the lateral width of the affected vadose zone in the direction of groundwater flow(m)*

$$AF = exp[(L_{gw}/2a_x)*(1 - \surd(1+4*(D_g a_x/v_{coc}))] \text{ x } erf[W/4\surd a_y L_{gw})] \text{ x } erf[D/4\surd a_z L_{gw})] \qquad (Equation\ 6)$$

Where L_{gw} = down gradient distance from the contamination source to the water supply well or discharge point (m)
D_g = first order decay constant (day^{-1})
v_{coc} = the contaminant retarded velocity (m/day)
W = *source zone width (m)*
D = *source zone depth (m)*
$a_{x,y,z}$ = *the longitudinal(a_x), transverse (a_y) and vertical (a_z) groundwater dispersivities*

Of all the DAF calculation methods considered, the CRWR method, requires the most input data, both in terms of volume and detail. Given the limited information on site hydrogeological conditions, and in particular on the fill layers, DAF calculations undertaken in this assessment have set the value of AF to 1. An AF value of 1, input into Equation 3, assumes that no attenuation processes are occurring within the water bearing zones, and any reduction in contaminant concentration that occurs is due to dilution only. This was considered to be suitably conservative for the current purpose.

The remaining values used as input into Equations 3 to 5 are presented in **Table 6**.

Table 6: CRWR (2003) Method DAF Calculation Input Values

Parameter	Value	Reference
i, hydraulic gradient (m/m)	3.1×10^2	SKM 2006, highest gradient value reported for shallow wells
ρ_b, soil bulk density	1.67	CRWR 2003, density value quoted for clayey soils
θ_{ws}	0.16	CRWR 2003, value quoted for clayey soils
θ_{as}	0.21	CRWR 2003, value quoted for clayey soils
k_d, the soil water partitioning coefficient (cm^3-water/g-soil)	Contaminant dependent	Used formula $k_d = f_{oc} \times K_{oc}$ Where f_{oc} *value set to 0.002* g-carbon/ g-soil (CRWR, 2003), and K_{oc} values taken from (RAIS, 2010[2]) 1540 for naphthalene, 146 for benzene, 234 for toluene, 446 for ethylbenzene and 338 for xylene (all K_{oc} values in cm^3-water/g soil)
H', Henrys Law constant	Contaminant dependent	Values taken from (RAIS, 2010[3]) 0.018 for naphthalene, 0.322 for benzene, 0.271 for toluene, 0.322 for ethylbenzene and 0.212 for xylene (Henry's constant values unitless)
L_1, thickness of affected soil (m)	6	Estimated thickness of shallow fill and clay soils based on (CH2M Hill, 2007)
L_2, Depth from top of affected soil to groundwater table (m)	1	Based on SKM 2006 observations that groundwater in fill occurs as shallow as 1 m bgl
I_f, infiltration rate (m/yr)	1.214	Bureau of Meteorology – Historical Annual Average Rainfall for Sydney (bom website on 28/07/10)- worst case scenario that 100% of rainfall infiltrates subsurface
δgw, groundwater mixing zone thickness (m)	5	Estimated thickness of shallow water bearing zone from SKM 2006 observations that groundwater in fill occurs as shallow as 1 m bgl, and clay extends to approximately 6 m depth
W_s, lateral width of affected vadose zone in direction of groundwater flow	68	Maximum length of site running south-east

Table 7 presents the spreadsheet calculations using the above values for the groundwater COPC identified in Section 3. **Table 8** provides the DAF calculated for naphthalene using alternate input parameters.

The two main limitations of the CRWR (2003) method for the current application include:

- The model formulas require the input of values for detailed hydrogeological properties at the site, e.g. volumetric water content, volumetric air contents, 'retarded contaminant velocity', which have not been determined for the site. While values can be, and have been, assumed for these properties based on literature reviews, this approach is considered to be insufficiently robust for the variable shallow water bearing zone under assessment; and
- The limited sensitivity analysis, focused on the parameters with the greatest potential for variation, indicated that the calculated DAF value showed the greatest change as the value for the fraction organic carbon content was increased. The value of this parameter is governed by soil properties which are likely to be highly variable in shallow soils on the site and potentially in soils located off-site. Insufficient data is available of catchment organic carbon levels to allow robust application for the current purpose.

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[2] The Risk Assessment Information System (RAIS) website, Chemical Specific Parameters, http://rais.ornl.gov/cgi-bin/tools/TOX_search?select=chem_spef as on 29 July 2010

[3] The Risk Assessment Information System (RAIS) website, Chemical Specific Parameters, http://rais.ornl.gov/cgi-bin/tools/TOX_search?select=chem_spef as on 29 July 2010

Table 7: CRWR Method DAF Calculations

Contaminant	**AF** **-**	**Ugw** **Cm/yr**	**δgw** **m**	**If** **Cm/yr**	**Ws** **m**	**LDF** **-**	**ρb** **Kg/L**	**Θws** **-**	**Foc** **g-carbon / g-soil**	**Koc** **Cm^3-water /g soil**	**Kd** **Cm^3-water /g soil**	**H’** **-**	**θas** **-**	**L1** **m**	**L2** **m**	**DF** **-**
naphthalene	1	620	5	121.4	68	1.376	1.67	0.16	0.002	1540	3.08	0.018	0.21	6	1	0.038
Benzene	1	620	5	121.4	68	1.376	1.67	0.16	0.002	146	0.292	0.322	0.21	6	1	0.283
Toluene	1	620	5	121.4	68	1.376	1.67	0.16	0.002	234	0.468	0.271	0.21	6	1	0.203
ethylbenzene	1	620	5	121.4	68	1.376	1.67	0.16	0.002	446	0.892	0.322	0.21	6	1	0.118
Xylenes	1	620	5	121.4	68	1.376	1.67	0.16	0.002	383	0.766	0.212	0.21	6	1	0.136

