

BOREHOLE CONSTRUCTION	SAMPLE		SOIL VAPOUR (ppm)	GROUNDWATER	DEPTH (m)	GEOLOGY	BOREHOLE NUMBER: MSMW114D		PAGE 1 of 2	
	NUMBER	TYPE					START DATE: 31/3/99		DRILLING METHOD: ROTARY AIR FLUSH	
							FINISH DATE: 1/4/99		BOREHOLE DIAMETER: 150 mm	
							DRILLER: RD4		SCREEN TYPE & DIAMETER: 50 mm ID UPVC	
LOGGED BY: DB		APPR'D BY:		SCREEN SLOT SIZE: 0.5 mm						
							DESCRIPTION	COMMENTS		
					0		Soft dark grey CLAY with frequent fine to coarse gravel and rootlets	No odour Slightly damp		0
					1.0					1.0
					2.0		Soft dark brown clayey PEAT with some fine to medium gravel			2.0
					3.0		Soft to medium brown gravelly CLAY			3.0
					4.0		becoming more gravelly	No odour		4.0
					5.0		Loose brown-orange clayey coarse sub-angular GRAVEL			5.0
					6.0		Loose grey medium to coarse GRAVEL with some clay and cobbles			6.0
					7.0		Loose brown sandy clayey GRAVEL	Water cased out at 6.3 m		7.0
					8.0			No odour		8.0
					9.0					9.0
					10					10

LOCATION / NOTES:	LEGEND	BOREHOLE LOG	
1. All measurements in m below ground level (mbgl)	☒ Disturbed Sample ■ Undisturbed Sample * Headspace Analysis † Down Borehole Analysis ▽ Groundwater Table ▽ Perched Water Table	Job Title	SOIL & GROUNDWATER INVESTIGATION
		Location	LLANDARCY REFINERY
		Client	BP LLANDARCY LTD
		App'd	DRAFT
		Ref.	CR/MC/BRS
		Date	MAY 99
		Job No.	39991-004-401
		 DAMES & MOORE	

BOREHOLE CONSTRUCTION	SAMPLE		SOIL VAPOUR (ppm)	GROUNDWATER	DEPTH (m)	GEOLOGY	BOREHOLE NUMBER: MSMW114D		PAGE 2 of 2	
	NUMBER	TYPE					START DATE: 31/3/99	DRILLING METHOD: ROTARY AIR FLUSH		
							FINISH DATE: 1/4/99		BOREHOLE DIAMETER: 150 mm	
							DRILLER: RD4		SCREEN TYPE & DIAMETER: 50 mm ID UPVC	
							LOGGED BY: DB APPR'D BY:		SCREEN SLOT SIZE: 0.5 mm	
							DESCRIPTION		COMMENTS	
					10		Soft brown sandy and clayey GRAVEL (BOULDER CLAY)		No odour Slightly damp	
					11					
					12					
					13				No odour	
					14				All rod connections dry from 6.3m to 15.5m	
					15					
					16		Very coarse sandstone GRAVEL		Water strike at 15.6m Very productive	
					17		ROCKHEAD - Soft light grey to medium grey silty MUDSTONE		No odour	
					18					
					19		COAL measures			
					20		Silty MUDSTONE			
							COAL measures			
							Borehole terminated at 20 mbgl			

LOCATION / NOTES:	LEGEND	BOREHOLE LOG	
1. All measurements in m below ground level (mbgl)	☒ Disturbed Sample ■ Undisturbed Sample * Headspace Analysis † Down Borehole Analysis ▽ Groundwater Table ▽ Perched Water Table	Job Title	SOIL & GROUNDWATER INVESTIGATION
		Location	LLANDARCY REFINERY
		Client	BP LLANDARCY LTD
		App'd	DRAFT
		Ref.	CR/MC/BRS
		Date	MAY 99
		Job No.	39991-004-401
		 DAMES & MOORE	

BOREHOLE CONSTRUCTION		SAMPLE		SOIL VAPOUR (ppm)	GROUNDWATER	DEPTH (m)	GEOLOGY	BOREHOLE NUMBER: MSMW115D1,D2		PAGE 1 of 2	
		NUMBER	TYPE					START DATE: 31/3/99	DRILLING METHOD: ROTARY AIR FLUSH	FINISH DATE: 31/3/99	BOREHOLE DIAMETER: 165 mm
D1	D2					0		Loose grey-brown (mottled orange-brown) sandy, gravelly, clayey SILT with some cobbles (TOPSOIL)			0
				*0		1.0		Loose brown clayey fine to coarse sub-angular GRAVEL		Wet at 1.2m	1.0
						2.0		Dark brown-black CLAY with fine to medium sub-angular gravel		No hydrocarbon odour	2.0
				*0		3.0		Soft dark grey-brown silty CLAY with occasional fine gravel			3.0
						4.0		Soft grey very sandy CLAY with occasional fine gravel			4.0
				*0		5.0		Loose grey-brown sandy GRAVEL with frequent cobbles and some clay			5.0
						6.0		ROCKHEAD - Hard light grey medium grained crystalline SANDSTONE			6.0
				*0		7.0		Silty CLAY with some gravel (MINEWORKINGS)		Void	7.0
						8.0				Easy drilling from 5.8-8.5m (mineworkings)	8.0
						9.0				Very productive	9.0
						10.0				Very poor returns	10.0
										No hydrocarbon odour	
								Hard grey medium grained crystalline SANDSTONE			

LOCATION / NOTES:		LEGEND		BOREHOLE LOG	
1. All measurements in m below ground level (mbgl)		Disturbed Sample Undisturbed Sample Headspace Analysis Down Borehole Analysis Groundwater Table Perched Water Table		Job Title SOIL & GROUNDWATER INVESTIGATION	
2. ODEX to 10.5m, Rotary to 13.5m				Location LLANDARCY REFINERY	
3. D1 installed with 19 mm HDPE pipe				Client BP LLANDARCY LTD	
				App'd DRAFT	
				Ref. CR/MC/BRS	
				Date MAY 99	
				Job No. 39991-004-401	

	DAMES & MOORE

BOREHOLE CONSTRUCTION	SAMPLE		SOIL VAPOUR (ppm)	GROUNDWATER	DEPTH (m)	GEOLOGY	BOREHOLE NUMBER: MSMW115D1,D2		PAGE 2 of 2	
	NUMBER	TYPE					START DATE: 31/3/99	DRILLING METHOD: ROTARY AIR FLUSH	FINISH DATE: 31/3/99	BOREHOLE DIAMETER: 165 mm
D1							DESCRIPTION	COMMENTS		
					10		Hard grey medium grained crystalline SANDSTONE	No odour		10
							Soft black COAL with some 'coal shale' beds			
					11		Soft light grey silty MUDSTONE			11
					12					12
					13		Hard grey medium grained crystalline SANDSTONE	Both wells flowing artesian		13
					14					14
					15					15
					16					16
					17					17
					18					18
					19					19
					20					20

LOCATION / NOTES: 1. All measurements in m below ground level (mbgl)		LEGEND ☒ Disturbed Sample ☐ Undisturbed Sample ☐ Headspace Analysis ☐ Down Borehole Analysis ☐ Groundwater Table ☐ Perched Water Table	BOREHOLE LOG Job Title SOIL & GROUNDWATER INVESTIGATION Location LLANDARCY REFINERY Client BP LLANDARCY LTD App'd DRAFT Ref. CR/MC/BRS Date MAY 99 Job No. 39991-004-401	 DAMES & MOORE GROUP
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BOREHOLE CONSTRUCTION	SAMPLE		SOIL VAPOUR (ppm)	GROUNDWATER	DEPTH (m)	GEOLOGY	BOREHOLE NUMBER: MSMW171D		PAGE 1 of 2	
	NUMBER	TYPE					START DATE: 22/4/99		DRILLING METHOD: ROTARY AIR FLUSH	
							FINISH DATE: 22/4/99		BOREHOLE DIAMETER: 165 mm	
							DRILLER: R1		SCREEN TYPE & DIAMETER: 50 mm ID UPVC	
						LOGGED BY: MC APPR'D BY:		SCREEN SLOT SIZE: 0.5 mm		
							DESCRIPTION	COMMENTS		
					0		Loose black gravelly ASH with cobbles and brick fragments (MADE GROUND)	No odour	0	
					1.0		Soft dark brown sandy SILT with frequent fine to coarse sub-angular gravel (MADE GROUND)	No odour	1.0	
					2.0		Loose black gravelly ASH with cobbles and occasional brick fragments (MADE GROUND)	No odour	2.0	
					3.0				3.0	
					4.0				4.0	
					5.0				5.0	
					6.0				6.0	
					7.0		Firm grey (mottled orange-brown in places) CLAY with fine to medium sub-angular gravel	Slight to moderate hydrocarbon odour	7.0	
					8.0		Soft grey CLAY with fine to medium sub-angular gravel	Moderate hydrocarbon odour	8.0	
					9.0		Dense brown gravelly and sandy SILT		9.0	
					10		Grey silty and sandy GRAVEL	Moderate hydrocarbon odour	10	

LOCATION / NOTES: 1. All measurements in m below ground level (mbgl)		LEGEND Disturbed Sample Undisturbed Sample Headspace Analysis Down Borehole Analysis Groundwater Table Perched Water Table		BOREHOLE LOG Job Title SOIL & GROUNDWATER INVESTIGATION Location LLANDARCY REFINERY Client BP LLANDARCY LTD App'd DRAFT Ref. CR/MC/BRS Date MAY 99 Job No. 39991-004-401		DAMES & MOORE	
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BOREHOLE CONSTRUCTION	SAMPLE		SOIL VAPOUR (ppm)	GROUNDWATER	DEPTH (m)	GEOLOGY	BOREHOLE NUMBER: MSMW171D		PAGE 2 of 2	
	NUMBER	TYPE					START DATE: 22/4/99		DRILLING METHOD: ROTARY AIR FLUSH	
							FINISH DATE: 22/4/99		BOREHOLE DIAMETER: 165 mm	
							DRILLER: R3		SCREEN TYPE & DIAMETER: 50 mm ID UPVC	
						LOGGED BY: MC APPR'D BY:		SCREEN SLOT SIZE: 0.5 mm		
							DESCRIPTION		COMMENTS	
					10		Dark grey sandy and gravelly CLAY (BOULDER CLAY)		Water at pipe connection	10
					11		Loose grey sandy GRAVEL boulder at 10.8m		Hydrocarbon odour	11
					12		Brown silty sandy and gravelly CLAY (BOULDER CLAY)		Dry Water cased out	12
					13		ROCKHEAD: Grey-brown MUDSTONE (BEDROCK)			13
					14		becoming loose with angular blocks of sandstone and siltstone from 13.7-18.7m - suspected colliery working or fill therefrom		Very productive	14
					15				No hydrocarbon odour in water	15
					16					16
					17					17
					18					18
					19		Borehole terminated at 18.7 mbgl on refusal			19
					20					20

LOCATION / NOTES:		LEGEND		BOREHOLE LOG	
1. All measurements in m below ground level (mbgl)		☒ Disturbed Sample		Job Title	
2. ODEX to 16.4 m, Rotary to 18.7 m		■ Undisturbed Sample		SOIL & GROUNDWATER INVESTIGATION	
3. Borehole collapsed from 18.7m to 18.0m		* Headspace Analysis		Location	
		† Down Borehole Analysis		LLANDARCY REFINERY	
		▽ Groundwater Table		Client	
		▽ Perched Water Table		BP LLANDARCY LTD	
				App'd	DRAFT
				Ref.	CR/MC/BRS
				Date	MAY 99
				Job No.	39991-004-401
				 DAMES & MOORE	



Appendix E Limitations

All conclusions and recommendations made within this report are based upon and limited to the factual information obtained as part of this study. PJA Engineering will state where it has utilised and relied upon information obtained by others. It has been assumed that all third-party information provided is true and accurate. No responsibility is accepted by PJA Engineering for the accuracy or completeness of such information.

There is a possibility that there may exist on site, conditions that could not be identified within the scope of the assessment or which were not reasonably identifiable from the available information. The conclusions drawn in the report are considered correct, although any subsequent additional information may allow refinement of the conclusions.

The findings of this report represent the professional opinion of experienced environmental scientists and contaminated land specialists. All advice, opinions, assessments and views set out in this report are based on relevant UK standards, codes, construction practices and legislation understood to be current and applicable at the date of this report. Further assessment and a revision of the report may be required should new information come to light or legislation/changes to best practice be introduced after the date of issue of the report.

PJA Engineering confirms it offers no duty to update the report in the light of any such information or changes to regulation and / or guidance. PJA Engineering does not provide legal advice and the advice of solicitors may also be required.

PJA Engineering has prepared the report for the sole use and reliance of the Client. The report may not be used or relied upon by any unauthorised third party without the explicit written agreement of PJA Engineering.

The interpretative work undertaken within this report remains the intellectual property of PJA Engineering. This information must not be divulged to any other commercial third party without prior written agreement from PJA Engineering.

Appendix E Report Limitations

All conclusions and recommendations made within this report are based upon and limited to the factual information obtained as part of this study. PJA Engineering will state where it has utilised and relied upon information obtained by others. It has been assumed that all third-party information provided is true and accurate. No responsibility is accepted by PJA Engineering for the accuracy or completeness of such information.

PJA Engineering encountered data limitations by not interviewing the past Site owners and adjacent property owners, as none were available for comment and due to the confidential nature of this development. However, based on our review of the available historical information, the absence of information obtained from interviews with these individuals is not considered significant to the findings, conclusions, and recommendation of this report.

There is a possibility that there may exist on site, conditions that could not be identified within the scope of the assessment or which were not reasonably identifiable from the available information. The conclusions drawn in the report are considered correct, although any subsequent additional information may allow refinement of the conclusions.

The findings of this report represent the professional opinion of experienced environmental scientists and contaminated land specialists. All advice, opinions, assessments and views set out in this Phase 1 report are based on relevant UK standards, codes, construction practices and legislation understood to be current and applicable at the date of this report. Further assessment and a revision of the report may be required should new information come to light or legislation/changes to best practice be introduced after the date of issue of the report.

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Appendix F Risk Assessment Matrix

The approach to risk evaluation is a qualitative method in general accordance with the CIRIA C552 2001 document. It involves the classification of the potential consequence of risk occurring and the probability of the risk occurring.

Classification of Consequence

The terms and definitions relating to the classification of consequence are summarised in Table F1:

Table F1: Classification of Consequence

Classification	Definition	Example
Severe	Short term (acute) risk to human health likely to result in “significant harm” as defined by the Environment Protection Act 1990, Part IIA. Short term risk of pollution (note: Water Resources Act contains no scope for considering significance of pollution) of sensitive water resource. Catastrophic damage to buildings/property. A short-term risk to a particular ecosystem, or organism forming part of such ecosystem (note: the definitions of ecological systems within the Circular on Contaminated Land, DETR, 2000).	- High concentrations of cyanide on the surface of an informal recreation area. - Major spillage of contaminants from site into controlled water. - Explosion, causing building collapse (can also equate to a short term human health risk if buildings are occupied).
Medium	Chronic damage to Human Health (“significant harm” as defined in the DETR, 2000). Pollution of sensitive water resources (note: Water Resources Act contains no scope for considering significance of pollution). A significant change in a particular ecosystem, or organism forming part of such ecosystem. (note: the definitions of ecological systems within Circular on Contaminated Land, DETR, 2000).	- Concentrations of a contaminant from site exceed the generic, or site-specific assessment criteria. - Leaching of contaminants from a site to a major or minor aquifer (renamed principal, secondary and significant drift under the Water Framework Directive). - Death of a species within a designated nature reserve.
Mild	Pollution of non-sensitive water resources. Significant damage to buildings/structures and crops (“significant harm” as defined in the Circular on Contaminated Land, DETR, 2000). Damage to sensitive buildings/structures or the environment.	- Pollution of non-classified groundwater. - Damage to building rendering it unsafe to occupy (e.g. foundation damage resulting in instability).
Minor	Harm, although not necessarily significant harm, which may result in a financial loss, or expenditure to resolve. Non-permanent health effects to human health (easily prevented by means such as Personal Protective Clothing, etc.). Easily repairable effects of damage to buildings/structures.	- The presence of contaminants at such concentrations that protective equipment is required during site works. - The loss of plants in a landscaping scheme. - Discolouration of concrete.

Classification of Probability

Probability is classified based on the following terms and definitions:

Table F2: Classification of Probability

Classification	Definition
High Likelihood	There is a pollution linkage and an event which would either appear very likely in the short term and almost inevitable over the long term, or, there is evidence at the receptor of harm or pollution.
Moderate Likelihood	There is a pollution linkage and all the elements are present and in the right place which means that it is probable that an event will occur. Circumstances are such that an event is not inevitable, but possible in the short term and likely over the long term.
Low Likelihood	There is a pollution linkage and circumstances are possible under which an event could occur. However, it is by no means certain that even over a longer period such event would take place and is less likely in the shorter term.
Unlikely	There is a pollution linkage, but circumstances are such that it is improbable that an event would occur even in the very long term.