Table 8: CRWR method DAF Calculations for Naphthalene with Altered Input Values

Contaminant	**AF** **-**	**Ugw** **Cm/yr**	**δgw** **m**	**If** **Cm/yr**	**Ws** **m**	**LDF** **-**	**ρb** **Kg/L**	**Θws** **-**	**Foc** **g-carbon / g-soil**	**Koc** **Cm^3-water /g soil**	**Kd** **Cm^3-water /g soil**	**H’** **-**	**θas** **-**	**L1** **m**	**L2** **m**	**DF** **-**	**% change**
naphthalene	1	620	5	**36.42**[1]	68	2.252	1.67	0.16	0.002	1540	3.08	0.018	0.21	6	1	0.0233	38.9
naphthalene	1	620	5	121.4	68	1.376	**1.8**[2]	0.16	0.002	1540	3.08	0.018	0.21	6	1	0.0382	0.2
naphthalene	1	620	5	121.4	68	1.376	1.67	0.16	**0.02**[3]	1540	**30.8**	0.018	0.21	6	1	0.0039	89.7
naphthalene	1	**1370**[4]	5	121.4	68	1.830	1.67	0.16	0.002	1540	3.08	0.018	0.21	6	1	0.0287	24.8

Notes:

1. Assuming only 30% of all rainfall on site infiltrates soil profile.
2. Assuming greater soil bulk density of 1.8 kg/L.
3. Assumes conductivity values are 1 order of magnitude below slug test calculated value, based on SKM 2006 report.
4. Using a hydraulic gradient value of 4.41 x 10^5 in the direction of groundwater flow. Based on the water levels reported in SKM 2006, at two shallow wells (17.57 m AHD at MW07S and 17.54 m AHD at MW03s) placed 68m apart

Commonwealth Scientific and Industrial Research Organisation (CSIRO, 2009).

A report prepared by CSIRO (CSIRO, 2009)[4] describes the National Environment Protection Council (NEPC) and Environment Protection and Heritage Council (EPHC) accepted and endorsed Australian method for deriving ecological investigation levels (EILs). The endorsed Australian method for deriving EILs is reported to be included as part of the revised National Environment Protection (Assessment of Site Contamination) Measure for public comment (CSIRO, 2009).

Appendix C of the CSIRO report (CSIRO, 2009) includes an endorsed method for deriving EILs that protect aquatic ecosystems. The method provides a means of calculating a dilution attenuation factor (DAF) for use in EIL calculations, which takes into account that groundwater catchments will most likely contain both contaminated and uncontaminated soils and pore water concentrations will not always equal groundwater concentrations of specific contaminants. The fraction of contaminated land to the total area of the groundwater/aquifer catchment is used to calculate the DAF as follows:

$$DAF = 100 \div \text{percentage of contaminated soil in catchment} \qquad \text{(Equation 7)}$$

It is noted that in calculating a DAF the size of the whole catchment should be taken into consideration.

In calculating a DAF for the site using Equation 7, JBS has run two total catchment size scenarios to allow for the different discharge conditions that apply to shallow and deep groundwater from the site:

- Deep groundwater migrating south-east and discharging directly into Munni Street Creek and then Alexandra Canal; and
- Shallow perched water migrating south east off site and discharging into the piped stormwater channels along Railway Parade.

The DAF calculated for each catchment size scenario are provided in **Table 9** below. Adopting a conservative approach it was assumed that the areas of 'contaminated soil' comprised the entire site area.

Table 9: CSIRO (2009) Method - Summary of DAF Calculations

Parameter	Alexandra Canal – deep groundwater	Reference	Railway Parade stormwater channel – shallow groundwater	Reference
Total Area of Catchment (m^2)	16.6×10^7	PPK 1999[1]	117 600	PPK 1999[1]
Site Area (m^2)	7732	CH2M Hill 2007[2]	7732	CH2M Hill 2007[2]
Ratio of 'Contaminated Soil' Area to Total Catchment Area	4.66×10^{-4}	-	0.065748	-
Percentage of Contaminated Soil in Catchment	0.05	-	7	-
DAF	**2000**	**-**	**16.6**	**-**

Notes: 1 Catchment area estimated from PPK 1999 "*Cooks River Stormwater Management Plan*' Figure 2.4: Existing Stormwater Infrastructure, and Department of Lands Six Viewer website. Both figures included are as **Figure 2** and **Figure 3** respectively

2 CH2M Hill (December 2007) '*Remedial Action Plan*'.

While the CSIRO (2009) method appears to be the most simplistic of all the three methods considered, the basis of the method i.e. assessing the DAF at the point of discharge, rather than the site boundary, is considered to be the most appropriate for the project. The DAF value of 16.6 was calculated in a suitably conservative manner, i.e. assuming the nearest discharge point for shallow groundwater is the piped stormwater channel 50m south of the site on Railway Parade, and therefore reducing the catchment area size to less than 12 Ha. It is also noted that this calculated DAF is less than the USEPA (1996) default DAF value of 20 for site greater than 0.5 acres in area.

---

[4] *The Australian Methodology to Derive Ecological Investigation levels in Contaminated Soils*. CSIRO Land and Water Science Report 43/09, prepared for the National Environment Protection Council, (CSIRO, 2009).

7. Calculation of Site Specific Criteria for the Site

The three different approaches to DAF calculation have produced a range of results varying by four orders of magnitude. The CRWR method yields the most conservative results, which if adopted, would result in leachable concentrations criteria being only a small fraction of the corresponding GIL. The CSIRO method produces seemingly, the least conservative results. Consideration of the model assumptions and the anticipated context of application, has confirmed that the CSIRO (2009) method to be most suitable to be adopted for the site.