Risk Matrix

The risk matrix based on probability and consequence is presented in Table E3:

Table F3: Risk Matrix

		Consequences			
		Severe	Medium	Mild	Minor
Probability	High Likelihood	Very high	High	Moderate	Moderate / Low
	Moderate Likelihood	High	Moderate	Moderate / Low	Low
	Low likelihood	Moderate	Moderate / Low	Low	Very Low
	Unlikely	Moderate / Low	Low	Very Low	Very Low

Risk Descriptions

Definitions of the risk categories are presented in Table F4:

Table F4: Description of the classified risks and likely action required

Classification	Definition
Very High Risk	There is a high probability that severe harm could arise to a designated receptor from an identified hazard, or there is evidence that severe harm to a designated receptor is currently happening. This risk, if realised, is likely to result in a substantial liability. Urgent investigation (if not undertaken already) and remediation are likely to be required.
High Risk	Harm is likely to arise to a designated receptor from an identified hazard. Realisation of the risk is likely to present a substantial liability. Urgent investigation (if not undertaken already) is required and remedial works may be necessary in the short term and are likely over the longer term.
Moderate Risk	It is possible that harm could arise to a designated receptor from an identified hazard. However, it is either relatively unlikely that any such harm would be severe, or if any harm were to occur it is more likely that the harm would be relatively mild. Investigation (if not already undertaken) is normally required to clarify the risk and to determine the potential liability. Some remedial works may be required in the longer term.
Low Risk	It is possible that harm could arise to a designated receptor from an identified hazard, but it is likely that this harm, if realised, would at worst normally be mild.
Very Low Risk	There is a low probability that harm could arise to a receptor. In the event of such harm being realised it is not likely to be severe.

Appendix G Available Reports

Technical Note 336

Subject:	Mine working investigation		
Reference:	5041216-REM-TN-000336	Revision:	1
Author:	Alex Mann	Checker:	Howel Morris
Issued to:	Coal Authority, St Modwen Developments and Prosurv	Reviewer:	Michelle Lee
Date:	June 2010	Authoriser:	Mike Poland

Introduction

The former Llandarcy Oil Refinery in Neath, South Wales is currently under redevelopment as Coed Darcy Urban Village by St. Modwen Developments Ltd. At the time of writing, the Masterplanning exercise is being finalised and detailed information on proposed development layouts and levels within the final site are not yet known.

The refinery has been previously investigated on a number occasions by the previous site owners (BP), however, in July, further investigation was carried out by Atkins to further investigate the potential for shallow coal/mineworkings beneath the initial phases of redevelopment at the site, namely the 'Demonstration Village' and the 'Trial Areas/first 600' (refer to Drawing 5041216/REM/DWG/000494 attached).

In order to enable this 'preliminary' investigation to be undertaken, Atkins applied for appropriate Coal Authority Permission (ref. 5041216-REM-OUT-218). Coal Authority permission (ref.4533) was issued on the 21st July 2009.

Due to the need for further investigative works, this document has been prepared as a summary of the works to date. Full details of all assessment relating to the potential for shallow mineworkings and/or recorded mine entries will be documented for each phase of the proposed redevelopment as the works progress.

Background

Geological maps (BGS Sheet 247, 1:50,000 and Sheet 79 NW, 1:10,560) indicate the Hughes and Bodwr seam to subcrop along part of the southern boundary of the former refinery and dipping towards the north (refer to Drawing 5041216/REM/DWG/000494). The Hughes Seam is indicated as being an average thickness of 3ft (approximately 1m) and the overlying Bodwr seam is recorded as being an average of between 3ft and 6ft (approximately 1-2m). Historical maps record a colliery (*cwert y bettws*) to the east of the former refinery, on the opposite side of the B4290.

A Ground Stability report for the former refinery (ref.00056014-08) indicates that the site is in the likely zone of influence from workings in 4 seams of coal at shallow to 180m depth, and last worked in 1914. Within, or within 20 metres of, the boundary of the property there are 25 mine entries highlighted in the report.

A separate Coal Authority Mining Report (ref.00040665-08) obtained prior to demolition of the former Bath House in the eastern part of the former refinery, indicates that the *"property lies within the likely zone of influence from workings in 2 seams of coal at 40m to 90m depth and last worked in 1909"*.

A further Coal Authority Mining Report (ref.00008739-09) obtained as part of the assessment of the proposed 'Demonstration Village' plot does not indicate any recorded workings or mine entries at this location. The nearest subcrop to this location shown on geological maps is the Swansea 3 feet seam which lies to the north, however the geological succession records a series of older seams that could potentially exist at shallow depth beneath this area.

Preliminary Investigation

A total of 11 no. rotary (open) boreholes were drilled to depths of between 24m and 50m bgl, the locations of which are shown on Drawing 5041216/REM/DWG/000494. Copies of relevant borehole logs are attached.

Four of these boreholes (RO1–3 and 12) were installed with gas/groundwater standpipes for subsequent monitoring. Boreholes without installations were grouted on completion. Any groundwater installations will ultimately be grouted up on as the redevelopment of the refinery progresses.

A summary of the coal identified during the works found is presented in Table 1. The name of the likely seams represented is suggested in brackets.

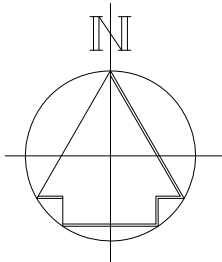
Table 1: Summary of coal identified during the works

Borehole	Approximate Grid Ref		Total Depth (mbgl)	Identified coal (mbgl)
RO1	270182	195275	45	NE
RO2	270271	195345	35	NE
RO3	270272	195166	35	NE
RO4	270971	195620	30	NE
RO5	271092	195549	30	NE
RO6	271450	195592	24	21.60 – 22.00 (Bodwr seam)
RO7	271477	195769	30	26.20 – 26.50 (Bodwr seam)
RO8	271705	195771	25	12.80 – 13.10 (Bodwr seam) 13.70 – 13.90 (Bodwr seam) 14.50 – 14.70 (Bodwr seam/ Hughes seam?)
RO9	271705	195838	40	NE
RO11	271887	195997	50	NE
RO12	271685	196003	50	NE

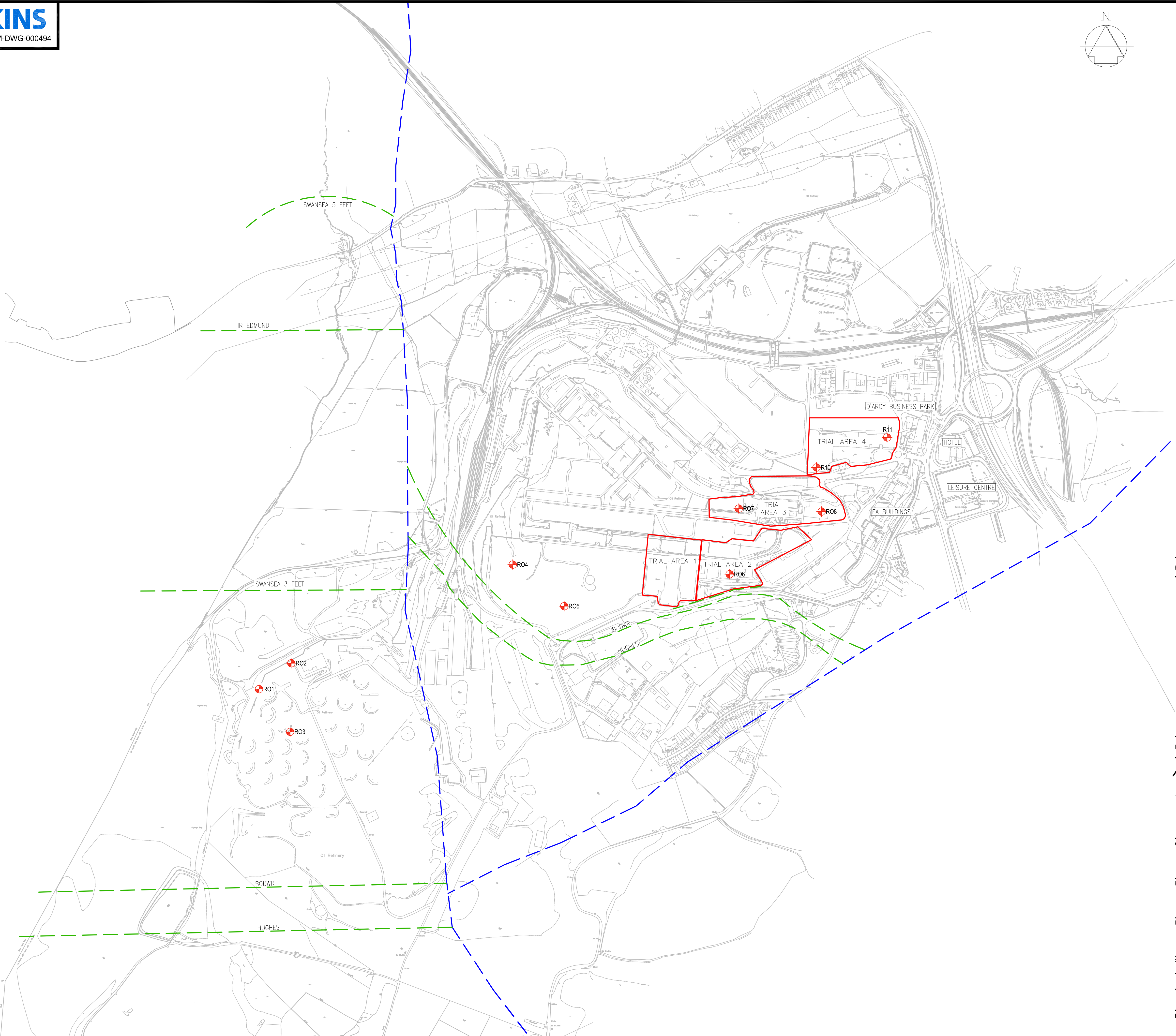
Conclusions and Outstanding Works

Based on the findings of the preliminary investigation, no evidence of any shallow workings has been identified beneath either the top terrace or the Demonstration Village plot. This will be confirmed by further investigation, as necessary.

A number of shafts/adits exist around the site. It is anticipated that these will form the next phase of investigation relating to historical mining beneath the site. Due to the depth to rockhead and the presence of existing infrastructure (roads etc) the potential for geophysical survey surrounding each of the recorded locations is currently being explored. Appropriate permission will be sought prior to the start of any intrusive works at these locations.



- LEGEND:
- PROPOSED TRIAL AREA BOUNDARY
 - BOREHOLE LOCATION POINTS
 - DV DEMONSTRATION VILLAGE
 - RO ROTERY
 - SBH SENTINEL WELLS
 - TA1 TRIAL AREA 1
 - DME D'IME AREA
 - FAULT
 - COAL CROP



REVISIONS	Drawn By	Checked By	Date

CONTRACTORS – FOR PRICING	–	ML	03/06/09
PURPOSE OF ISSUE	Rev.	Authorised for issue	Date

Atkins Ltd
Consulting Engineers
The Axis, 10 Holliday Street
Birmingham West Midlands B1 1TF

Tel 0121 483 5000
Fax 0121 483 5252

©
THIS DRAWING IS NOT TO BE SCALED

CLIENT

ST.MODWEN

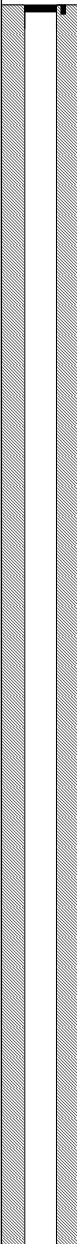
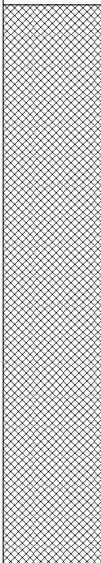
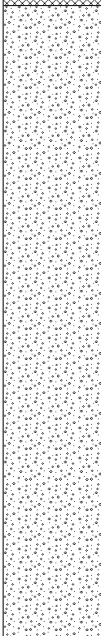
PROJECT

COED DARCY URBAN VILLAGE DEVELOPMENT

DRAWING TITLE

MINE WORKING BOREHOLE LOCATION PLAN
(GI REF 357)

Scales	DRAWN JSD	CHECKED AM	CO-ORD CHECK -
1 : 5000	DATE 20/05/09	DATE 20/05/09	DATE -
0		SHEET A1	PLOT DATE 15/06/09
DRAWING NO			REV
5041216-REM-DWG-000494			-

REC Geotechnical Log							Borehole: RO1		
 Resource & Environmental Consultants Ltd.			Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)						
Client: St Modwen			Ground Level:		Coordinates:		Date: 22 & 23/07/09		
Installat ion	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample			Test
						Type	No.		
	Ground Surface	0.00		0.00	0.00				
	MADE GROUND : Compact fill.			1.00	1.00				
				2.00	2.00				
				3.00	3.00				
				4.00	4.00				
		-4.60		5.00	5.00				
	SAND and GRAVEL. (Slow penetration).			6.00	6.00				
				7.00	7.00				
				8.00	8.00				
				9.00	9.00				
		-9.80							
		-10.00		10.00	10.00				
	Sandstone BOULDER.								
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks 63mm diameter standpipe installed to 33.00m. Water encountered @ 30.00m. Notes Strong odour of diesel/oil from GL to 4.60m.									
Logged by: AD Scale: FIG:									

REC Geotechnical Log						Borehole: RO1			
 Resource & Environmental Consultants Ltd.		Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)							
Client: St Modwen		Ground Level:		Coordinates:		Date: 22 & 23/07/09			
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample Type No.	Test		
	Sandstone BOULDER.	-10.50							
	Soft CLAY with bands of grey mudstone.			11.00	11.00				
				12.00	12.00				
				13.00	13.00				
				14.00	14.00				
					15.00	15.00			
					16.00	16.00			
	Grey SANDSTONE.	-16.30							
	Hard, grey SANDSTONE. (Slow penetration).	-16.50		17.00	17.00				
				18.00	18.00				
				19.00	19.00				
				20.00	20.00				
			-20.00						

Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test

Remarks

63mm diameter standpipe installed to 33.00m.
Water encountered @ 30.00m.

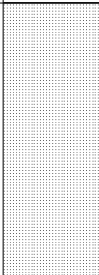
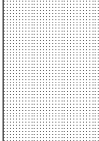
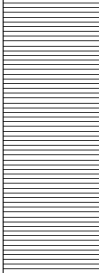
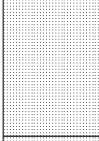
Notes

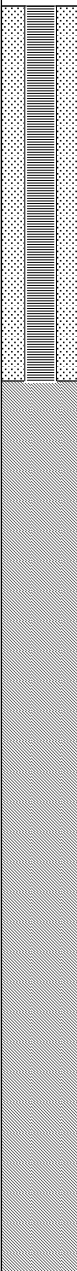
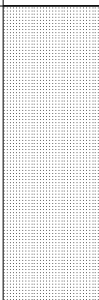
Strong odour of diesel/oil from GL to 4.60m.

Logged by: AD

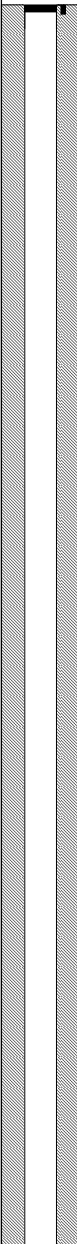
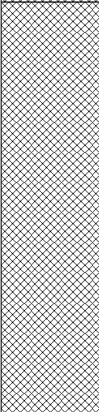
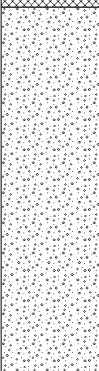
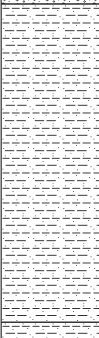
Scale:

FIG:

REC Geotechnical Log						Borehole: RO1				
 Resource & Environmental Consultants Ltd.			Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)							
Client: St Modwen			Ground Level:		Coordinates:		Date: 22 & 23/07/09			
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records		
					Depth	Sample			Test	
						Type	No.			
	Hard, grey SANDSTONE. (Slow penetration).			21.00	21.00					
		-22.30		22.00	22.00					
	Dark grey MUDSTONE.									
		-23.10		23.00	23.00					
	Hard, grey SANDSTONE. (Slow penetration).									
		-24.30		24.00	24.00					
	Grey MUDSTONE.									
		-25.70		25.00	25.00					
	Hard, grey SANDSTONE. (Slow penetration).			26.00	26.00					
		-26.50								
	Grey MUDSTONE.			27.00	27.00					
				28.00	28.00					
		-28.90								
	Grey SANDSTONE.			29.00	29.00					
	-30.00			30.00	30.00					
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks 63mm diameter standpipe installed to 33.00m. Water encountered @ 30.00m. Notes Strong odour of diesel/oil from GL to 4.60m.									Logged by: AD Scale: FIG:	

REC Geotechnical Log							Borehole: RO1				
 Resource & Environmental Consultants Ltd.			Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)								
Client: St Modwen			Ground Level:		Coordinates:		Date: 22 & 23/07/09				
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records			
					Depth	Sample			Test		
						Type	No.				
	Grey SANDSTONE.	-32.40		31.00	31.00						
			32.00	32.00							
	Black SILTSTONE with grey sandstone bands. (Very slow penetration).				33.00	33.00					
					34.00	34.00					
					35.00	35.00					
					36.00	36.00					
					37.00	37.00					
					38.00	38.00					
					39.00	39.00					
					40.00	40.00					
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks 63mm diameter standpipe installed to 33.00m. Water encountered @ 30.00m. Notes Strong odour of diesel/oil from GL to 4.60m.										Logged by: AD	
										Scale:	
										FIG:	

REC Geotechnical Log						Borehole: RO1			
 Resource & Environmental Consultants Ltd.		Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)							
Client: St Modwen		Ground Level:		Coordinates:			Date: 22 & 23/07/09		
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample			Test
						Type	No.		
	Black SILTSTONE with grey sandstone bands. (Very slow penetration).			41.00	41.00				
				42.00	42.00				
				43.00	43.00				
				44.00	44.00				
				-45.00					
	End of Log			45.00	45.00				
				46.00	46.00				
				47.00	47.00				
				48.00	48.00				
				49.00	49.00				
				50.00	50.00				
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks 63mm diameter standpipe installed to 33.00m. Water encountered @ 30.00m. Notes Strong odour of diesel/oil from GL to 4.60m.						Logged by: AD			
						Scale:			
						FIG:			

REC Geotechnical Log							Borehole: RO2			
 Resource & Environmental Consultants Ltd.			Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)							
Client: St Modwen			Ground Level:		Coordinates:		Date: 20 & 21/07/09			
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records		
					Depth	Sample			Test	
						Type	No.			
	Ground Surface	0.00		0.00	0.00					
	MADE GROUND : Topsoil.									
	MADE GROUND : Concrete.									
		-1.00		1.00	1.00					
	MADE GROUND : Soft, dark brown CLAY. (Poor returns).			2.00	2.00					
				3.00	3.00					
				4.00	4.00					
				4.40					5.00	5.00
	Brown SAND and GRAVEL. (Slow penetration).		6.00	6.00						
			7.00	7.00						
			7.40						8.00	8.00
		Soft, sandy CLAY with gravel bands.							9.00	9.00
			10.00		10.00					
	-10.00									

Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test

Remarks

63mm diameter standpipe installed to 15.00m.
Water strike @ 22.00m

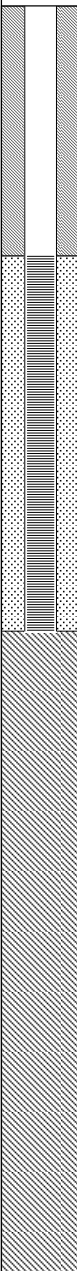
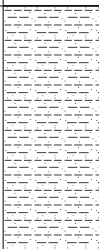
Notes

Drill bit damaged on extraction from hole.
Strong diesel odour @ 6.90m. Diesel odour @ 13.00m.