A value of 16.6 as determined by the CSIRO (2009) method, is the most appropriate DAF value for the site.

The DAF value of 16.6 has been used with the adopted GILs to derive of leachability criteria, as summarised in **Table 10**. The site specific leachability criteria assume the background concentrations of the contaminants of concern are zero, and that the leachable concentration in the treated material accounts for the total contaminant load at the discharge point. With the exception of heavy metals, this assumption is considered valid given the low concentrations of organic contaminants in wells located on the upper hydraulic gradient end of the site. While some heavy metal impact was noted in the groundwater migrating onto the site, this impact was considered to be representative of local conditions, and therefore it is considered adoption of the site specific values in **Table 10** for these contaminants would not adversely impact the environmental values at the point of discharge.

Table 10: Leachate Assessment Criteria (all units in µg/L)

	Limit of Reporting	Aquatic Ecosystems[1]	Site Specific Criteria for assessment for leachable concentrations in soil[3]
Arsenic (III/V)	0.1	2.3[2] / 4.5[2, 5]	38.2 / 74.7
Cadmium	0.1	0.7[1]	11.6
Chromium (III)	1	10	166
Chromium (VI)	0.1	4.4	73
Copper	0.1	1.3	21.6
Lead	0.1	4.4	73
Manganese	1	80[2]	1328
Mercury	0.05	0.1[1]	1.76
Nickel	1	70	1162
Zinc	1	15	249
VOLATILE ORGANIC COMPOUNDS			
Benzene		500	8300
Toluene		180[2]	2988
Ethylbenzene		5[2]	83
Xylene (M+O+P)		625[2]	10 375
Styrene		1600	26560
Phenols		400	6640
POLYCYCLIC AROMATIC HYDROCARBONS			
Benzo(a)Pyrene	0.1	0.1[2]	1.7
Naphthalene	0.1	50	830
Phenanthrene	0.1	0.6[2]	10.3
Anthracene	0.1	0.01[2]	0.2
Fluoranthene	0.1	0.1[2]	1.7

[1] 95% protection levels (marine ecosystems) have been used. When these levels fail to protect key test species, the 99% protection levels were used - ANZECC/ARMCANZ (2000). The 99% protection levels have been adopted in line with recommendations in Section 8.3.7 of ANZECC/ARMCANZ 2000.

[2] Insufficient data to derive a reliable trigger value. In these instances, reference has been made to low reliability trigger levels contained in ANZECC/ARMCANZ (2000).

It is noted that TPH has not been included in **Table 10**, as the more prevalent indicator contaminants have been included.

It is concluded that the site specific criteria provided are over protective of the existing aquatic ecosystems of Alexandra Canal and can be used for future decision making for the site.

Prepared by,

Sumi Dorairaj
Senior Environmental Consultant
JBS Environmental Pty Ltd

Reviewed by,

Matthew Parkinson
Principal - Contaminated Land
JBS Environmental Pty Ltd

Attachments: (1) Limitations
(2) Figures

Attachment 1 - Limitations

This report has been prepared for use by Incoll Management Pty Ltd who commissioned the works in accordance with the project brief only and has been based in part on information obtained from other parties. The advice herein relates only to this project and all results conclusions and recommendations made should be reviewed by a competent person with experience in environmental investigations, before being used for any other purpose.

JBS Environmental Pty Ltd accepts no liability for use or interpretation by any person or body other than Incoll Management Pty Ltd or the appointed Site Auditor. This report should not be reproduced without prior approval by Incoll Management Pty Ltd, or amended in any way without prior approval by JBS Environmental Pty Ltd, and should not be relied upon by other parties, who should make their own enquires.