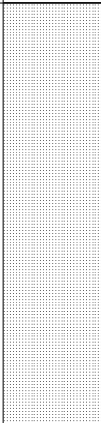
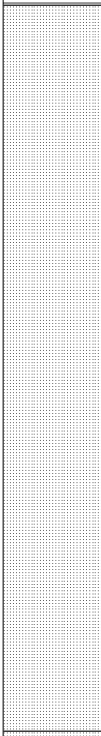
Logged by: AD

Scale:

FIG:

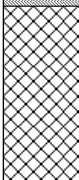
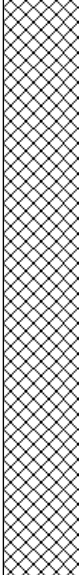
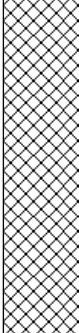
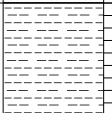
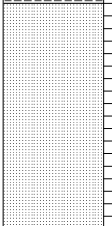
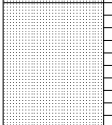
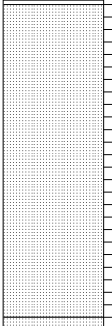
REC Geotechnical Log							Borehole: RO2		
 Resource & Environmental Consultants Ltd.			Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)						
Client: St Modwen			Ground Level:		Coordinates:		Date: 20 & 21/07/09		
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample			Test
						Type	No.		
	Soft, sandy CLAY with gravel bands.	-12.80		11.00	11.00				
				12.00	12.00				
				13.00	13.00				
				14.00	14.00				
	Brown, sandy CLAY with mudstone bands.	-17.30		15.00	15.00				
				16.00	16.00				
				17.00	17.00				
				18.00	18.00				
	Grey MUDSTONE.	-17.80		19.00	19.00				
				20.00	20.00				
	Grey SILTSTONE/SANDSTONE. (Slow penetration).								
		-20.00		20.00	20.00				

Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test			Logged by: AD	
Remarks 63mm diameter standpipe installed to 15.00m. Water strike @ 22.00m			Scale:	
Notes Drill bit damaged on extraction from hole. Strong diesel odour @ 6.90m. Diesel odour @ 13.00m.			FIG:	

REC Geotechnical Log						Borehole: RO2			
 Resource & Environmental Consultants Ltd.			Equipment and Methods: Open Hole Rig						
			Location: Coed Darcy, Neath (80132)						
Client: St Modwen			Ground Level:		Coordinates:		Date: 20 & 21/07/09		
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample			Test
						Type	No.		
	Grey SILTSTONE/SANDSTONE. (Slow penetration).	-23.40		21.00	21.00				
				22.00	22.00				
				23.00	23.00				
	Grey MUDSTONE. (Fast penetration).	-24.20		24.00	24.00				
	Grey SILTSTONE/SANDSTONE with mudstone bands. (Slow penetration).	-30.00		25.00	25.00				
				26.00	26.00				
				27.00	27.00				
				28.00	28.00				
				29.00	29.00				
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks 63mm diameter standpipe installed to 15.00m. Water strike @ 22.00m Notes Drill bit damaged on extraction from hole. Strong diesel odour @ 6.90m. Diesel odour @ 13.00m.								Logged by: AD	
								Scale:	
								FIG:	

REC Geotechnical Log							Borehole: RO2		
 Resource & Environmental Consultants Ltd.			Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)						
Client: St Modwen			Ground Level:		Coordinates:		Date: 20 & 21/07/09		
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample			Test
						Type	No.		
	Grey SILTSTONE/SANDSTONE with mudstone bands. (Slow penetration).			31.00	31.00				
				32.00	32.00				
				33.00	33.00				
				34.00	34.00				
		-35.00		35.00	35.00				
	End of Log			36.00	36.00				
				37.00	37.00				
				38.00	38.00				
				39.00	39.00				
				40.00	40.00				
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks 63mm diameter standpipe installed to 15.00m. Water strike @ 22.00m Notes Drill bit damaged on extraction from hole. Strong diesel odour @ 6.90m. Diesel odour @ 13.00m.							Logged by: AD		
							Scale:		
							FIG:		

REC Geotechnical Log						Borehole: RO3			
 Resource & Environmental Consultants Ltd.		Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)							
Client: St Modwen		Ground Level:		Coordinates:		Date: 23/07/09			
Installat ion	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample			Test
						Type	No.		
	Ground Surface	0.00		0.00	0.00				
	MADE GROUND : Compact fill.								
				1.00	1.00				
				2.00	2.00				
				3.00	3.00				
		-3.40							
	Brown CLAYS.	-3.90		4.00	4.00				
	SILTSTONE boulder. (Slow penetration).			5.00	5.00				
		-5.80		6.00	6.00				
	CLAYS with gravel beds/silts at 9.00m.			7.00	7.00				
			8.00	8.00					
			9.00	9.00					
			10.00	10.00					
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks 63mm diameter standpipe installed to 10.50m. Water encountered from 10.00m. Notes									
						Logged by: AD			
						Scale:			
						FIG:			

REC Geotechnical Log							Borehole: RO3		
 Resource & Environmental Consultants Ltd.			Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)						
Client: St Modwen			Ground Level:		Coordinates:		Date: 23/07/09		
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample			Test
						Type	No.		
    	Boulder CLAYS with gravel beds/silts at 9.00m.	-10.90		11.00	11.00				
	Grey SANDSTONE.			12.00	12.00				
		-12.90		13.00	13.00				
	Brown SANDSTONE.			14.00	14.00				
	MUDSTONE with coal traces. (Fast penetration).	-14.10		15.00	15.00				
				16.00	16.00				
				17.00	17.00				
	Brown SANDSTONE. (Slow penetration).	-17.50		18.00	18.00				
				19.00	19.00				
		-20.00		20.00	20.00				
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks 63mm diameter standpipe installed to 10.50m. Water encountered from 10.00m. Notes							Logged by: AD Scale: FIG:		

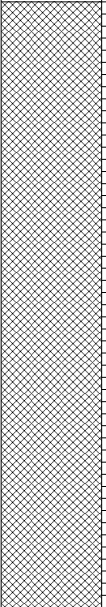
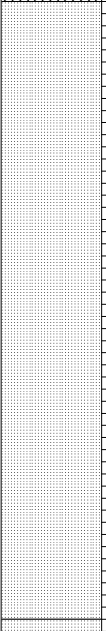
REC Geotechnical Log						Borehole: RO3			
 Resource & Environmental Consultants Ltd.		Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)							
Client: St Modwen		Ground Level:		Coordinates:			Date: 23/07/09		
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample			Test
						Type	No.		
	Brown SANDSTONE. (Slow penetration).	-21.10		21.00	21.00				
	Grey MUDSTONE.			22.00	22.00				
				23.00	23.00				
		Brown SANDSTONE. (Slow penetration).	-23.70		24.00	24.00			
				25.00	25.00				
				26.00	26.00				
				27.00	27.00				
				28.00	28.00				
				29.00	29.00				
				30.00	30.00				
	-30.00								
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks 63mm diameter standpipe installed to 10.50m. Water encountered from 10.00m. Notes								Logged by: AD Scale: FIG:	

REC Geotechnical Log							Borehole: RO3		
 Resource & Environmental Consultants Ltd.			Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)						
Client: St Modwen			Ground Level:		Coordinates:		Date: 23/07/09		
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample			Test
						Type	No.		
	Brown SANDSTONE. (Slow penetration.			31.00 32.00 33.00 34.00 35.00 36.00 37.00 38.00 39.00 40.00	31.00 32.00 33.00 34.00 35.00 36.00 37.00 38.00 39.00 40.00				
	End of Log	-35.00							
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks 63mm diameter standpipe installed to 10.50m. Water encountered from 10.00m. Notes							Logged by: AD Scale: FIG:		

REC Geotechnical Log						Borehole: RO4		
 Resource & Environmental Consultants Ltd.		Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)						
Client: St Modwen		Ground Level:		Coordinates:		Date: 21/07/09		
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records
					Depth	Sample Type No.	Test	
	Ground Surface	0.00		0.00	0.00			
	MADE GROUND : GRAVEL/CLAY fill.	-0.50						
	Grey SANDSTONE.							
				1.00	1.00			
				2.00	2.00			
				3.00	3.00			
				4.00	4.00			
				5.00	5.00			
				6.00	6.00			
				7.00	7.00			
			8.00	8.00				
			9.00	9.00				
		-10.10		10.00	10.00			
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks Notes						Logged by: AD		
						Scale:		
						FIG:		

REC Geotechnical Log							Borehole: RO4		
 Resource & Environmental Consultants Ltd.			Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)						
Client: St Modwen			Ground Level:		Coordinates:		Date: 21/07/09		
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample			Test
						Type	No.		
	Grey SANDSTONE.								
				11.00	11.00				
				12.00	12.00				
				13.00	13.00				
				14.00	14.00				
				15.00	15.00				
				16.00	16.00				
				17.00	17.00				
				18.00	18.00				
				19.00	19.00				
		-20.20		20.00	20.00				
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks Notes							Logged by: AD		
							Scale:		
							FIG:		

REC Geotechnical Log						Borehole: RO4		
 Resource & Environmental Consultants Ltd.		Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)						
Client: St Modwen		Ground Level:		Coordinates:		Date: 21/07/09		
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records
					Depth	Sample Type No.	Test	
	Grey SANDSTONE.	-21.00						
	Grey MUDSTONE with sandstone bands.			21.00	21.00			
				22.00	22.00			
				23.00	23.00			
				24.00	24.00			
				25.00	25.00			
				26.00	26.00			
				27.00	27.00			
				28.00	28.00			
				29.00	29.00			
			-30.00		30.00	30.00		
	End of Log							
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks Notes						Logged by: AD Scale: FIG:		

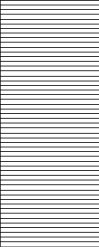
REC Geotechnical Log						Borehole: RO5			
 Resource & Environmental Consultants Ltd.		Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)							
Client: St Modwen		Ground Level:		Coordinates:		Date: 21/07/09			
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample Type No.	Test		
	Ground Surface	0.00		0.00	0.00				
	MADE GROUND : GRAVEL/SOIL/CLAY fill.			1.00	1.00				
					2.00				2.00
					3.00				3.00
					4.00				4.00
					5.00				5.00
					6.00				6.00
					7.00				7.00
					8.00				8.00
					9.00				9.00
				10.00	10.00				
	Grey SANDSTONE with mudstone bands.	-5.00		5.00					
					6.00				
					7.00				
					8.00				
					9.00				
					10.00				
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test						Logged by: AD			
Remarks						Scale:			
Notes						FIG:			

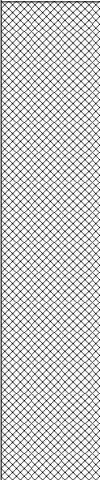
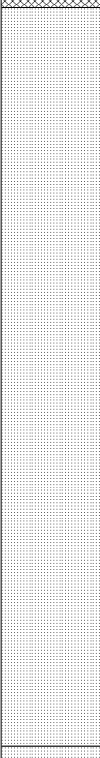
REC Geotechnical Log							Borehole: RO5		
 Resource & Environmental Consultants Ltd.			Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)						
Client: St Modwen			Ground Level:		Coordinates:		Date: 21/07/09		
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample	Test		
	Grey SANDSTONE with mudstone bands.					Type	No.		
				11.00	11.00				
				12.00	12.00				
				13.00	13.00				
				14.00	14.00				
				15.00	15.00				
				16.00	16.00				
				17.00	17.00				
				18.00	18.00				
				19.00	19.00				
		-20.20		20.00	20.00				
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks Notes							Logged by: AD		
							Scale:		
							FIG:		

REC Geotechnical Log						Borehole: RO5			
 Resource & Environmental Consultants Ltd.		Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)							
Client: St Modwen		Ground Level:		Coordinates:			Date: 21/07/09		
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample	Test		
	Grey SANDSTONE with mudstone bands.	-21.00							
	Grey SANDSTONE with mudstone bands.			21.00	21.00				
				22.00	22.00				
				23.00	23.00				
				24.00	24.00				
				25.00	25.00				
				26.00	26.00				
				27.00	27.00				
				28.00	28.00				
				29.00	29.00				
		-30.00		30.00	30.00				
	End of Log								
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks Notes						Logged by: AD			
						Scale:			
						FIG:			

REC Geotechnical Log						Borehole: RO6			
 Resource & Environmental Consultants Ltd.		Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)							
Client: St Modwen		Ground Level:		Coordinates:		Date: 22/07/09			
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample			Test
						Type	No.		
	Ground Surface	0.00		0.00	0.00				
	MADE GROUND : GRAVEL/STONE/CLAY.			1.00	1.00				
				2.00	2.00				
		-2.50							
	MADE GROUND : SANDSTONE boulder.	-3.00		3.00	3.00				
	MADE GROUND : GRAVEL/CLAY fill.			4.00	4.00				
				5.00	5.00				
		-5.50		6.00	6.00				
	Grey SANDSTONE with mudstone bands.			7.00	7.00				
				8.00	8.00				
			9.00	9.00					
		-10.00		10.00	10.00				
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks Water encountered from 18.00m to 24.00m Notes						Logged by: AD Scale: FIG:			

REC Geotechnical Log							Borehole: RO6		
 Resource & Environmental Consultants Ltd.			Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)						
Client: St Modwen			Ground Level:		Coordinates:		Date: 22/07/09		
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample			Test
						Type	No.		
	Grey SANDSTONE with mudstone bands.								
				11.00	11.00				
				12.00	12.00				
				13.00	13.00				
				14.00	14.00				
				15.00	15.00				
				16.00	16.00				
				17.00	17.00				
				18.00	18.00				
				19.00	19.00				
		-20.00		20.00	20.00				
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks Water encountered from 18.00m to 24.00m Notes								Logged by: AD	
								Scale:	
								FIG:	

REC Geotechnical Log							Borehole: RO6							
 Resource & Environmental Consultants Ltd.			Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)											
Client: St Modwen			Ground Level:		Coordinates:		Date: 22/07/09							
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records						
					Depth	Sample			Test					
						Type	No.							
	Grey SANDSTONE with mudstone bands.	-21.60 -22.00		21.00	21.00									
	COAL with fine mudstone trace.			22.00	22.00									
	Grey MUDSTONE.			23.00	23.00									
	End of Log	-24.00		24.00	24.00									
				25.00	25.00									
				26.00	26.00									
				27.00	27.00									
				28.00	28.00									
				29.00	29.00									
				30.00	30.00									
				Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test					Logged by: AD					
				Remarks Water encountered from 18.00m to 24.00m					Scale:					
Notes					FIG:									

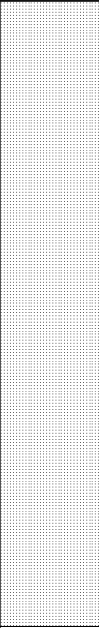
REC Geotechnical Log						Borehole: RO7			
 Resource & Environmental Consultants Ltd.		Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)							
Client: St Modwen		Ground Level:		Coordinates:		Date: 24/07/09			
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample			Test
						Type	No.		
	Ground Surface	0.00		0.00	0.00				
	MADE GROUND : CLAY/SOIL/GRAVEL fill.			1.00	1.00				
	Grey SANDSTONE.	-4.00		2.00	2.00				
				3.00	3.00				
				4.00	4.00				
				5.00	5.00				
				6.00	6.00				
				7.00	7.00				
				8.00	8.00				
				9.00	9.00				
				-10.10	10.00				
				Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks Hydrocarbon odour in fill to 4.00m. Notes Logged by: AD Scale: FIG:					

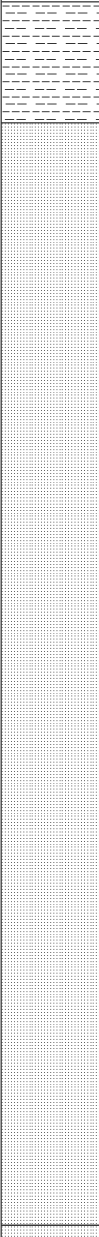
REC Geotechnical Log							Borehole: RO7		
 Resource & Environmental Consultants Ltd.			Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)						
Client: St Modwen			Ground Level:		Coordinates:		Date: 24/07/09		
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample			Test
						Type	No.		
	Grey SANDSTONE.								
				11.00	11.00				
				12.00	12.00				
				13.00	13.00				
				14.00	14.00				
				15.00	15.00				
				16.00	16.00				
				17.00	17.00				
				18.00	18.00				
				19.00	19.00				
		-20.20		20.00	20.00				
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks Hydrocarbon odour in fill to 4.00m. Notes							Logged by: AD		
							Scale:		
							FIG:		