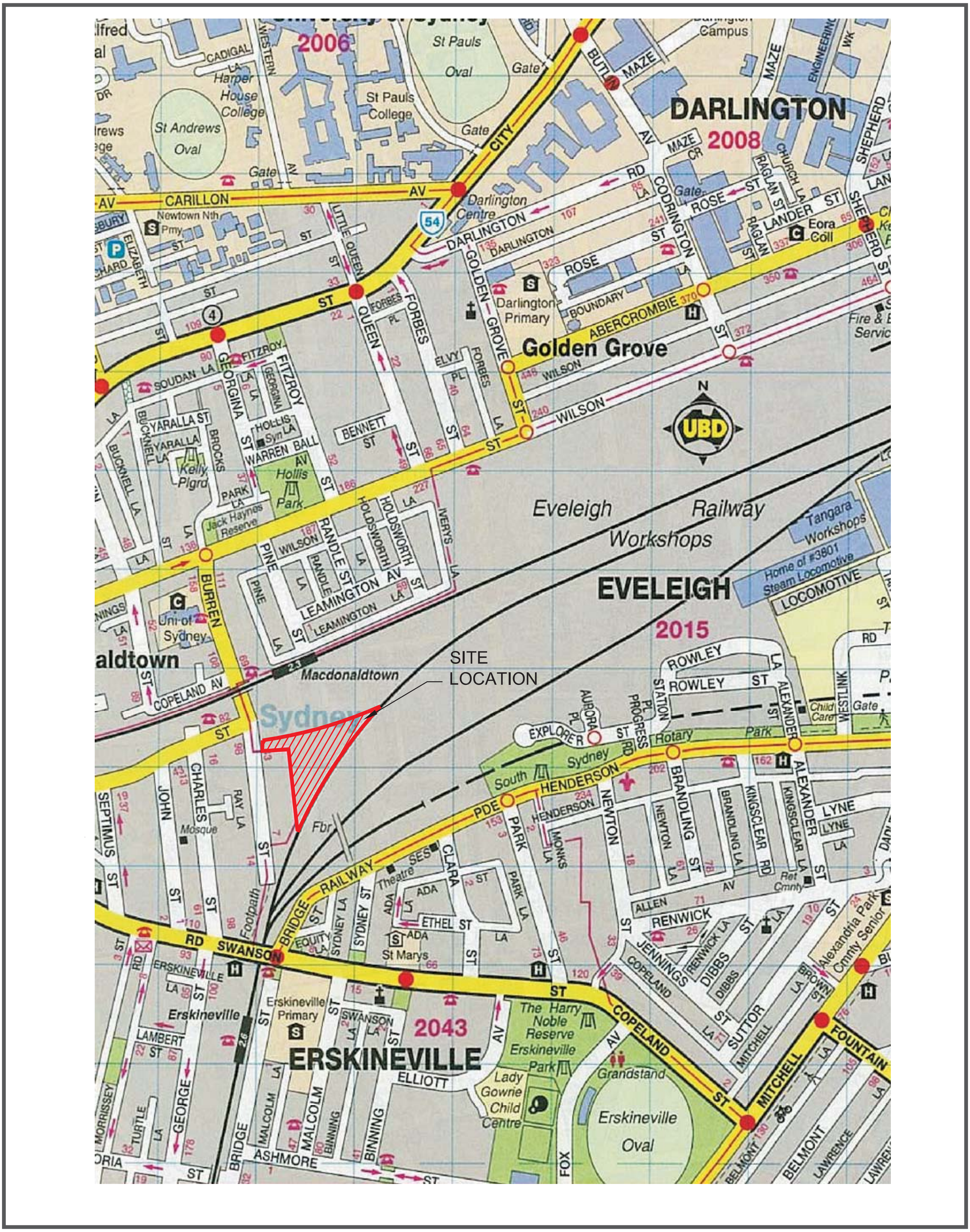
Sampling and chemical analysis of environmental media is based on appropriate guidance documents made and approved by the relevant regulatory authorities. Conclusions arising from the review and assessment of environmental data are based on the sampling and analysis considered appropriate based on the regulatory requirements and site history, not on sampling and analysis of all media at all locations for all potential contaminants.

Limited sampling and laboratory analyses were undertaken as part of the investigations, as described herein. Ground conditions between sampling locations may vary, and this should be considered when extrapolating between sampling points. Chemical analytes are based on the information detailed in the site history. Further chemicals or categories of chemicals may exist at the sites, which were not identified in the site history and which may not be expected at the site.

Changes to the subsurface conditions may occur subsequent to the investigations described herein, through natural processes or through the intentional or accidental addition of contaminants. The conclusions and recommendations reached in this report are based on the information obtained at the time of the investigations.

This report does not provide a complete assessment of the environmental status of the site, and it is limited to the scope defined herein. Should information become available regarding conditions at the site including previously unknown sources of contamination, JBS Environmental Pty Ltd reserves the right to review the report in the context of the additional information.

Attachment 2 Figures



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0 500m

Approximate scale

Figure 1 **Site Location (Macdonaldtown)**

CH2M Hill (2007)
Note- All locations shown are approximate only

Figure 2

Cooks River Catchment
Existing Stormwater
Infrastructure

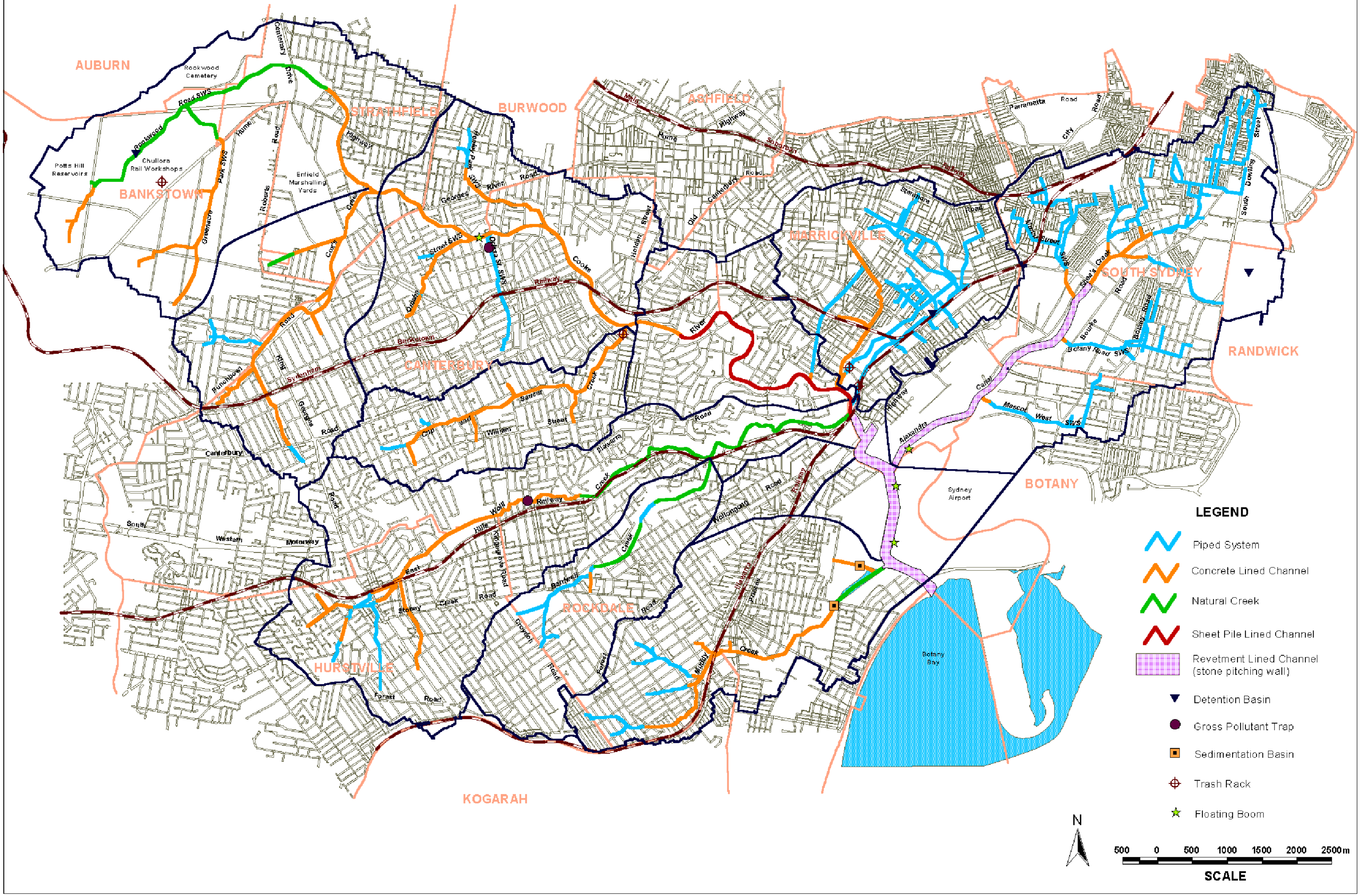
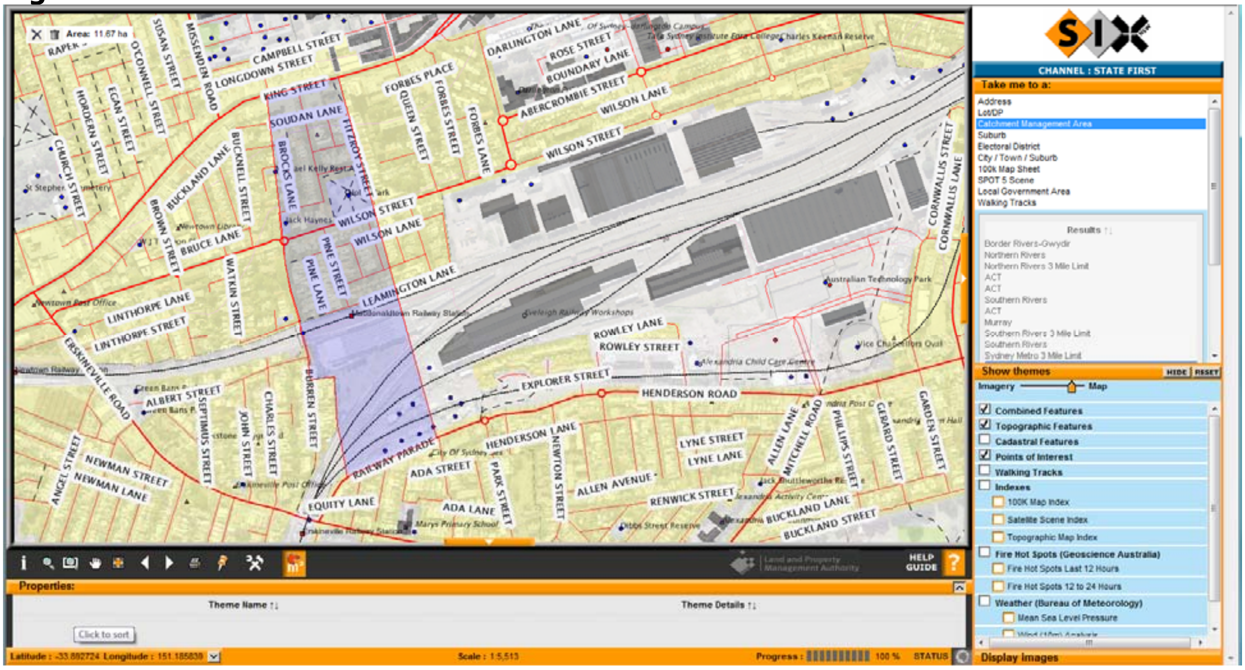


Figure 3: Extent of Shallow Groundwater Catchment Area



Take me to a:
- Address
- Lot/DP
- Catchment Management Area
- Suburb
- Electoral District
- City / Town / Suburb
- 100k Map Sheet
- SPOT 5 Scene
- Local Government Area
- Walking Tracks

Results ↑↓
- Border Rivers-Gwydir
- Northern Rivers
- Northern Rivers 3 Mile Limit
- ACT
- ACT
- Southern Rivers
- ACT
- Murray
- Southern Rivers 3 Mile Limit
- Southern Rivers
- Sydney Metro 3 Mile Limit

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- ☑ Combined Features
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- ☐ Cadastral Features
- ☑ Points of Interest
- ☐ Walking Tracks
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  - ☐ 100K Map Index
  - ☐ Satellite Scene Index
  - ☐ Topographic Map Index
- ☐ Fire Hot Spots (Geoscience Australia)
  - ☐ Fire Hot Spots Last 12 Hours
  - ☐ Fire Hot Spots 12 to 24 Hours
- ☐ Weather (Bureau of Meteorology)
  - ☐ Mean Sea Level Pressure

Display Images

Properties:

Theme Name ↑↓	Theme Details ↑↓

Latitude : -33.892724 Longitude : 151.185838

Scale : 1:5,513

Progress : 100 % STATUS

Purple shaded area showing extent of site catchment discharging into piped stormwater system leading to Munni Creek.