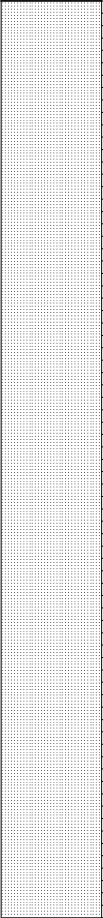
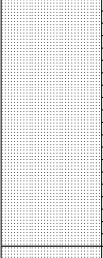
REC Geotechnical Log							Borehole: RO7		
 Resource & Environmental Consultants Ltd.			Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)						
Client: St Modwen			Ground Level:		Coordinates:		Date: 24/07/09		
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample			Test
						Type	No.		
	Grey SANDSTONE.			21.00	21.00				
				22.00	22.00				
				23.00	23.00				
				24.00	24.00				
				25.00	25.00				
				26.00	26.00				
	COAL.	-26.20							
	Grey SANDSTONE with mudstone bands.	-26.50							
				27.00	27.00				
				28.00	28.00				
			29.00	29.00					
			30.00	30.00					
	End of Log	-30.00							
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks Hydrocarbon odour in fill to 4.00m. Notes							Logged by: AD Scale: FIG:		

REC Geotechnical Log						Borehole: RO8			
 Resource & Environmental Consultants Ltd.		Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)							
Client: St Modwen		Ground Level:		Coordinates:		Date: 23/07/09			
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample			Test
						Type	No.		
	Ground Surface	0.00		0.00	0.00				
	MADE GROUND : STONE fill.	-0.30							
	Brown SANDSTONE.			1.00	1.00				
				2.00	2.00				
				3.00	3.00				
				4.00	4.00				
	Grey SANDSTONE.	-4.10		5.00	5.00				
				6.00	6.00				
				7.00	7.00				
				8.00	8.00				
			9.00	9.00					
			10.00	10.00					
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test						Logged by: AD			
Remarks						Scale:			
Notes						FIG:			

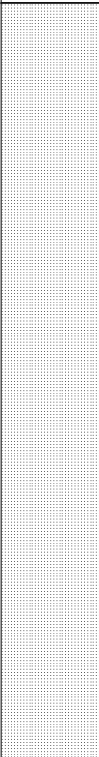
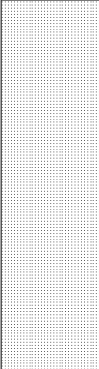
REC Geotechnical Log							Borehole: RO8			
 Resource & Environmental Consultants Ltd.			Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)							
Client: St Modwen			Ground Level:		Coordinates:		Date: 23/07/09			
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records		
					Depth	Sample Type No.	Test			
	Grey SANDSTONE.									
				11.00	11.00					
				12.00	12.00					
		-12.80								
	COAL.	-13.10		13.00	13.00					
	Grey SANDSTONE.									
		-13.70								
	COAL.	-13.90		14.00	14.00					
	Grey SANDSTONE.									
		-14.50								
	COAL.	-14.70		15.00	15.00					
	Grey SANDSTONE.									
				16.00	16.00					
				17.00	17.00					
				18.00	18.00					
				19.00	19.00					
			-20.00							
				20.00	20.00					
	Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks Notes								Logged by: AD Scale: FIG:	

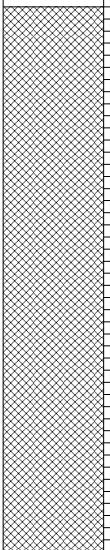
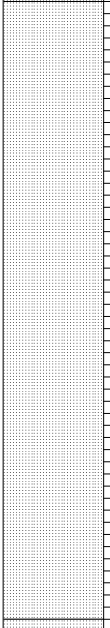
REC Geotechnical Log							Borehole: RO8								
 Resource & Environmental Consultants Ltd.			Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)												
Client: St Modwen			Ground Level:		Coordinates:		Date: 23/07/09								
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records							
					Depth	Sample			Test						
						Type	No.								
	Grey SANDSTONE.	-25.00		21.00	21.00										
	22.00			22.00											
	23.00			23.00											
	24.00			24.00											
	25.00			25.00											
	26.00			26.00											
	27.00			27.00											
	28.00			28.00											
	29.00			29.00											
	30.00			30.00											
	End of Log														
	Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks Notes									Logged by: AD Scale: FIG:					

REC Geotechnical Log						Borehole: RO9			
 Resource & Environmental Consultants Ltd.		Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)							
Client: St Modwen		Ground Level:		Coordinates:		Date: 27/07/09			
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample Type No.	Test		
	Ground Surface	0.00		0.00	0.00				
	Brown CLAY.								
		-1.00		1.00	1.00				
	Grey SANDSTONE.			2.00	2.00				
				3.00	3.00				
				4.00	4.00				
				5.00	5.00				
				6.00	6.00				
				7.00	7.00				
				8.00	8.00				
		9.00	9.00						
		-10.10		10.00	10.00				
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks Water encountered from 18.00m to 19.00m, and from 33.00m to 34.00m Hole backfilled with bentonite on completion. Notes								Logged by: AD Scale: FIG:	

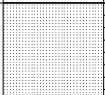
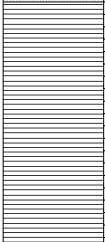
REC Geotechnical Log							Borehole: RO9			
 Resource & Environmental Consultants Ltd.			Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)							
Client: St Modwen			Ground Level:		Coordinates:		Date: 27/07/09			
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records		
					Depth	Sample Type No.	Test			
	Grey SANDSTONE.			11.00	11.00					
				12.00	12.00					
				13.00	13.00					
				14.00	14.00					
				15.00	15.00					
				16.00	16.00					
				17.00	17.00					
		-17.50								
	Grey MUDSTONE.				18.00	18.00				
		-18.20								
Grey SANDSTONE.			19.00	19.00						
			20.00	20.00						
	-20.20									
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks Water encountered from 18.00m to 19.00m, and from 33.00m to 34.00m Hole backfilled with bentonite on completion. Notes							Logged by: AD Scale: FIG:			

REC Geotechnical Log						Borehole: RO9			
 Resource & Environmental Consultants Ltd.		Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)							
Client: St Modwen		Ground Level:		Coordinates:		Date: 27/07/09			
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample			Test
						Type	No.		
	Grey SANDSTONE.								
				21.00	21.00				
				22.00	22.00				
				23.00	23.00				
				24.00	24.00				
				25.00	25.00				
				26.00	26.00				
				27.00	27.00				
				28.00	28.00				
				29.00	29.00				
				30.00	30.00				
		-30.30							
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks Water encountered from 18.00m to 19.00m, and from 33.00m to 34.00m Hole backfilled with bentonite on completion. Notes								Logged by: AD Scale: FIG:	

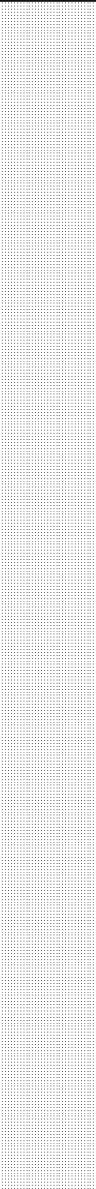
REC Geotechnical Log						Borehole: RO9			
 Resource & Environmental Consultants Ltd.			Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)						
Client: St Modwen			Ground Level:		Coordinates:		Date: 27/07/09		
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample			Test
						Type	No.		
	Grey SANDSTONE.			31.00	31.00				
				32.00	32.00				
				33.00	33.00				
				34.00	34.00				
				35.00	35.00				
			36.00	36.00					
		-36.40							
	Grey MUDSTONE.								
		-37.00		37.00	37.00				
	Grey SANDSTONE.			38.00	38.00				
				39.00	39.00				
			-40.00		40.00	40.00			
		End of Log							
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test									
Remarks Water encountered from 18.00m to 19.00m, and from 33.00m to 34.00m Hole backfilled with bentonite on completion. Notes						Logged by: AD			
						Scale:			
						FIG:			

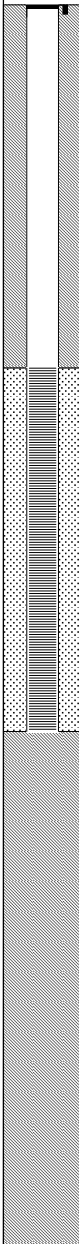
REC Geotechnical Log						Borehole: RO11			
 Resource & Environmental Consultants Ltd.			Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)						
Client: St Modwen			Ground Level:		Coordinates:		Date: 29/07/09		
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample			Test
						Type	No.		
	Ground Surface	0.00		0.00	0.00				
	MADE GROUND : Sandy CLAY with gravel.			1.00	1.00				
				2.00	2.00				
				3.00	3.00				
				4.00	4.00				
	Grey, weathered SANDSTONE.	-4.50							
	Grey SANDSTONE.	-5.00		5.00	5.00				
					6.00				6.00
					7.00				7.00
					8.00				8.00
					9.00				9.00
-10.10					10.00	10.00			
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test									
Remarks Water encountered from 18.00m to 50.00m. Hole backfilled with bentonite on completion. Notes Hydrocarbon odour from 0.50m.						Logged by: AD			
						Scale:			
						FIG:			

REC Geotechnical Log						Borehole: RO11			
 Resource & Environmental Consultants Ltd.		Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)							
Client: St Modwen		Ground Level:		Coordinates:		Date: 29/07/09			
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample			Test
						Type	No.		
	Grey SANDSTONE.								
				11.00	11.00				
				12.00	12.00				
				13.00	13.00				
				14.00	14.00				
				15.00	15.00				
				16.00	16.00				
				17.00	17.00				
				18.00	18.00				
				19.00	19.00				
		-20.20		20.00	20.00				
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks Water encountered from 18.00m to 50.00m. Hole backfilled with bentonite on completion. Notes Hydrocarbon odour from 0.50m.						Logged by: AD			
						Scale:			
						FIG:			

REC Geotechnical Log						Borehole: RO11						
 Resource & Environmental Consultants Ltd.			Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)									
Client: St Modwen			Ground Level:		Coordinates:		Date: 29/07/09					
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records				
					Depth	Sample			Test			
						Type	No.					
	Grey SANDSTONE.	-21.00		21.00	21.00							
	Grey MUDSTONE.			22.00	22.00							
	Grey SANDSTONE.	-23.00		23.00	23.00							
				24.00	24.00							
				25.00	25.00							
				26.00	26.00							
				27.00	27.00							
				28.00	28.00							
				29.00	29.00							
				30.00	30.00							
				-30.30								
				Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks Water encountered from 18.00m to 50.00m. Hole backfilled with bentonite on completion. Notes Hydrocarbon odour from 0.50m.								Logged by: AD Scale: FIG:

REC Geotechnical Log						Borehole: RO11			
 Resource & Environmental Consultants Ltd.		Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)							
Client: St Modwen		Ground Level:		Coordinates:		Date: 29/07/09			
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample			Test
						Type	No.		
	Grey SANDSTONE.								
				31.00	31.00				
				32.00	32.00				
				33.00	33.00				
				34.00	34.00				
				35.00	35.00				
				36.00	36.00				
				37.00	37.00				
				38.00	38.00				
				39.00	39.00				
				40.00	40.00				
		-40.40							
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks Water encountered from 18.00m to 50.00m. Hole backfilled with bentonite on completion. Notes Hydrocarbon odour from 0.50m.						Logged by: AD			
						Scale:			
						FIG:			

REC Geotechnical Log						Borehole: RO11			
 Resource & Environmental Consultants Ltd.		Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)							
Client: St Modwen		Ground Level:		Coordinates:		Date: 29/07/09			
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample Type No.	Test		
	Grey SANDSTONE.			41.00	41.00				
				42.00	42.00				
				43.00	43.00				
				44.00	44.00				
				45.00	45.00				
				46.00	46.00				
				47.00	47.00				
				48.00	48.00				
				49.00	49.00				
				-50.00	50.00				
				50.00	50.00				
				End of Log					
	Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks Water encountered from 18.00m to 50.00m. Hole backfilled with bentonite on completion. Notes Hydrocarbon odour from 0.50m.								Logged by: AD Scale: FIG:

REC Geotechnical Log						Borehole: RO12			
 Resource & Environmental Consultants Ltd.			Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)						
Client: St Modwen			Ground Level:		Coordinates:		Date: 27 & 28/07/09		
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample			Test
						Type	No.		
	Ground Surface	0.00		0.00	0.00				
	MADE GROUND : SAND and GRAVEL fill.			1.00	1.00				
				2.00	2.00				
				3.00	3.00				
				4.00	4.00				
				5.00	5.00				
				6.00	6.00				
		-7.00		7.00	7.00				
	Brown SANDSTONE.			8.00	8.00				
		-9.20		9.00	9.00				
	Grey SANDSTONE.			10.00	10.00				
		-10.10							
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test									Logged by: AD Scale: FIG:
Remarks Water encountered from 1.00m to 50.00m. Strong odour from 1.00m to 7.00m. 63mm diameter standpipe installed to 6.00m									
Notes									

REC Geotechnical Log							Borehole: RO12		
 Resource & Environmental Consultants Ltd.			Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)						
Client: St Modwen			Ground Level:		Coordinates:		Date: 27 & 28/07/09		
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample			Test
						Type	No.		
	Grey SANDSTONE.			11.00	11.00				
				12.00	12.00				
				13.00	13.00				
				14.00	14.00				
				15.00	15.00				
				16.00	16.00				
				17.00	17.00				
				18.00	18.00				
				19.00	19.00				
				20.00	20.00				
				-20.20					
				Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks Water encountered from 1.00m to 50.00m. Strong odour from 1.00m to 7.00m. 63mm diameter standpipe installed to 6.00m Notes					

REC Geotechnical Log							Borehole: RO12		
 Resource & Environmental Consultants Ltd.			Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)						
Client: St Modwen			Ground Level:		Coordinates:		Date: 27 & 28/07/09		
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample			Test
						Type	No.		
	Grey SANDSTONE.			21.00	21.00				
				22.00	22.00				
				23.00	23.00				
				24.00	24.00				
				25.00	25.00				
				26.00	26.00				
				27.00	27.00				
				28.00	28.00				
				29.00	29.00				
				30.00	30.00				
					-30.30				
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks Water encountered from 1.00m to 50.00m. Strong odour from 1.00m to 7.00m. 63mm diameter standpipe installed to 6.00m Notes							Logged by: AD Scale: FIG:		

REC Geotechnical Log							Borehole: RO12			
 Resource & Environmental Consultants Ltd.				Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)						
Client: St Modwen				Ground Level:		Coordinates:		Date: 27 & 28/07/09		
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records		
					Depth	Sample			Test	
						Type	No.			
	Grey SANDSTONE.			31.00	31.00					
				32.00	32.00					
				33.00	33.00					
				34.00	34.00					
				35.00	35.00					
				36.00	36.00					
				37.00	37.00					
		-37.60								
	Grey MUDSTONE.	-38.00		38.00	38.00					
	Grey SANDSTONE.			39.00	39.00					
				40.00	40.00					
		-40.40								
	Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks Water encountered from 1.00m to 50.00m. Strong odour from 1.00m to 7.00m. 63mm diameter standpipe installed to 6.00m Notes									Logged by: AD Scale: FIG:

REC Geotechnical Log						Borehole: RO12			
 Resource & Environmental Consultants Ltd.		Equipment and Methods: Open Hole Rig Location: Coed Darcy, Neath (80132)							
Client: St Modwen		Ground Level:		Coordinates:		Date: 27 & 28/07/09			
Installation	Description	Reduced	Legend	Depth (m)	Sample/Tests			Field Records	
					Depth	Sample			Test
						Type	No.		
	Grey SANDSTONE.			41.00	41.00				
				42.00	42.00				
				43.00	43.00				
				44.00	44.00				
				45.00	45.00				
				46.00	46.00				
				47.00	47.00				
				48.00	48.00				
				49.00	49.00				
				50.00	50.00				
	Grey MUDSTONE.	-47.00		47.00	47.00				
				48.00	48.00				
				49.00	49.00				
				50.00	50.00				
	End of Log	-50.00							
Notes:U-undisturbed B-bulk D-disturbed SPT-standard penetration test U-U100 CPT-cone penetration test Remarks Water encountered from 1.00m to 50.00m. Strong odour from 1.00m to 7.00m. 63mm diameter standpipe installed to 6.00m Notes						Logged by: AD Scale: FIG:			

Coed Darcy Urban Village
DiMe Area
Controlled Waters Risk
Assessment

Coed Darcy Urban Village DiMe Area Controlled Waters Risk Assessment

August 2010

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Glossary of Terms

Term	Meaning / Definition
BTEX	Benzene, Toluene, Ethyl benzene and Xylenes
CSM	Conceptual Site Model
DiMe	blend of dichloromethane, 'DCM' or Me), and 1,2-dichloroethane (or 'DCA' or Di, hence 'Di-Me' plant)
DNAPL	Dense Non-Aqueous Phase Liquid
DWS	Drinking Water Standard
EAL	Environmentally Acceptable Limit
EQS	Environmental Quality Standard
K_d	Partition coefficient
K_{oc}	Partition coefficient to organic carbon
LNAPL	Light Non-Aqueous Phase Liquid
LoD	Limit of Detection
mAOD	metres Above Ordinance Datum
mbgl	metres below ground levels
NAPL	Non-Aqueous Phase Liquid
SSSI	Sites of Special Scientific Interest
TPH	Total Petroleum Hydrocarbon
WHO	World Health Organisation
WQS	Water Quality Standard

1. Introduction

1.1 Overview

Atkins Limited (Atkins) has been commissioned by St Modwen Developments Ltd to undertake a Controlled Waters Risk Assessment for contamination within the area of the former DiMe plant at the historical BP Llandarcy refinery, which is currently under redevelopment as Coed Darcy Urban Village. The former refinery is located close to junction 43 of the M4, west of the town of Neath in South Wales. The area referred to as the DiMe area is located in the northern portion of the Llandarcy site adjoining the northern railhead (Figure 1). The area is generally flat and, at the time of writing, is covered by demolition rubble and floor slabs from the demolished DiMe plant.