Appendix C

JBS Letter '*Results of Water Treatment Trial, former Macdonaldtown Gasworks, Burren Street Erskineville*' JBS Environmental Pty Ltd (2010b)

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JBS40913-15434 Rev 1

25 November 2010

John Dawson
Project Director
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(Sent Via email: jdawson@incoll.com.au)

Groundwater Treatment Trial, Former Macdonaldtown Gasworks, Revision 1

Dear John,

1. Introduction and Objectives

JBS Environmental Pty Ltd (JBS) was engaged by Incoll Management Pty Ltd (Incoll). on behalf of Rail Corporation NSW Environment Projects Unit (RailCorp), to undertake works for the revision of the remedial strategy prepared for the former Macdonaldtown Gasworks site, This letter details the trial operation of a water treatment system on the site to assess the potential discharge locations for water collected during dewatering operations.

The former Macdonaldtown gasworks site has previously been the subject of environmental investigations which have identified a number of soil and groundwater contamination issues which require remediation and/or management in order to make the site suitable for ongoing commercial use. A remedial action plan (CH2M Hill 2007[1]) for the site, has previously been prepared to document the procedures that will be undertaken to remediate and/or manage the identified issues at the site.

Excavation works proposed for the site include remedial works to remove contamination associated with naphthalene, benzo(a)pyrene (BaP) and Total Petroleum Hydrocarbons (TPH) within groundwater underlying the site. It is understood that proposed remedial excavations will extend to below the depth of groundwater underlying the site.

As a result of the contamination identified on the site, any groundwater collected during dewatering of the site for remediation is considered unsuitable to be disposed directly to stormwater. This ‘dewater’ will therefore require treatment prior to off-site disposal. JBS has undertaken a groundwater treatment trial, using a water treatment plant (WTP) transported to the site, to provide an indicative assessment of the ‘treatability’ of potential dewater from the site and an indicative assessment of treatment steps that will be required to manage the ‘dewater’.

2. Methodology

Groundwater was extracted from existing monitoring wells MW37S, MW07S, MW06S and MW04S (**Figure 1**) from 05 July to 09 July 2010. The majority of water for the trial was pumped from MW04S and MW37S, which differed from the wells nominated for extraction in SAQP[2] for the works, as follows:

- SAQP nominated well MW03S was unable to be located at the time of the trial. The well was located in the vicinity of several large soil stockpiles, and it is uncertain whether this well remains viable;
- SAQP nominated well MW06S ran dry after extraction of approximately 40L on both 7 and 9 July 2010;
- SAQP nominated well MW07S ran dry after extraction of approximately 50L on both 7 and 9 July 2010;

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[1] *Remedial Action Plan, Former Macdonaltown Gasworks Site,Burren Street, Erskineville NSW* 2007 (CH2M Hill, 2007)
[2] *Sampling, Analysis and Quality Plan, Pre-Remedial Investigations, Former Macdonaltown Gasworks*, JBS 2010

- SAQP nominated well MW31 was unable to be located at the time of the trial and it is likely this well has been destroyed.

Given the limited time available for completion of the trial, a total of only 4000L was pumped over the trial period from wells MW37S and MW04S. While not located within the source zones identified on site the groundwater pumped from MW37S and MW04S these wells is considered to be representative of impacted water.

Groundwater was extracted using bottom filling air operated in-well pumps installed to the base of the monitoring wells. Extracted groundwater was transferred to a new 9,000L storage poly tank. Approximately 4,000L of dewater was collected within the storage tanks during the pumping period.

The treatment system in use required a minimum of 8,000L of water to operate efficiently i.e. run for a sufficient length of time, and complete a meaningful trial i.e. allow for collection of sufficient samples. Consequently a further 4,000 L of water, sourced from on site fire hydrant was added to the 'dewater' in the influent tank on 9 July 2010. This approach was considered necessary because:

- Two of the four wells nominated for use in the trial were unable to be located and were presumed destroyed;
- The yield of groundwater in the two wells pumped in the vicinity of shallow groundwater plume was low, with a total of 4,000L pumped from both wells over the duration of the pumping trial.

The addition of water to influent tank for completion of the trial was considered not to impact the findings of the trial, given that the main objective of the trial was to assess the system's ability to remove the contaminants of concern from the 'dewater'. Provided the system is appropriate for the contaminants, treatment of water with higher concentrations will simply be a process of 'scaling up' the trialled components to the requirements of the remediation works. The findings of the trial are not intended to provide detailed design of the water treatment system, but rather to provide proposed remediation tenderers with sufficient information to anticipate the requirements of the remediation program.

The WTP used for the trial included the following components (listed in order of installation and water treatment):

- Oil / water separators;
- Multi-media (i.e. sand) filter (see **Attachment 4**);and
- Five 150L granular activated carbon (GAC) filters. Commercially available GAC was used in the filters. The amount of GAC used in the trial, equates to a GAC contact time during water treatment of 8 minutes.

Water flow through the WTP was controlled by the 92L/min flow restrictor provided to the oil-water separator. Effluent was discharged to an additional new sealed water storage tank. The water treatment trial was undertaken on the 9 July 2010.

Water sampling was undertaken at three intervals during the WTP operation (i.e. 'Run 1' collected 15 minutes after commencement, 'Run 2' collected 30mins after commencement and 'Run 3'collected 40 minutes after commencement). This series of runs was adopted to provide a 'snapshot' of water quality in the system between treatment components. The sampling strategy is listed in **Table 1**and depicted as a flow chart in **Figure 2.** Samples were collected from sampling 'taps' installed in pipe lines connecting the system components.

Table 1: Summary of Water Treatment Trial Sampling

Sample ID	Sample Description
MW04S	Collected from undiluted groundwater held within storage tank prior to trial commencement.
Sample 1 – Run 1	Collected from water pumped out of influent tank, 15 minutes after trial commencement
Sample 1 – Run 2	Collected from water pumped out of influent tank, 30 minutes after trial commencement
Sample 1 – Run 3	Collected from water pumped out of influent tank, 40 minutes after trial commencement
Sample 2 – Run 1	Collected from water in WTP at outlet of oil / water separator at 15 minutes after trial commencement
Sample 2 – Run 2	Collected from water in WTP at outlet of oil / water separator at 30 minutes after trial commencement
Sample 2 – Run 3	Collected from water in WTP at outlet of oil / water separator at 40 minutes after trial commencement
Sample 3 – Run 1	Collected from water in WTP at outlet of air stripper at 15 minutes after trial commencement
Sample 3 – Run 2	Collected from water in WTP at outlet of air stripper at 30 minutes after trial commencement
Sample 3 – Run 3	Collected from water in WTP at outlet of air stripper 40 minutes after trial commencement
Sample 4 – Run 1	Collected from WTP effluent at 15 minutes. Additional treatment stages include sand filter, iron filter and GAC filter.
Sample 4 – Run 2	Collected from WTP effluent at 30 minutes. Additional treatment stages include sand filter, iron filter and GAC filter.
Sample 4 – Run 3	Collected from WTP effluent at 40 minutes. Additional treatment stages include sand filter, iron filter and GAC filter.

All samples were analysed for:

- Field parameters;
- Volatile organic compounds (VOCs);
- Total petroleum hydrocarbons (TPH);
- Polycyclic Aromatic Hydrocarbons (PAHs); and
- Heavy metals (including As, Cd, Cr, Cu, Pb, Hg, Ni and Zn) subsequent to field filtering.

3. Quality Assurance / Quality Control

A program of quality assurance / quality control (QA/QC) was undertaken with the sampling and analysis works conducted during the water treatment trial. QA/QC assessment included:

- Sampling and analysis of one inter-laboratory duplicate sample;
- Preparation and analysis of trip spike and trip blank samples;
- Conducting all sampling and sample preservation in accordance with JBS procedures;
- Use of NATA accredited laboratories for all analysis; and

- Assessment of laboratory QA/QC.

QA/QC has been assessed by reference to JBS standard quality protocols.

Based on the assessment of QA/QC, the environmental data generated during the water treatment trial are considered sufficiently representative to assess potential water treatment of groundwater underlying the site.

4. Results

Analytical results for the water treatment trial have been summarised in **Table 2**. Only COPCs which have been recorded above laboratory detection limits are summarised in **Table 2**. Laboratory result certificates are provided as **Attachment 3**.

From review of **Table 2**, observations during field works and the objectives of the water treatment trial the following points are observed:

- With the exception of arsenic, the concentrations of all heavy metals were significantly reduced by the system. Consistent reductions in these heavy metals concentrations were recorded after passing through each of the system components in all 3 ‘runs conducted, with the heavy metals concentrations in the final effluent samples from all runs (i.e. the Number 4 samples) less than the laboratory detection limits. ;

- Levels of arsenic and suspended solids increased slightly in effluent samples. GAC commonly has trace levels of arsenic contamination present which can become apparent in treated water. GAC also commonly releases fines, which can be recorded as suspended solids. This can be minimised by the selection of acid washed GAC filter for use in the operational WTP;

- Phase Separated Hydrocarbons (PSH) were not observed n the

- In Run 2, the majority of TPH C_{10}-C_{36} removal was achieved by the oil-water separator. The significantly reduced level achieved at the ‘Sample No. 2’ location was further reduced to a concentrations less than the detection limits by the GAC filters;

- The results for Runs 1 and 3 indicate that the TPH C_{10}-C_{36} concentrations in the Sample 3 locations exceeded the Sample 2 values. As the plant operation and sampling methods used were consistent for the trial it is considered that these results are a reflection of the variable nature of groundwater under treatment, even after dilution. It is noted that regardless of this variation the concentrations of TPH C_{10}-C_{36} in the final effluent sample of both Runs 1 and 3 were less than the laboratory detection limits, and indicates the system provides an effective treatment process for these contaminants;

- The majority of PAH removal was achieved by the oil-water separator. This is most notable in naphthalene concentrations dropping by an order of magnitude between Sample 1 and Sample 2 locations for all three runs. Ultra-trace analysis was completed on the final effluent samples collected during the trial and in all three ‘runs’, all PAH concentrations were further reduced to concentrations less than the detection limits by the GAC filters;

- The majority of VOC removal was achieved by the GAC filters. GAC materials used in GAC filters are noted to have design lives, often measured as a ‘breakthrough point’. Water treatment completed during dewatering will require to be cognisant of the mass of contaminants removed by the GAC and the relative absorption capacity; and

- Water used from the trial was removed from developed groundwater monitoring wells and had low levels of suspended solids. Levels of suspended solids from dewater generated during excavation works would be anticipated to have higher levels of dissolved solids.