At the time of writing, it is anticipated that the DiMe is to be redeveloped as a series of sports pitches within the final development.

1.2 Objectives

The objectives of this report are to:

- Produce a conceptual site model (CSM) of the DiMe site summarising the likely pathway linkages for contamination sources at the site to impact controlled waters receptors; and
- Produce a controlled waters risk assessment for the DiMe site.

This report presents remedial targets for those substances considered to pose a risk to controlled waters. An assessment of potential risks to human health across this area has been undertaken under a separate cover. A discussion of potential remedial options, based on the findings of both the controlled waters and human health risk assessments is outside of the scope of this report and will be reported separately

1.3 Limitations

The study was conducted and this report prepared by the Atkins is for the sole use of St Modwen Developments Ltd. This report shall not be relied upon or transferred to any other parties. If an unauthorised third party comes into possession of this report, they rely on its contents at their own risk.

The findings and opinions conveyed via this report are based on information obtained from a variety of sources as detailed within this report, and which Atkins believes are reliable. Nevertheless, Atkins cannot and does not guarantee the authenticity or reliability of the information. No attempt has been made to verify independently any data collected by others from other sources.

As with all assessments of this type, a great deal of emphasis is placed on results of chemical analyses, which have been undertaken according to established protocols. It is possible that the ground investigation and assessment carried out, whilst appropriate to comply with the agreed brief, may not indicate the full extent of conditions beneath the site and the existence of other important information sources. Hence, it should be noted that there might be areas of undetected contamination or environmental media, which, if sampled, may be of concern.

The potential for alternative pathways for contaminants to reach controlled waters receptors have not been directly considered in the risk assessments provided. These alternative pathways could be via culverts/drains and service pathways through the site. These potential pathways will be addressed separately as part of the remediation/redevelopment of this area as proposed

1.4 Report Structure

Section 2 of this report presents a summary of the historical land-use and nature of the surrounding area relating to the DiMe site as a whole, and is written in the context of previous knowledge of the site.

Section 3 of this report presents a summary of historical and supplementary site investigations, with specific reference to historical reports. Furthermore, a summary of the boreholes carried forward in this assessment and an appraisal of ground gas is also discussed in this section.

Section 4 of this report presents the conceptual site model for the site. This draws on existing knowledge of the geology, hydrogeology, hydrology and contamination data relating to the site, and is based on published documents, ground investigation and monitoring data.

The Controlled Waters Risk Assessment is presented in Section 5 and is based on the findings of Section 4. The model methodology, parameterisation and results are summarised in this section.

Section 6 provides a detailed discussion of the results of the risk assessment and their implications for the future impacts of the site on Controlled Waters.

2. Site Land Use and Surrounding Area

2.1 Land Use

The DiMe area is associated with former oil refinery operations, and represents the area where one of the final stages in the production of lubrication oils took place. The historical site layout (1978) plan of the refinery shows the area to include a kerosene extraction plant, boiler houses, storage tanks, a sub-station, pump separator and office buildings.

2.2 Surrounding Area

The area directly around the DiMe area is all part of the BP Llandarcy site, directly north of the DiMe area is a railway cutting approximately 13m deep, and north of this the North Site Reservoir. Historical plans show that before demolition there were storage tanks and industrial buildings situated adjacent to the reservoir, there was a caustic soda plant and acid washer to the east of the DiMe area, with numerous storage tanks and industrial buildings to the west and south of the DiMe area. Directly south of the BP Llandarcy site is Llandarcy village which predominantly comprises residential dwellings.

2.3 Brief History of the Site

The URS, DiMe Investigation Summary report, 2008 (Ref. 1) summarises the site history as:

The DiMe plant is a term used to describe the facility at the BP Llandarcy refinery where one of the final stages in the production of lube oil took place. The facility was constructed in the early 1970s and remained operational until lube oil production ceased in 1998. Hot solvent, a blend of methylene chloride (dichloromethane, 'DCM' or Me), and 1,2-dichloroethane (or 'DCA' or Di, hence 'Di-Me' plant) was used to extract waxy materials from the lubricating oil. The resultant effluent stream was then passed through filter and chilling units to recover the wax, and the solvent recycled and reused. Prior to use, solvent was stored in three tanks. The quantity of solvent used remains unclear.

Site personnel have reported that solvent loss occurred at the storage tanks during filling, through gradual leakage, and occasionally larger scale events at the filters and chiller units, which, it is believed, operated under considerable pressure. Demolition of the above-ground structures of the DiMe area commenced in 2000.

3. Site Investigations

3.1 Previous Site Works

The Llandarcy site has been subject to intensive investigation and assessment by the previous site owners BP, since approximately 1997. As a result there are a significant number of boreholes installed into Made Ground, Crymlyn Bog Sequence, Glacial Drift and Pennant Sandstone. Many of these boreholes have been sampled and monitored frequently since installation.

Table 3.1 - Summary of Previous Investigations by URS

Report Type	Reference and Date	Location	Details
URS: Factual and Interpretative: Environmental Liability Assessment	2048R/2049R September 1997	BP Llandarcy Site	Assessed the identification of potential liabilities following the merger of BP with Mobil
URS: Phase 2 Stage 1 data report	R642 August 1998	BP Llandarcy Site	Following the desktop study, phased site investigation undertaken
URS: Phase 2 Stage 2 final data report	DR785 July 1999	BP Llandarcy Site	Expansion of the stage 1 work to include issues at the site boundaries
URS: Final Data Assessment Report	DR786R August 1999	BP Llandarcy Site	An interpretation of all data collected in stages 1 & 2, included an assessment of potential risks to sensitive receptors around the site.
URS: Remedial Action Plan (RAP)	DR869r3 March 2000	BP Llandarcy Site	This presented remedial options for addressing cross boundary contamination identified at the sensitive boundaries of the site.
URS: Routine groundwater monitoring	September 2000 - ongoing	BP Llandarcy Site	Routine groundwater monitoring to assess the potential for natural attenuation of contaminants to occur within the site, routine dipping of wells to assess the presence of free phase hydrocarbons.
URS: Site Investigation Phase I area	DR1140 September 2003	BP Llandarcy Site	URS undertook a gap analysis of the proposed phase I area

3.2 Supplementary Site Works (2009)

REC Limited was appointed as the Contractor for ground investigations which were undertaken by Atkins between 13th July and 3rd August 2009. Site operations were carried out in accordance with 'Site Investigation in Construction, Volume 3, Specification for Ground Investigation', (Ref. 2).

A total of 13 No. cable percussion boreholes designated DM3-DM4, DM7-DM8, DM10, DM13, DM15-DM16 and DV1-DV5, were drilled across the DiMe site to supplement existing ground investigation data. In addition to the cable percussion boreholes, 9 rotary open hole boreholes designated, DV2B, DME2, DME5, DME6, DME9, DME11, DME17, DME19 and DME20 were also installed. A borehole location plan is presented on Figure 2 detailing the relative positions of each borehole installed on the DiMe area.

Based upon the concentrations of recorded solvents, part of the former DiMe has been classified as an 'exclusion area' by previous assessment. As a result, occupiable structures are not permitted overlying this area within the final development. A number of the boreholes are installed within the 'DiMe exclusion area'. These included DM6, DM9, and DE11. Boreholes DME5 and DME17 were installed to the west of the DiMe exclusion area, while DME2 was installed directly north of the exclusion area.

A further 2 No. boreholes were installed down hydraulic gradient to the north east of the DiMe area. These boreholes are SBH07 and SBH08. These two boreholes were installed to further constrain hydrogeological conditions and identify contaminants leaving the site in groundwater.

Figure 2 shows the locations of boreholes for which logs are available from across the DiMe area from all the phases of site investigation.

4. Conceptual Model

This section presents the information used to derive the conceptual model of the site using the available site investigation data and published sources. Where relevant the data have been contoured using Surfer 8.05 software using linear interpolation to show spatial patterns of strata or groundwater and presented as figures (3 to 9). This method of interpolation is considered justifiable given the relatively small number of monitoring points available for each geological/hydrogeological unit.

4.1 Geology

4.1.1 Regional Geology

Reference has been made to the British Geological Survey Sheet for Swansea (Sheet 247) Drift Edition (Ref. 3) which indicates that the area is underlain by Glacial Drift (undifferentiated) overlying rocks belonging to the Carboniferous, Upper Pennant Measures, part of the South Wales coalfield. No geological faults crossing the DiMe area are shown on the geological map.

4.1.2 Local Geology

A review of historical and supplementary boreholes present within the boundary of the proposed site has been undertaken and a summary of the local geology is presented in Table 4.1. Appendix A presents the borehole logs available for the DiMe area.

Table 4.1 - Summary of Local Geology Underlying the DiMe area

Lithology	Primary Composition	Secondary Composition	Thickness	
			Min.	Max.
Made Ground	Concrete Loose brown – black sandy fine to medium GRAVEL, Loose clayey, sandy GRAVEL with rubble, Loose grey –black fine to coarse silty GRAVEL Loose orange-brown SAND Black-orange-brown sandy –silty CLAY	Gravel and cobbles of brick , clinker, sandstone, wood fragments, with ash, slag, polystyrene foam.	0.1m	4.8m
Granular Drift Deposits Sand and Gravels	Dense grey / greenish grey coarse GRAVEL Very loose to medium dense brown-grey silty sandy GRAVEL Loose grey gravelly SAND	Gravel is typically sub-rounded to sub-angular.	0	4.1m

Lithology	Primary Composition	Secondary Composition	Thickness	
			Min.	Max.
Cohesive Drift Deposits Silty or Clayey Sands and Gravels	Firm reddish-brown / black slightly gravelly CLAY Loose dark grey very silty CLAY with cobbles Loose dark grey- dark brown sandy silty CLAY with cobbles Stiff dark grey CLAY with gravel and cobbles	Gravel is rounded to sub-angular, there are angular to sub-rounded cobbles of sandstone Cobbles are rounded predominantly of sandstone though some mudstone cobbles present (weathered bedrock)	1.6m	19.2m
Bedrock	Strong, grey fine -coarse grained SANDSTONE Soft, light brown SILTSTONE Grey-brown silty MUDSTONE	Occasional coal bands, thin interbedded bands of siltstone,	thickness not proven > 18.9m	

The interpretation of the Drift geology presented above represents a change in the previous interpretation of the main Drift into two layers (A and B) in the URS reporting (Ref. 1). There is a general trend for an increasing clayey content to the Drift with depth. However the trend does not seemingly permit an easy division except at a shallow depth where in places predominantly granular deposits are described from the borehole logs. The previous division of the Drift into A and B has therefore not been carried forward in this report. Granular Drift from here on refers to the patchy extent of largely granular deposits sandwiched between the Made Ground and the deeper Cohesive Drift. There are some granular bands noted on some boreholes logs within the Cohesive Drift, however these have not been found to be consistent across the site and have been considered likely to represent isolated lenses based on the boreholes evidence and lack of groundwater seepages into the railway cutting, and therefore unlikely to provide pathways off-site.

Some of the borehole records indicate that there is a weathered zone at the top of the bedrock. This has not been reported in all the boreholes, probably due to the rotary drilling methods not being sensitive to such layers, however this weathered horizon is considered likely to exist across the entire site.

The following succession of strata is therefore interpreted as being present across the DiMe area:

- **Made Ground** generally comprising concrete and coarse grained fill material predominantly of ash clinker and brick.
- **Granular Drift Deposits** which are patchy in extent, comprising slightly silty sands and gravels.
- **Cohesive Drift Deposits** comprising more cohesive stiff grey brown clays and silts with varying proportions of gravel, cobbles and boulders.
- **Coal Measures Strata** underlie the Drift deposits and comprise inter bedded sandstones, siltstones and mudstones with occasional traces of coal. The top of the coal measures strata are weathered.

4.1.2.1 Geological Structure (Bedrock)

The DiMe site, as mentioned previously, is largely flat and occupies the lowest of a number of terraces up the side of the hill in the central area of the former Llandarcy refinery site. The thickness of the Drift deposits varies across the terrace the DiMe plant was built upon, thickening

away from southern boundary of the DiMe Area with bedrock being encountered at depths of as little as 6mbgl (below ground level) along the southern DiMe boundary (Borehole MSMW64d) and as deep as 19.7mbgl (Borehole MSMW66d) further north.

The elevation of the top of bedrock, shown as contours in Figure 3, indicates that bedrock generally varies between 20 and 25mAOD (metres Above Ordinance Datum) across most of the site with some variations including a ridge like feature running east-west along the northern boundary.

There is variation in the bedrock rock types encountered across the DiMe site; sandstones predominate, with layers of siltstone, mudstone and minor coal seams also recorded in some borehole logs. The rock types described are all consistent with the bedrock being part of the Carboniferous, Upper Pennant Measures.

It is likely that the bedrock dips towards the north, in accordance with the general regional dip of the South Wales coalfield. It is also possible that the bedrock is cut by geological faults but the presence of such structures also cannot be confirmed from the borehole evidence available.

4.1.2.2 Drift and Made Ground

Made Ground overlies the whole DiMe area and varies in thickness from 0.1m at MSMW066D2 located in the centre of the area to 4.8m thick at DM5 in the north east of the area. The thickness of Made Ground is shown as contours in Figure 4. There is no obvious pattern to the thickness of Made Ground across the DiMe area; however the thickness of Made Ground generally seems to be less in the central areas of the DiMe area, and thicker towards the eastern and western boundaries.

The Granular Drift deposits are shown as contours of thickness in Figure 5. The thicknesses encountered vary markedly with thin inconsistent patterns over most of the site, and a thicker stripe along the northern boundary alongside the railway cutting. The Granular Drift is assumed on this basis to exist as isolated pockets sitting on top of the Cohesive Drift.

The Cohesive Drift is commonly referred to as boulder clay in the borehole logs. This name has not been carried forward in this report as it can mislead. The thickness of the Cohesive Drift shown in Figure 6 is generally large and consistent across the site. It does thin towards the southern boundary as the bedrock approaches the current land surface. It is probable that the natural slopes of the hill were cut back to produce the terrace the DiMe plant was built on reducing the thickness of Drift along the southern boundary of the site.

4.2 Hydrogeology

The aquifer status at the DiMe site has been reviewed using the newly published designations on the Environment Agency web site (Ref. 4). This shows that the site is not underlain by a superficial Drift aquifer, but is underlain by a bedrock aquifer designated as Secondary A Aquifer. A Secondary A aquifer is defined on the Environment Agency web site as;

'permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers.'

The bedrock sandstones, belonging to the Upper Pennant measures are considered to be this Secondary A Aquifer. This aquifer is considered to be the principal groundwater receptor for the DiMe site. The granular drift has been discounted as a principal receptor as water within such limited deposits is considered likely to comprise discrete perched bodies rather than extensive groundwater.

4.2.1 Groundwater Levels

4.2.1.1 Coal Measures

A summary of the monitored groundwater levels are presented in full in Appendix B. Table 4.2 below summarises the groundwater levels monitored within the coal measure on the DiMe area. Figure 7 shows the contours of groundwater levels in mAOD on three separate monitoring occasions. The boreholes dipped varied depending on the available network at the time of monitoring. A large number of the older boreholes were destroyed or lost in the demolition of the site. There is a clear gradient from the south towards the north and north east corner of the site indicated in the groundwater within the bedrock. The groundwater levels are relatively consistent once the vagaries of different monitoring locations and the interpolated contours are taken into account with levels falling from around 40mAOD along the southern boundary of the site falling to around 29mAOD in the boreholes towards the northeast (MSMW225 and MSMW068). The gradient follows the topography generally and seems to indicate groundwater will move off the DiMe area towards the River Neath to the east. The previous assessments (Ref. 1) suggested that groundwater may divide across the DiMe site with groundwater flowing towards the west and the Crumlin bog from parts of the western end of the DiMe site. The inferred groundwater divide was not identified from the groundwater levels recorded by Atkins more recently.

The groundwater levels in the bedrock are confined beneath the Cohesive Drift as can be seen by the water levels in any given part of the site, as shown in Figure 7, being higher than the elevation of rock head shown in Figure 3. The groundwater within the bedrock is considered likely to be fed primarily by infiltration to the bedrock cropping out around the sandstone ridge south of the DiMe site..

The gradient of groundwater in the bedrock under the DiMe area calculated from the contours in Figure 7 is generally between 0.09 and 0.04 towards the north or northeast, which is a relatively steep hydraulic gradient. If the relatively small recharge area is considered, it is likely that the flux of groundwater flow will be relatively small. Therefore for the steep hydraulic gradient to be generated the hydraulic conductivity of the bedrock might be low, or the transmissive part of the aquifer might be restricted to a relatively narrow weathered zone at the top of the bedrock.

Table 4.2 - Summary of Groundwater levels recorded in Coal Measures Strata to date

Borehole	Count	Min (m AOD)	Max (m AOD)	Range (m)
MSMW053D1	3	32.24	32.47	0.23
MSMW64d	7	37.22	39.88	2.66
MSMW65d	11	32.22	40.63	8.41
MSMW068D2	15	26.91	28.35	1.44
MSMW68d	18	27.82	32.67	4.85
MSMW69d	6	28.67	29.36	0.69
MSMW069D2	6	26.99	28.01	1.02
MSMW220D	18	33.62	34.33	0.71
MSMW222D1	8	18.24	38.80	20.56
MSMW223D2	3	31.29	37.89	6.6
MSMW223D1	2	34.37	34.45	0.08

Borehole	Count	Min (m AOD)	Max (m AOD)	Range (m)
MSMW224D2	28	32.17	35.68	3.51
MSMW224D1	20	31.99	33.43	1.44
MSMW225D	9	26.94	27.56	0.62
DME5	7	29.67	30.39	0.72
DME6	7	37.33	37.86	0.53
DME11	7	34.40	35.26	0.86

4.2.1.2 Free Product

A number of the shallow boreholes at the site record free product as LNAPL on the top of shallow groundwater. The thickness of this varies dramatically between boreholes from thin films, millimetres in thickness, to over 1m thick in places. The presence of LNAPL is likely to be the result of leaks and spillages of the lubrication oils manufactured in the DiMe plant and the hydrocarbon fraction they were manufactured from. Figure 10 indicates the thickness of LNAPL found in some boreholes during recent monitoring of the DiMe site. The LNAPL is not found in all shallow boreholes and the thicknesses found in some boreholes probably exaggerate the real thickness present in the ground as the LNAPL is likely to pool in the boreholes preferentially. A significant residual source of LNAPL hydrocarbon contamination is considered likely to be present within the Made Ground and extending possibly through the Granular Drift in places. This is discussed in greater detail in the following sections.

4.2.1.3 Cohesive Drift

The groundwater levels monitored within the Cohesive Drift on two occasions (March 2002 and March 2010) are shown on Figure 8. The levels of water in these boreholes it can be noted are elevated by between 0.06 and 0.79m above those in the bedrock in the same locations, suggesting a vertical gradient exists across the Cohesive Drift. A general trend of decreasing water levels is apparent from the south towards the north and northeast boundaries.

This groundwater is assumed to be perched within or above the Cohesive Drift deposits on the basis that no discharges appear to occur to the sides of the deep railway cutting. If the water within the Drift was flowing off-site at the elevations it is found in boreholes (e.g. MSMW222, DSB026S1, DSB025S1, DME2), in the direction indicated by the hydraulic gradients then discharge into the railway cutting would be expected.

The majority of water flow within the Cohesive Drift is assumed to be by vertical percolation downwards. The vertical hydraulic gradients have been calculated through the Cohesive Drift for a number of boreholes shown in Table 4.3, which have either dual installations or closely adjacent boreholes. The vertical gradients calculated varied between 0.16 and 0.7 on average, indicating that water has the potential to move vertically in response to these gradients.

Table 4.3 – Vertical hydraulic gradients from paired boreholes between Cohesive Drift and Bedrock

Borehole Pairs	Vertical separation (m)	Average water level difference (m)	Minimum water level difference (m)	Maximum water level difference (m)	Average vertical hydraulic gradient
MSMW53 / MSMW053D1	20	4.88	0.23	0.25	0.24
MSMW68s /	12	4.41	0.30	0.35	0.34

Borehole Pairs	Vertical separation (m)	Average water level difference (m)	Minimum water level difference (m)	Maximum water level difference (m)	Average vertical hydraulic gradient
MSMW068D2					
MSMW069S2 / MSMW69d	10	6.97	0.66	0.79	0.70
MSMW220S1/A / MSMW220D/A	18	3.51	0.06	0.23	0.19
MSMW224S1/A / MSMW224D2/A	20	3.21	0.07	0.19	0.16
DME10 / DME9	11	3.26	0.28	0.32	0.30
DME11 / DME10	14	3.75	0.25	0.29	0.27

The groundwater contours in Figure 8 show another notable feature which comprises depressed groundwater levels in particular locations in the eastern part of the site. These slightly anomalous levels appear to be related to certain specific boreholes (DSB025S2, DSB027S2 and DSB030S2) which appear to vary widely in the water levels they record (see Table 4.4 below). These variations appear to be related to LNAPL in these boreholes, which depresses the apparent water table. The LNAPL floats on the water in the boreholes as it has a lower specific gravity than water but displaces it producing the lower dips. Tests have shown the LNAPL to have a specific gravity between 0.84 kg/l and 0.91 kg/l, with an average of 0.876 kg/l. Therefore, the pressure head exerted by 1m of LNAPL is less than that exerted by 1m of water, and as a result, where LNAPL is present the water would be depressed but the top of the LNAPL would be at a greater elevation than would only water be present in the borehole. Tables 4.4 and 4.5 below show the corrected piezometric surface in boreholes DSB025S2 and DSB027S2 over time with consideration of the thickness of LNAPL monitored over the same period.

Table 4.4 - Corrected water levels (mAOD) in Borehole DSB025S2

Date	Water Level (mAOD)	Thickness of LNAPL (m)	Correction for density of LNAPL (m)	Piezometric water Level (mAOD)
01/02/2002	37.38	-		37.38
01/09/2002	37.15	0.01	0.009	37.16
01/03/2003	37.01	0.03	0.026	37.04
01/09/2003	34.9	1.88	1.65	36.55
01/03/2004	35.07	2.34	2.05	37.12
01/09/2004	35.6	1.92	1.68	37.28
01/04/2005	33.31	4.13	3.62	36.93
01/10/2006	33.38	3.8	3.33	36.71
01/03/2007	33.17	4.21	3.69	36.86

The corrected piezometric water levels in boreholes DSB025S2 and DSB027S2 in Tables 4.4 (above) and 4.5 (below) show that once the thickness of LNAPL is accounted for, the water levels in the boreholes have been relatively constant. The corrected water levels however are likely to be approximations due to the use of the average specific gravity in the calculations. The density of the LNAPL is likely to have varied over time and is likely to vary between boreholes. The monitoring of LNAPL thicknesses across the site over time shows that there may be some

migration of the LNAPL, however this pattern is not clear due to variations in the thickness of LNAPL between monitoring events and a lack of boreholes which record LNAPL precluding contouring with any confidence.

Table 4.5 - Corrected water levels (mAOD) in Borehole DSB027S2

Date	Water Level (mAOD)	Thickness of LNAPL (m)	Correction for density of LNAPL (m)	Piezometric water Level (mAOD)
01/01/2002	37.55	-		37.55
01/03/2002	33.56	4.24	3.71	37.27
01/04/2003	33.36	4.37	3.83	37.19
01/09/2003	33.69	3.82	3.35	37.04
01/03/2004	34.2	3.62	3.17	37.37
01/09/2004	33.81	4.21	3.69	37.50
01/09/2005	33.51	4.31	3.77	37.28
01/10/2006	35.42	2.07	1.81	37.23
01/03/2007	33.33	4.31	3.77	37.10

4.2.1.4 Made Ground and Granular Drift

Groundwater within the Made Ground and Granular Drift has been grouped as it is considered likely that the water in these units will be in direct continuity, ponded above the Cohesive Drift. The water levels in these units are shown as contours in Figure 9. The number of boreholes monitoring water levels in any given data set is relatively limited therefore an incomplete picture of the distribution of water levels might be expected on any given monitoring event, however the general trends are similar to the water levels monitored at greater depth. The elevation of water levels in this unit is higher than those in the Cohesive Drift suggesting the vertical hydraulic gradient exists across the entire thickness of the Cohesive Drift. The water levels in some of these boreholes are significantly affected by the presence of LNAPL (light non-aqueous phase liquid) resting upon the water in the boreholes displacing it, such as boreholes DSB025S1 and DSB027S1.

4.2.2 Hydraulic Conductivity

4.2.2.1 Water in the Drift

Rising head tests were carried out and reported in Ref. 5 on wells within the Made Ground and glacial deposits across the entire site. The results showed a range of permeability between 0.006 and 14.1 m/d with a geometric mean value of 1.3 m/d. It is noted in relation to these numbers that the wells used were purposely selected as intercepting productive units within the glacial deposits and are therefore likely to be much higher than typical hydraulic conductivity of the Cohesive Drift under the DiMe site. The likely bulk hydraulic conductivity of the Cohesive Drift at DiMe is considered likely to be low and in the range of clay or clayey silts (8.64×10^{-3} to 8.64×10^{-6} m/d).

4.2.2.2 Deep groundwater

The deep groundwater in the bedrock is from a continuous unit of fractured sandstones (coal measures). The uppermost parts of this unit are apparently weathered and coincided with increased yields of water during drilling (Ref. 5). The geology of this unit suggests that the

primary porosity is low making the intergranular permeability of the unit low but the fracture networks, faults and bedding surfaces provide a secondary porosity which is capable of transmitting groundwater.

Long term aquifer pumping tests performed on the sandstones on the main site, as reported in Ref. 5, found permeability values ranging from 0.1 to 2.3 m/d with a geometric mean value of 0.7 m/d. Storage values were apparently low with a geometric mean value of 0.005. Rising head slug tests on wells within the sandstones yielded permeability values ranging from 0.001 to 6.7 m/d with a geometric mean value of 0.65 m/d.

4.3 Ecology and Hydrology

The Crymlyn Bog is situated approximately 700m to the west of the DiMe area and is designated both a Site of Special Scientific Interest (SSSI), Special Area of Conservation (SAC) and a Ramsar site. The nearest surface water body to the DiMe site is the reservoir located approximately 150m to the north. There is also a network of drains in the eastern part of the Crymlyn Bog. The Crymlyn Brook is 990m to the west of the site, with the River Neath approximately 1,555m to the east.

According to the Environment Agency website (Ref. 4), the site does not lie within an Environment Agency indicative floodplain. The nearest Environment Agency indicative floodplain present is approximately 1,370m east of the boundary of the site, this floodplain appears to be associated with the River Neath.

4.4 Contamination Data Assessment

4.4.1 Chemical Properties of DiMe Solvents

The chlorinated hydrocarbons 1,2-dichloroethane and dichloromethane used as solvents in the DiMe area (and giving it its name) are both well defined in their physical properties (Ref. 1 and Table 4.6 below). Both substances are highly soluble in water but as a free phase they are denser than water. They have relatively small K_{oc} values in literature therefore do not partition strongly to organic carbon. These two solvents, individually and as a mixture, would be anticipated to act as a DNAPL (Dense Non-Aqueous phase Liquid) if introduced into the ground as free products. The high solubility of these two substances would suggest they could readily move from a free phase DNAPL into solution if a significant volume of groundwater was intercepted.

Table 4.6 - Chemical and Physical and Environmental Behaviour of DiMe Solvents (Ref. 8)

Parameter	1,2-Dichloroethane	Dichloromethane
Density (g/cm ³ at 25°C)	1.25	1.326
Solubility (g/m ³ at 25°C)	7809 – 8800 - 11000	13030 – 20000 - 22700
Henry's Law (Pa m ³ /mol at 25°C)	55 – 185	200 – 300
Log K_{oc}	1.15 – 2.19	0.944 – 1.44
Biodegradation (1/2 life in groundwater in days)	100 – 360	14 – 56

Anaerobic degradation is considered the only likely process in groundwater at the site. Anaerobic biodegradation through fermentation and methanogenesis is possible for both substances and

dichloromethane is also apparently able to degrade under nitrate reducing conditions. However, biodegradation can be limited by concentration of contaminant, availability of nutrients for biota degrading the hydrocarbons and other chemical factors.

It is notable that dichloromethane is the more soluble of the two substances, has a lower K_{oc} value and also a shorter half-life which means it would be anticipated to be more easily dissolved into groundwater, more mobile in groundwater, and more readily biodegraded once in solution in groundwater. This has important implications in assessing the patterns of groundwater contamination as discussed in Section 4.4.4 below.

4.4.2 LNAPL Chemistry

Analysis of 5 samples of the LNAPL in boreholes at DiMe was carried out in January 2009 for the chemical constituents and specific gravity of the LNAPL.

The full results of these analyses are provided as Appendix D to this report and are summarised below in Table 4.7.

Table 4.7 – Composition of LNAPL, Values in %

Sample date	21/01/2009	23/01/2009		30/01/2009	
Sample No.	1	1	2	1	2
Aliphatic C5-C6	<0.01	<0.01	<0.01	<0.01	<0.01
Aliphatic C6-C8	2.59	0.35	0.56	0.14	0.13
Aliphatic C8-10	10.7	11.14	10.59	0.34	0.16
Aliphatic C10-C12	15.32	12.19	23.84	0.56	0.25
Aliphatic C12-C16	21.56	5.59	32.18	3.52	2.99
Aliphatic C16-21	3.22	0.81	2.43	14.05	16.03
Aliphatic C21-C35	<0.01	<0.01	<0.01	34.36	29.48
Aromatic C6-C8	0.05	0.17	0.39	0.06	0.04
Aromatic C8-C10	4.64	18.72	3.75	0.22	0.06
Aromatic C10-C12	14.02	29.32	9.32	0.32	0.26
Aromatic C12-C16	20.5	16.6	11.86	1.98	2.08
Aromatic C16-C21	3.27	2.69	3.94	8.61	9.95
Aromatic C21-C35	<0.01	<0.01	<0.01	23.33	25.52
Benzene	0.03	0.05	0.13	0.01	<0.01
Toluene	0.04	0.12	0.26	0.05	0.04
Ethyle benzene	0.09	0.08	<0.01	0.05	0.02
Xylene (m&p)	0.49	0.12	0.36	0.13	0.03
Xylene (o)	0.01	0.05	0.18	0.04	0.01
Naphthalene	0.19	0.15	0.3	<0.01	<0.01
1,2,4 Trimethylbenzene	1.44	2.75	1.52	0.12	0.16
Total % of substances	99.16	101.9	103.61	88.89	89.21

Sample date	21/01/2009	23/01/2009		30/01/2009	
Sample No.	1	1	2	1	2
listed					
Specific gravity	0.8434	0.8514	-	0.9107	0.8977

- Denotes no data

The results summarised in Table 4.7 show that the majority of the LNAPL consists of relatively conventional hydrocarbons as indicated by the high total percentage represented by those substances listed in Table 4.7. The total in excess of 100% for the two samples from the 23rd January 2009 is due to double counting of aromatic hydrocarbons, e.g. BTEX substances would also be measured as part of the Aromatic TPH Fractions C6-C8.

There is an obvious difference between the two most recent samples dated 30th January 2009 and the previous three samples. The later samples are more dense (higher specific gravity) and have a preponderance of larger hydrocarbons (e.g. C21-C35) which are not elevated in the previous three samples. Some spatial variations in the composition of the LNAPLs are evident from the analyses carried out, however this has not been assessed further due to the small number of samples available.

4.4.3 Historical Contamination Data

The historical ground contamination data (1998 - 2008) for the site is addressed in the previous investigations (Ref. 1). The main conclusions regarding the distribution and types of contaminants considered at the DiMe site by URS were considered to be as follows:

- The distribution of 1,2-dichloroethane and dichloromethane in soil and water were found to increase generally with depth through the drift and into the aquifer.
- Areas of LNAPL are mentioned as being present, however their origin and chemical constituents are not discussed by URS.
- BTEX substances were present in soil samples within the Made Ground and Drift with elevated concentrations in the bedrock aquifer also.
- PAHs, while detected in soils and groundwater, were in low concentrations; naphthalene being the most elevated in groundwater.

4.4.4 Supplementary Contamination Data

To supplement the historical data, groundwater sampling and analysis has been carried out since 2009 at DiMe, including the additional boreholes installed in 2009 to extend the network of groundwater monitoring boreholes over the southern parts of the site where other boreholes had been lost during site demolition works.

Table 4.8 – Summary of chemical data 2009/2010.