Table 2: Summary of Water Treatment Trial Results (all units in µg/L unless otherwise specified)

Sample ID	pH	Analyte												
		VOCs			TPH		Heavy Metals							
		Chloroform	Bromodichloromethane	Dibromochloromethane	C_6-C_9	C_{10}-C_{36}	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn
MW04S	Pumped groundwater holding tank	21	25	18	<10	6,200	<1	<0.1	<1	<1	<1	<0.5	1	110
Sample 1 – Run 1	Influent (15 mins)	14	8.9	2.7	<10	1,100	<1	<0.1	<1	<1	<1	<0.5	1	110
Sample 2 – Run 1	Post oil-water separator / pre sand filter (15 mins)	9.8	5.8	1.7	<10	170	<1	<0.1	<1	1	<1	<0.5	2	100
Sample 3 – Run 1	Post sand filter/ pre GAC (15 mins)	12	7.6	2.2	<10	3,210	<1	<0.1	<1	10	<1	<0.5	8	63
Sample 4 – Run 1	**Post GAC Effluent (15 mins)**	**<1**	**<1**	**<1**	**<10**	**<250**	**16**	**<0.1**	**<1**	**<1**	**<1**	**<0.5**	**<1**	**1**
Sample 1 – Run 2	Influent (30 mins)	12	2.1	2.1	<10	3,600	<1	<0.1	<1	3	<1	<0.5	7	170
Sample 2 – Run 2	Post oil-water separator / pre sand filter (30 mins)	11	6.6	2.0	<10	322	<1	<0.1	<1	4	<1	<0.5	9	91
Sample 3 – Run 2	Post sand filter/ pre GAC (30 mins)	9.7	6.3	2.0	<10	190	<1	<0.1	<1	7	<1	<0.5	8	48
Sample 4 – Run 2	**Post GAC Effluent (30 mins)**	**<1**	**<1**	**<1**	**<10**	**<250**	**17**	**<0.1**	**<1**	**<1**	**<1**	**<0.5**	**<1**	**<1**
Sample 1 – Run 3	Influent (40 mins)	9.6	5.9	1.8	<10	5,700	<1	<0.1	<1	<1	<1	<0.5	2	160
Sample 2 – Run 3	Post oil-water separator / pre sand filter (40 mins)	10	5.5	1.7	<10	<250	<1	<0.1	<1	<1	<1	<0.5	2	140
Sample 3 – Run 3	Post sand filter/ pre GAC (40 mins)	11	5.2	1.6	<10	1230	<1	<0.1	<1	4	1	<0.5	2	49
Sample 4 – Run 3	**Post GAC Effluent (40 mins)**	**<1**	**<1**	**<1**	**<10**	**<250**	**24**	**<0.1**	**<1**	**<1**	**<1**	**<0.5**	**<1**	**<1**

Table 2: **Summary of Water Treatment Trial Results (all units in µg/L unless otherwise specified)**

Sample ID	**Component or sampling stage (time after system commencement)**	**Analyte - PAHs**														
		Naphthalene	**Acenaphthylene**	**Acenaphthene**	**Fluorene**	**Phenanthrene**	**Anthracene**	**Fluoranthene**	**Pyrene**	**Benzo(a)anthracene**	**Chrysene**	**Benzo(b+k)fluoranthene**	**Benzo(a)pyrene**	**Indeno(1,2,3-c,d)pyrene**	**Dibenzo(a,h)anthracene**	**Benzo(g,h,i)perylene**
MW04S	Pumped groundwater holding tank	5.6	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sample 1 – Run 1	Influent (15 mins)	2.2	<0.1	0.7	0.5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
Sample 2 – Run 1	Post oil-water separator / pre sand filter (15 mins)	0.3	<0.1	0.4	0.4	0.4	<0.1	0.2	0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
Sample 3 – Run 1	Post sand filter/ pre GAC (15 mins)	0.2	<0.1	0.3	0.2	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
Sample 4 – Run 1	**Post GAC (15 mins)**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.02**	**<0.01**	**<0.01**	**<0.01**	**<0.01**
Sample 1 – Run 2	Influent (30 mins)	3.4	<0.1	0.5	0.4	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
Sample 2 – Run 2	Post oil-water separator / pre sand filter (30 mins)	0.2	<0.1	0.5	0.5	1	0.2	0.7	0.4	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
Sample 3 – Run 2	Post sand filter/ pre GAC (30 mins)	0.2	<0.1	0.4	0.4	0.5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
Sample 4 – Run 2	**Post GAC (30 mins)**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.02**	**<0.01**	**<0.01**	**<0.01**	**<0.01**
Sample 1 – Run 3	Influent (45 mins)	3.8	<0.1	0.8	0.6	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
Sample 2 – Run 3	Post oil-water separator / pre sand filter (40 mins)	0.2	<0.1	0.6	0.5	0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
Sample 3 – Run 3	Post sand filter/ pre GAC (40 mins)	0.2	<0.1	0.6	0.5	0.6	0.1	0.1	0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
Sample 4 – Run 3	**Post GAC (40 mins)**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.02**	**<0.01**	**<0.01**	**<0.01**	**<0.01**

Overall it is noted that samples of the treatment system effluent (i.e. all 'Sample 4' results, collected post GAC filter) were reported to contain very low concentrations of all contaminants of concern at the site. Based on these results it appears that a water treatment plant could be used as part of the remediation process to enable discharge of collected groundwater as follows:

- To stormwater following receipt of relevant approvals from City of Sydney Council; or
- To sewer should a 'trade waste agreement' be entered into with Sydney Water.

Additionally, the results indicate that the treated effluent was of a suitable quality for reinjection into the subsurface. The feasibility of this option is however uncertain, given the required discharge rates during remediation are likely to exceed the infiltration potential of the clay soils underlying the site. This option would also require licensing by the NSW Office of Water.

If you wish to discuss any part of this letter further, then please free to contact Sumi Dorairaj on (02) 8338 1011. If you wish to discuss specifics of the WTP used during the works, or possible supply of water treatment components, Cameron Grant of Total Environmental Solutions (who supplied and operated the WTP during the trial) can be contacted on 0400 993 112.

Prepared by:	Peer Review by:
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Attachments:
(1) Limitations
(2) Figures
(3) Laboratory Analysis Report and COC documentation
(4) WTP media specifications