Substance	Units	Count	Lowest Conc.	Average Conc.	Highest Conc.	Location of Max Conc.
Arsenic Dissolved	ug/l	22	0	5.15	22.1	DME10
Beryllium Dissolved	ug/l	20	0	0	0	ND
Cadmium Dissolved	ug/l	22	0	0.05	0.3	DSB023S2
Chromium Dissolved	ug/l	22	0	1.38	14	MSMW222S2
Copper Dissolved	ug/l	22	0	1.77	6.1	RFSW012

Substance	Units	Count	Lowest Conc.	Average Conc.	Highest Conc.	Location of Max Conc.
Iron Dissolved	ug/l	17	0	69606	650000	DSB028S2
Lead Dissolved	ug/l	22	0	0.50	1.4	RFSW012, RFSW014
Magnesium Dissolved	mg/l	17	4000	38876	130000	MSMW222S2
Manganese Dissolved	ug/l	17	39	11381	130000	MSMW222S2
Mercury Dissolved	ug/l	22	0	0.0043	0.0546	DME10
Nickel Dissolved	ug/l	22	0	7.68	74	MSMW222S2
Potassium Dissolved	mg/l	17	3200	6041	21000	MSMW220S2
Selenium Dissolved	ug/l	22	0	5.85	86.1	DME10
Zinc Dissolved	ug/l	22	0	13.6	39	MSMW222S2
Chloride	mg/l	17	17	393	1900	MSMW222S2
Nitrate	mg/l	17	0	0.05	0.9	RFSW012
Sulphate	mg/l	17	0	30.9	160	MSMW069D
Boron	ug/l	17	0	34.5	260	DSB023S2
Aliphatic C5-C6	ug/l	34	0	2954	100000	MSMW222S2
Aliphatic C6-C8	ug/l	34	0	3362	100000	MSMW222S2
Aliphatic C8-C10	ug/l	34	0	111	2770	DME17
Aliphatic C10-C12	ug/l	34	0	111	1970	DME17
Aliphatic C12-C16	ug/l	33	0	638	12000	RFSW011
Aliphatic C16-C21	ug/l	34	0	2342	70000	RFSW011
Aliphatic C21-C35	ug/l	34	0	3446	110000	RFSW011
Aromatic C6-C7	ug/l	34	0	5.00	<10	ND
Aromatic C7-C8	ug/l	34	0	5.00	<10	ND
Aromatic C8-C10	ug/l	34	0	164	4150	DME17
Aromatic C10-C12	ug/l	34	0	165	2960	DME17
Aromatic C12-C16	ug/l	34	0	404	7500	RFSW011
Aromatic C16-C21	ug/l	34	0	1093	31000	RFSW011
Aromatic C21-C35	ug/l	34	0	3121	100000	RFSW011
Aliphatic C5-C35	ug/l	34	0	13098	210000	MSMW222S2
Aromatic C6-C35	ug/l	34	0	4975	140000	RFSW011
TPH Ali/Aro	ug/l	17	<10	3239	48800	DME17
PAH	ug/l	12	<10	20.8	139	DME17
1,1-dichloroethane	ug/l	39	0	1.63	30	MSMW222S2
2,2-dichloropropane+1,2-dichloroethylene	ug/l	22	0	0.86	<3.8	ND
Bromochloromethane	ug/l	439	0	1.35	9	MSMW222S2
Chloroform	ug/l	39	0	2.21	43.0	MSMW222S2

Substance	Units	Count	Lowest Conc.	Average Conc.	Highest Conc.	Location of Max Conc.
1,1,1-trichloroethane	ug/l	39	0	3.68	120	MSMW222S2
Carbon tetrachloride + 1,1-dichloropropene	ug/l	39	0	0.62	<1.4	ND
Benzene	ug/l	40	0	0.64	2.25	DM10
1,2-dichloroethane	ug/l	39	0	1327	43000	DSB021S2
dichloromethane	ug/l	17	<3	3	<3	ND
Trichloroethene	ug/l	39	0	1.58	10	MSMW222S2
1,2-dichloropropane	ug/l	39	0	1.69	<3	ND
Dibromomethane	ug/l	39	0	1.65	<3	ND
Bromodichloromethane	ug/l	39	0	0.55	<1	ND
cis-1,3-dichloropropene	ug/l	39	0	1.12	<2	ND
Toluene	ug/l	40	0	0.86	5.36	DM10
trans-1,3-dichloropropene	ug/l	39	0	1.76	<3.5	ND
1,1,2-trichloroethane	ug/l	39	0	4.23	120	MSMW222S2
1,3-dichloropropane	ug/l	39	0	1.15	<2.2	ND
Dibromochloromethane	ug/l	39	0	1.09	<2	ND
1,2-dibromoethane	ug/l	22	0	0.52	<2.3	ND
Chlorobenzene	ug/l	39	0	2.19	<4	ND
Ethylbenzene+1,1,1,2-tetrachloroethane	ug/l	40	0	1.23	<2.5	ND
m+p-Xylene	ug/l	40	0	1.34	6.06	DM10
o-Xylene	ug/l	40	0	0.73	3.82	DM10
Styrene	ug/l	39	0	0.59	<1.2	ND
Bromoform	ug/l	39	0	1.69	<3	ND
Isopropylbenzene	ug/l	39	0	2.51	48	RFSW014
Bromobenzene	ug/l	39	0	0.69	<2	ND
1,2,3-trichloropropane	ug/l	36	0	5.33	<9	ND
n-propylbenzene	ug/l	19	0	0.68	<2.6	ND
2-chlorotoluene	ug/l	39	0	1.12	<2	ND
1,3,5-trimethylbenzene	ug/l	39	0	0.76	3.38	DM10
4-chlorotoluene	ug/l	39	0	1.12	<2	ND
Tert-butylbenzene	ug/l	36	0	1.25	4	RFSW014
1,2,4-trimethylbenzene	ug/l	39	0	1.11	7.31	DME10
sec-butylbenzene	ug/l	39	0	2.09	41	RFSW014
1,3-dichlorobenzene+p-isopropyltoluene	ug/l	39	0	1.15	<2.2	ND
1,4-dichlorobenzene	ug/l	36	0	0.76	<2.7	ND
n-butylbenzene	ug/l	39	0	1.13	<2	ND

Substance	Units	Count	Lowest Conc.	Average Conc.	Highest Conc.	Location of Max Conc.
1,2-dichlorobenzene	ug/l	39	0	1.78	<3.7	ND
1,2-dibromo-3-chloropropane	ug/l	39	0	5.62	<10	ND
1,2,4-trichlorobenzene	ug/l	39	0	1.45	8	DSB021S2
Hexachlorobutadiene	ug/l	39	0	1.63	<3	ND
Naphthalene	ug/l	39	0	2.54	4.80	RFSW014
1,2,3-trichlorobenzene	ug/l	39	0	2.14	11	DSB021S2
Phenol	ug/l	5	<1	1.20	2	DME10

* Note ND not detected.

Many of the hazardous (formerly list I) substances such as styrene, bromobenzene and 1,2-dichlorobenzene were not detected above the laboratory limit of detection in 2009 and 2010.

The groundwater contamination at DiMe, summarised in Table 4.8 above, comprises a relatively narrow group of substances. Inorganic contamination levels are relatively low with the exception of manganese and iron. The source of these substances is likely to be natural, originating in iron rich, iron stone bands within the bedrock comprising the coal measures, and much of the gravel, cobble and boulder clasts within the glacial deposits which are mostly derived from coal measure sources. Of the non-metals, chloride concentrations are relatively high. This is potentially significant in that the likely means of biodegradation of chlorinated hydrocarbons is reductive dechlorination under anaerobic conditions which would produce chloride ions in solution. However chloride in groundwater might also originate from a number of other potential sources some of which could be natural. No definitively up-gradient borehole has been consistently monitored in the bedrock, however borehole MSMW220D is on the up-gradient (southern) side of the main process area of the DiMe site and records chloride concentrations which vary between a 17 and 1900 mg/l in 2009/2010 but generally has monitored concentrations below 100mg/l. A natural background concentration for chloride might be assumed to be below 100mg/l on this basis.

The man-made contamination of groundwater appears to be largely confined to organic contaminants. The organic substances detected in the highest concentrations are the two DiMe solvents namely 1,2-dichloroethane and dichloromethane. This is unsurprising considering the long term use of these two substances at the site and the reported (Ref. 1) prevalence of leaks and occasional large spills of these substances at the former DiMe plant. Two other chlorinated hydrocarbons have been detected in the groundwater, all-be-it at much lower concentrations and occurrence than the DiMe solvents. These are chloroform (CHCl_3) and trichloroethane (C_2HCl_3) which are assumed likely to have been dissolved within the DiMe solvents at low concentrations during the manufacture of each solvent. In manufacturing chlorinated solvents such as dichloromethane and 1,2-dichloroethane small amounts of over chlorinated versions of the same alkane base molecule could be created, dissolved in the principal product.

There is groundwater contamination with various TPH (Total Petroleum Hydrocarbon) fractions, the highest concentrations of which were detected in the Aliphatic C5-C6 and Aliphatic C6-C8 ranges which, considering the low solubility of these bands of hydrocarbons, is possibly showing the inclusion of some free phase within the water samples analysed. Alternatively these hydrocarbons could be mobilised in solution as a result of the inclusion of solvents other than water in the mixture, e.g. the DiMe solvents. Concentrations of larger TPH fractions, BTEX compounds and wider group of alkylated benzene contaminants have also been detected in groundwater. Sources of the TPH fractions, BTEX and alkylated benzenes are present as LNAPL within Made Ground over some parts of the DiMe site which may have resulted in this contamination of groundwater.

4.4.5 Groundwater Contamination by Strata

The groundwater contamination has been further analysed in relation to boreholes within each strata as described in Section 4.1.2 above for a selected list of contaminants:

- 1,2-Dichloroethane;
- Dichloromethane;
- TPH Aliphatic C5-C6;
- TPH Aliphatic C6-C8;
- TPH Aromatic C12-C16;
- TPH Aromatic C16-C21;
- Benzene;
- Toluene;
- Ethylbenzene;
- Xylenes; and
- Chloride.

The available data on these selected contaminants from each borehole has been used in this analysis, however the number of boreholes monitored in any given monitoring round has varied over the years, therefore the data on some boreholes is relatively extensive and for others is very limited. Those boreholes with consistent monitoring over a number of years have been analysed more closely as reported below. The data summaries for each unit are provided in Appendix C.

Due to the spatial variability in depths between groundwater sampling horizons and the limited number of boreholes sampled in each monitoring event, spatial representations of the data on plans of the site are considered inappropriate. It is considered that such plots would be generally misleading as to the spread and severity of contamination of groundwater at the site at any given time.

4.4.5.1 Made Ground and Granular Drift (See Appendix C)

The shallowest waters sampled in the ground have been monitored sporadically. The DiMe solvents have not been detected in the shallow groundwater at high concentrations since the site ceased operations. Concentrations of up to 21 µg/l in borehole DSB023S2 have been detected in 2009, which is a low concentration compared to historical levels. The vast majority of the DiMe solvent contamination is considered likely to have migrated as DNAPL or dissolved phase out of the shallowest strata within the years following closure and demolition of the DiMe plant.

Contamination with benzene and other BTEX substances is relatively widespread in the Made Ground and Granular Drift deposits and is likely to reflect on going sources of these contaminants in the Made Ground (Ref. 1). TPH contamination of shallow groundwater is noted in some boreholes and is likely to be originating from the LNAPLs and Made Ground which has been contaminated by contact with the LNAPLs.

Chloride concentrations in the shallowest groundwater appear to be generally low with concentrations typically being in the range 18 to 50 mg/l. Some more elevated concentrations have been detected in individual samples up to 439 mg/l (in borehole MSMW224S1 in May 1999), however these do not appear to reflect a high source concentration of chloride leaching from the Made Ground. Alternative sources of chloride in groundwater such as from road salting are possible within the site, however no major roadways cross the DiMe area. This is important in assessing the likely origin of chloride in the deeper groundwater.

4.4.5.2 Cohesive Drift Deposits (See Appendix C)

The evidence of dissolved contamination with various organic contaminants in the Cohesive Drift is widespread. The concentrations of the two DiMe solvents is relatively consistent where they are detected; 1,2-dichloroethane has been found to be consistently elevated in boreholes MSMW220s, MSMW220S2, MSMW222S2 and DSB028S2. However dichloromethane concentrations in most of these boreholes appear to have decreased between 1999 and December 2009, with the exception of borehole MSMW222S2 where it has remained elevated throughout.

This might suggest that there are residual sources of 1,2-dichloroethane and dichloromethane, possibly including small quantities of free phase NAPL in places, within the Cohesive Drift deposits. These residual sources are likely to be composed largely of 1,2-dichloroethane as a result of the greater solubility and mobility of dichloromethane in groundwater.

Elevated concentrations of TPH and BTEX have been detected within the Cohesive Drift although the boreholes recording these substances appear to be inconsistent. The data appear to suggest these substances have migrated into these layers dissolved in the groundwater and may represent plumes moving vertically downwards, most likely being retarded and degraded as they migrate.

Chloride concentrations within the Cohesive Drift are typically in the hundreds of milligrams per litre range with some elevated concentrations up to 2810 mg/l. The origin of these high chloride concentrations is considered likely to be from dechlorination of the chlorinated hydrocarbons present in the groundwater, which are primarily the DiMe solvents 1,2-dichloroethane and dichloromethane. Chloride is a conservative contaminant in solution and would be expected to be preferentially transported, therefore the consistently high concentrations of chloride in this unit suggests ongoing generation of chloride over time. The average concentration of chloride in the Made Ground and Granular Drift is 92 mg/l while in the Cohesive Drift it is 611 mg/l. If a significant alternative source of this chloride is discounted then this would suggest that the majority (in the region of 500mg/l) of the chloride in the Cohesive Drift has been generated by reductive dechlorination of the DiMe solvents.

Table 4.9 below summarises the mass calculations to assess what the initial concentration of DiMe solvent would need to be to create a chloride signature of 500mg/l. There would be two chlorides for each molecule of either 1,2-dichloroethane or dichloromethane degraded therefore assuming half of the chloride was generated by the degradation of each substance the number of moles of each DiMe solvent would be a quarter of the chloride in any given volume of groundwater. The results predicted concentrations of each solvent is 349 mg/l for 1,2-dichloroethane and 299 mg/l for dichloromethane in order to generate a chloride signature of 500mg/l in solution. The concentrations of parent to daughter substances predicted are generally proportional to those monitored in groundwater, as shown by borehole MSMW222S2 in Table 4.9.

Table 4.9 – Calculations of DiMe solvent concentrations required to generate chloride signature in Cohesive Drift.

	Chloride	1,2-Dichloroethane	Dichloromethane
Chemical Formula	Cl	C ₂ H ₄ Cl ₂	CH ₂ Cl ₂
g/mol (molecular mass)	35.453	98.959	84.9325
mg/mol (molecular mass)	35453	98959	84932.5
Moles (mol) in 500mg	0.014103	0.003526	0.003526
mg/l	500	348.9091	299.4546

	Chloride	1,2-Dichloroethane	Dichloromethane
Groundwater in Cohesive Drift, MSMW222S2 (mg/l)	314 - 1900	49.3 - 1120	16.7 - 1140

Additional groundwater monitoring in a number of DiMe boreholes has been carried out in May 2010 for chloride, dissolved methane and ethane, and the DiMe solvents. The results are presented below in Table 4.10, and show that high concentrations of methane are prevalent within groundwater at the DiMe site, and the cohesive deposits specifically. This suggests methanogenic reducing conditions are present in the cohesive deposits which should be suitable for the biodegradation of both dichloromethane and 1,2-dichloroethane according to literature on their properties (see Section 4.4.1 including Table 4.6 above).

Table 4.10 – May 2010 monitoring of New DiMe boreholes, likely degradation products of DiMe solvents

Borehole	Chloride (mg/l)	Methane (µg/l)	Ethane (µg/l)	Dichloromethane (µg/l)	1,2-Dichloroethane (µg/l)
DME19	88.0	3590	2.16	<3.7	<3.3
DME2	77.80	12.1	<1	<3.7	<3.3
DME5	56.3	6280	<1	3.92	<3.3
DME17	37.0	1.97	<1	<3.7	<3.3
DME8	30.5	1130	5.96	<3.7	<3.3
DME20	24.7	8830	187	<3.7	<3.3
DME7	17.4	1590	6.07	<3.7	<3.3
DME15	14.6	23.7	<1	<3.7	7.36
DME16	8.7	70.8	<1	<3.7	<3.3
DME4	13.6	4640	<1	11.5	22.6
DME11	382.0	207	<1	79.6	2240
DME3	1550.0	1350	<1	39.5	13500
DME13	18.2	595	4.1	<3.7	156
DME9	258.0	2220	<1	12.0	14500
DME10	109.0	7030	377	1870	10600
DME1		2420	<1	<3.7	42.8

The data presented in Table 4.10 also shows there is a correlation between higher concentrations of chloride in groundwater, with the presence of 1,2-dichloroethane and dichloromethane. There are however no obvious correlations between methane and dichloromethane, or ethane with 1,2-dichloroethane.

From the results of this monitoring there is considered to be good circumstantial evidence for biodegradation of the DiMe solvents occurring within the Cohesive Drift.

4.4.5.3 Coal Measures Strata (See Appendix C)

The concentrations of 1,2-dichloroethane and dichloromethane occur at elevated concentrations within this unit in the late 1990s and early 2000s, however since that time concentrations appear to have been reducing consistently (see Figure 13 showing 1,2-dichloroethane in boreholes MSMW220D and MSMW222D2 located in the main process area at the DiMe site). This suggests that the supply of these two substances, through the Cohesive Drift, was cut significantly when the DiMe plant was shut and decommissioned. It also suggests that there is not a residual DNAPL source within the bedrock aquifer, as concentrations would be expected to remain high were DNAPL to be present, and that the discharges of 1,2-dichloroethane and dichloromethane to the bedrock aquifer as NAPL were dissolved effectively in the volumes of groundwater flowing in the bedrock aquifer.

It is inferred from this evidence that DNAPLs of DiMe solvents were capable of penetrating the Cohesive Drift relatively rapidly. Using the equation below; Table 4.11 presents the results of calculations to determine the relative conductivity of the DiMe solvents compared to water. The calculations use the properties of water to determine the intrinsic permeability equivalent to a hydraulic conductivity typical of the Cohesive Drift at the DiMe site. The calculations then use the physical properties of DiMe solvents and the intrinsic permeability to find the fluid conductivity for each of the DiMe solvents. The highest fluid conductivity is exhibited for dichloromethane, approximately 3 times that of water, which is not surprising if its low viscosity and high density is considered. 1,2-dichloroethane has a lower fluid conductivity, more similar to water, however the fluid conductivity of a mixture of the two DiMe solvents as a DNAPL can be conjectured to be somewhere between the two.

$$K = \frac{k\rho g}{\mu}$$

Where:

k = intrinsic permeability;

K = hydraulic or fluid conductivity;

g = acceleration due to gravity;

μ = dynamic viscosity; and

ρ = fluid density.

Table 4.11 – Calculations to show relative conductivity of DiMe solvents and water

	Viscosity	Density	g	Fluid Conductivity	Intrinsic permeability
Units	mPa/s	kg/m ³	m/s ²	m/s	m/s
Water	1	1000	9.8	1.00 x10 ⁻⁸	1.02 x10 ⁻¹²
1,2-DCA	0.84 ^(Ref 11)	1250 ^(Ref 8)	9.8	1.49 x10 ⁻⁸	1.02 x10 ⁻¹²
DCM	0.43 ^(Ref 10)	1325 ^(Ref 8)	9.8	3.08 x10 ⁻⁸	1.02 x10 ⁻¹²

The likely flow velocity of 3.8m/year for a DiMe DNAPL through the Cohesive Drift has been calculated using Darcy's Law to calculate flux and then divided by the porosity. This is on the assumption of a vertical gradient of 0.3 (average of calculated values as presented in Table 4.3), a fluid conductivity of 2x10⁻⁸ m/s (see Table 4.10), and a porosity of 5% for the Cohesive Drift. This

rate of flow is approximately double that for water through the same system, however contaminants dissolved in groundwater would not be anticipated to be transported at this rate due to the process of retardation, dilution, dispersion and degradation. The gradient driving flow of DNAPL may also be higher than the hydraulic gradient. This preferential transport of the DiMe contaminants as DNAPL through the Cohesive Drift, while dissolved phase contaminants remain within or above the Cohesive Drift, appears to provide a plausible explanation for the distribution of contaminants through the various strata beneath the DiMe site.

As a result it can be assumed that once the source of DNAPL (DiMe spillages and leaks) was stopped, the supply of contaminants to the bedrock aquifer reduced consistently. It is likely that relatively little residual DNAPL of DiMe solvents is present in the Cohesive Drift after 10 years without a source, but that some residual sources cannot be ruled out in especially low (intrinsic) permeability parts of the Cohesive Drift (see Section 4.4.4.2 above). The current concentrations of 1,2-dichloroethane and dichloromethane in the bedrock aquifer are therefore considered reflective of historical discharges to the aquifer and, to a lesser extent, dwindling residual sources within the Cohesive Drift. The likely presence of some residual NAPL of 1,2-dichloroethane within the Cohesive Drift appears to contradict the reduced impact on groundwater in the bedrock, unless it can be assumed that the remaining NAPL source is largely immobilised within the Cohesive Drift.

TPH and BTEX substances have not been detected in the bedrock aquifer widely or consistently. The only occurrences appear to be in the late 1990s. The logical inference from this is that the Cohesive Drift is effectively blocking transport of dissolved contaminants such as TPH and BTEX substances. This is considered reasonable if the typical thickness of the Cohesive Drift of several metres at minimum and up to 19m in places is taken into consideration. This adds weight to the likely mode of DiMe contamination reaching the bedrock aquifer as DNAPL while dissolved organic contaminants of all kinds (including the DiMe solvents), have been essentially contained by the Cohesive Drift.

The monitored concentrations of chloride in boreholes sampling the coal measure aquifer are generally high, in the range 50 to 300mg/l typically. This is lower than was detected in the Cohesive Drift but greater than the likely source from the Made Ground. The chloride which appears to be generated and concentrated in the Cohesive Drift appears to be diluted in the groundwater within the bedrock, although potentially chloride could also originate within the Coal Measures bedrock.

4.5 Conceptual Site Model (CSM)

4.5.1 Overview

A risk to groundwater and surface water exists when the presence and concentration of a substance has the potential to cause pollution to Controlled Waters. This occurs when there is a source of contamination with the potential to cause pollution, the presence of a receptor that may become polluted and the existence of a plausible pollutant linkage between the source and the receptor (pathway).

In the absence of a plausible pathway there should be no unacceptable risk, irrespective of the level of contamination or the sensitivity of the receptor. Outlined below are the sources, pathways and receptors considered to be present at the DiMe site together with the potential implications these may have on controlled waters.

Figure 11 shows a schematic view of the CSM for the DiMe area which is described further below.

4.5.2 Source

In the DiMe area, a large number of potential contaminants have been detected in soils (Ref. 1) and groundwaters, as detailed in Section 4.4 above. The principal contaminants of concern at DiMe are considered to be the two DiMe solvents; 1,2-dichloroethane and dichloromethane, and the main TPH fractions present in the LNAPL present on top of shallow groundwater. The principal contaminants present in the LNAPL which are likely to be mobile in groundwater, which have also been detected in groundwater, are the Aliphatic and Aromatic TPH fractions C10-C12 and C12-C16. Of these two groups Aromatic hydrocarbons tend to be of higher risk to groundwater by virtue of their higher solubility and lower K_{oc} values. The Aromatic TPH fractions C10-C12 and C12-C16 are therefore considered to be the highest risk and therefore most representative substances to consider as surrogate substances to represent the risks associated with the LNAPL source at DiMe.

4.5.3 Pathway

The principal pathway for contaminant migration towards the receptor(s) is considered to be by vertical migration through the Cohesive Drift which overlies the bedrock across the entire DiMe area. On review of the hydrogeological information and the patterns of groundwater contamination there are considered likely to be some higher permeability pathways through the Cohesive Drift by which DiMe DNAPLs migrated to the bedrock aquifer during the operational period which finished in 2000. A slower long term pathway seems to be operating for contaminants dissolved in groundwater. This later pathway seems to be the main method of contaminant transport currently and as such is the pathway considered in the risk assessment modelling in the Section 5 of this report.

Upon entry to the bedrock aquifer, contamination is considered to be diluted by groundwater and transported laterally towards the receptor(s) by advective groundwater flow.

The site is underlain by coal measures strata, the top of which are weathered. The coal measures strata typically consist of interbedded siltstones/mudstones within the sandstone. It is therefore likely the top few metres of the bedrock represent the principal unit able to transmit groundwater flow and therefore dissolved contaminants off-site.

4.5.4 Receptor

The principal surface water receptors are considered to be the Crymlyn Bog located 700m west and the River Neath located 1550m east of the down gradient boundary of the site. The reservoir located north of the Railway Cutting within the larger Coed Darcy site is not considered to be a potential receptor as it is not considered to be in direct continuity with groundwater in the bedrock (see Drawing 5041216-DIME-DWG_727). Groundwater flow within the bedrock aquifer appears to be towards the northeast at the DiMe site indicating that the groundwater from the site is likely to discharge to the River Neath eventually.

As the groundwater within the coal measures is classified as a Secondary A Aquifer it is a receptor in its own right and therefore the appropriate receptor point to consider in this regard would be the down gradient site boundary. In the context of the wider Coed Darcy site the downgradient site boundary considered relevant to the DiMe area would be the eastern site boundary, which in the direction of groundwater migration would place the receptor compliance point at the point groundwater would flow off-site under junction 43 of the M4. This location is approximately 360m from the down gradient edge of the DiMe area.

5. Controlled Waters Risk Assessment

5.1 Methodology

The modelling approach taken to quantify the risks to groundwater from the DiMe site has been developed in response to the conceptual model defined in Section 4 of this report.

Due to the relatively well defined site history and duration of activity on the DiMe site (approximately 30 years followed by 10 years since closure) it has been possible to use a predictive modelling approach and to calibrate the models based on the groundwater monitoring data over a number of years. The predictive model developed has been used to assess the ongoing risk to controlled waters of the residual sources of each contaminant understood from the available data to be present at the site. This model has been called the impact model. Where a potential risk is identified by this model, additional modelling to generate remedial targets has been carried out.

It should be noted that the plume of DiMe solvent groundwater contamination in the bedrock aquifer, which has been declining since the late 1990's, has been ignored in assessing the groundwater impacts from the current sources of contamination. This is owing to the likelihood that this contaminant plume was formed by the migration of DNAPL rather than dissolved contaminants, which have degraded to negligible concentrations since the site operations ceased over 10 years ago. This assumption is supported by the recent groundwater quality which shows low residual concentrations in the bedrock aquifer as a result of these historical impacts.

The modelling has been carried out using input ranges to stochastically assess the impacts on groundwater. The level of reported impacts vary between models depending on whether the model is predictive of current impacts where a most likely, 50th percentile, is considered most applicable, and the impact assessment was assessed at the realistic worst case impact i.e. the 95th percentile.

5.1.1 Modelling Package

The modelling package used in the risk assessment is ConSim v2.5. This modelling package has been chosen in preference to the Remedial Target Worksheet V3.1 (P20) as ConSim allows the simulation of an unsaturated pathway between the source and the receiving groundwater.

ConSim is a model developed by Golders Associates for the Environment Agency to simulate impacts at a receptor using a stochastic modelling approach in line with the tiered approach set out in the Environment Agency Remedial Targets Methodology document (Ref. 7).

ConSim provides a quasi-two dimensional model of contaminant transport through the unsaturated zone and aquifer pathways to a nominal receptor. It should be noted that ConSim is a forward-looking model i.e. it predicts the concentration at a receptor that arises as a result of a particular source concentration.

5.1.2 Modelling Assumptions

The following modelling assumptions have been made in constructing the ConSim risk assessment models:

- Only migration of dissolved phase contaminants is assessed in the risk assessment modelling. LNAPLs are not considered mobile for the purpose of this assessment, and residual quantities of DNAPLs are considered likely to be small considering the high solubility of the DiMe solvents.

- The Cohesive Drift deposits are assumed, when taken as a whole, to display the properties a homogeneous hydraulic unit.
- Within ConSim the Cohesive Drift has been simulated as a vertical pathway, described by ConSim as an unsaturated zone when in reality it is likely to be fully saturated, however the parameterisation of the unsaturated zone reflects the saturated nature of the Cohesive Drift.
- Advective flow is assumed to be prevalent through the Cohesive Drift deposits.
- There is assumed to be a relatively limited (i.e. thin) transmissive zone within the bedrock aquifer reflecting a weathered/fractured zone at the top of the bedrock. This is a conservative assumption considering the pathway length.
- The Aromatic TPH fractions C10-C12 and C12-C16 are considered to act as surrogates for other light aliphatic hydrocarbon fractions present in the LNAPL source.

5.2 Priority Contaminants

The priority contaminants have been selected on the basis of the groundwater contamination evident at the site and residual sources known to exist. Table 5.1 below lists these substances with their respective WQS (Water Quality Standard) which shall be the EAL (Environmentally Acceptable Limit) used in the risk assessment.

Table 5.1 – Substances Carried Forward for Quantitative Risk Assessment Modelling

Contaminant type	Substances	EAL (mg/l)	WQS
DiMe Solvents	1,2-Dichloroethane	0.003	UK DWS [^]
	Dichloromethane	0.02	WHO*
Aromatic TPH	C10-C12	0.01	UK DWS [^] (hydrocarbons total)
	C12-C16	0.01	

*World Health Organisation (WHO) Guidelines for Drinking Water Quality, 1984.

[^]Water Supply (Water Quality) Regulations 2000 (SI 2000/3184) (as amended).

5.3 Parameterisation

The modelling inputs summarised in the following sections have been derived from the literature sources, but have also been varied to influence the predicted impacts after 40 years (1970 – 2010) to calibrate the models. This calibration of the inputs has been relatively limited, but is indicated where relevant.

5.3.1 Physical Inputs

Table 5.2 – Physical Input Parameters used in ConSim Modelling

Parameter	Unit	Value/Range	PDF	Comment / Justification
Source Zone Properties (Made Ground and Granular Drift)				
Source Area		-		Source area assumed to be whole DiMe Site on a conservative basis (See Figure 12)
Source Depth	m	0.1 - 2 - 4.8	Triangular	Depth of Made Ground from DiMe Borehole Logs. Most

Parameter	Unit	Value/Range	PDF	Comment / Justification
				likely based on average.
Dry Bulk Density	g/cm ³	1.8	Single value	Assumption, typical for unconsolidated sedimentary materials
Fraction of Organic Carbon	%	0.01 - 0.1	Uniform	ConSim Help files (Clay-silt)
Air Filled Porosity	--	0.1	Single value	Assume total porosity of 0.3 for granular Made Ground after values for sand/gravels from Domencio and Schwartz (1990) and air filled porosity is 1/3 of total porosity.
Water Filled Porosity	--	0.2	Single value	Assume water filled porosity is 2/3 of total porosity (see above).
Infiltration	mm	200 - 500	Uniform	Conservative values. High rates of infiltration assumed, due to inefficiency of hard standing (i.e. groundwater contamination) and intended future use of DiMe site as playing fields.
Vertical pathway (Cohesive Drift)				
Thickness	m	6 - 11.6 - 19.2	Triangular	Thickness of Cohesive Drift from DiMe area borehole logs. Most likely based on average
Hydraulic Conductivity	m/s	1×10^{-10} - 1×10^{-7}	Log Uniform	Typical conductivity ranges for Clays & Silts from Domenico and Schwartz (1990). Log uniform to represent range over more than 1 order of magnitude.
Fraction of Organic Carbon	%	0.3 - 2	Uniform	Site specific testing of Cohesive Drift (DIME boreholes, 2009)
Water Filled Porosity	--	0.05 - 0.3	Uniform	Assumed ranges based on likely effective porosity of clays and silt after Domenico and Schwartz (1990).
Dry Bulk Density	g/cm ³	1.8	Single value	Assumption, typical for unconsolidated sedimentary materials
Aquifer Pathway Properties (Coal Measures, Secondary A Aquifer)				
Thickness	m	50	Single value	Full aquifer thickness assumed. Only mixing zone thickness used in risk assessment.

Parameter	Unit	Value/Range	PDF	Comment / Justification
Mixing Zone Thickness	m	3 - 6	Uniform	Mixing zone parameterised to the likely weathered thickness of Coal Measures.
Hydraulic Conductivity	m/s	1.16×10^{-6} – 8.1×10^{-6} – 2.66×10^{-5}	Triangular	Values from pumping tests on coal measure aquifer. URS report August 2005 (Ref. 5).
Hydraulic Gradient	--	0.04 - 0.09	Uniform	Gradient from groundwater water levels monitored across area. (Figure 7)
Dry Bulk Density	g/cm ³	2.2	Single value	Assumed for sedimentary rocks consisting of mudstones, siltstones and sandstones (insensitive parameter)
Effective Porosity	--	0.11 - 0.136	Uniform	The Physical Properties of Minor Aquifers in England and Wales (Ref. 6) – properties for the Coal Measures.
Fraction of Organic Carbon	fraction	0.007 - 0.008	Uniform	ConSim Help files (Sandstone).
Distance to Receptor	m	360	Single value	Down gradient site boundary (See Figure 12 and Section 4.5.4)

5.3.2 Chemical Inputs

Table 5.3 – Chemical Inputs used in ConSim Modelling

Substance	EALs (mg/l)	Henrys Law Coefficient (cm ³ /cm ³)	K _{oc} Source Zone (l/kg)	Solubility (max 25 °C) (mg/l)	Biodegradation Rates (years)
Aromatic TPH C ₁₀ -C ₁₂	0.01	0.14	2512	25	2-5
Aromatic TPH C ₁₂ -C ₁₆	0.01	0.053	5012	5.8	3-5
1,2-Dichloroethane	0.003	0.045	11.5 - 151.4	21850	0.35-0.49
Dichloromethane	0.02	0.105	8.8 - 27.5	9960	0.15 – 0.5*

*0.15 represents the highest value from literature and 0.5 a larger value as part of the calibration.

The sources and justifications for the values summarised in Table 5.3 above are contained in Appendix D. The biodegradation rates indicated for dichloromethane is the longest quoted from the literature in an attempt to raise the predicted impacts of this substances. Dichloromethane is readily degraded in the environment according to scientific literature, and this appears supported by the monitored concentrations, with corresponding chloride and methane, noted at DiMe in boreholes installed in the Cohesive Drift (see section 4.4 and 4.4.5.2 specifically).

5.4 Predictive Model Results

Table 5.4 – Results of Predictive Modelling, Concentrations in mg/l

Substance	Source Concentrations	Target concentrations	Concentration at base of Cohesive Drift 40 years (50 th %ile)
Aromatic TPH C ₁₀ -C ₁₂	Limited to Solubility	0	0
Aromatic TPH C ₁₂ -C ₁₆	Limited to Solubility	0	0
1,2-Dichloroethane	21850 – 1120*	0.02 – 0.2	0.023**
Dichloromethane	9960 – 1140*	0.001	0.0026

*the minimum concentrations of dichloromethane and 1,2-Dichloroethane have been deleted as part of calibration and a uniform distribution used.

**reported at 75th%ile, as no breakthrough at 50th%ile.

The results of the predictive modelling appear to demonstrate that dichloromethane and possibly 1,2-dichloroethane are less rapidly degraded in groundwater at DiMe than might be expected from the literature. This is because the predicted impacts using the literature values are lower at the 50th%ile than the concentrations currently in groundwater in the bedrock. The degradation rate for dichloromethane has been increased to produce an impact close to the target concentration to calibrate the properties. It must also be remembered in assessing these model results that there is likely to be residual impacts from the migration of the DiMe solvents as DNAPL which would make the target concentrations higher than could be reflected by the transport of dissolved concentrations of the same substances.

The predicted impacts from the Aromatic TPH fractions show that these substances are retarded by the Cohesive Drift. Considering the monitored concentrations in the Cohesive Drift are currently low and the biodegradation rates simulated for these two fractions are likely to be conservative, the predictive modelling is considered likely to be overestimating the potential impacts from these two substances compared to those monitored at the site in groundwater in the coal measures. This means that the parameterisation of the transport properties of these two substances is likely to be conservative in the predictive model.

5.5 Impact Modelling

The predictive model has been adapted to consider the current source concentrations of leachate to predict the likely impacts at the down gradient site boundary in the Impact Model.

The impact modelling simulates the potential impacts of the source concentrations, as summarised in Table 5.5 below, at the down gradient boundary receptor point in ConSim (see Figure 12) at the 95th %ile, after 1000 years. The period of 1000 years has been considered as a reasonable period over which the residual source at DiMe could pose a risk to controlled waters given the natural processes of degradation and dilution. Two models have been run in this mode, one considers the source as being constant and the second utilises the default ConSim declining source function. The results of the declining source model have been reported at the 95th%ile at the base of the Cohesive Drift at the approximate peak impact (time steps of 10 years for the DiMe solvents and 50 years for the Aromatic TPH fractions were used to find the approximate

peak impact concentration). The predicted impacts of both models are summarised in Table 5.5, and discussed further below.

Table 5.5 – Results of Impact Modelling, Concentrations in mg/l (at 95thile)

Substance	EALs	Starting Source Concentrations	Constant Source Impact at receptor	Declining Source, peak impact at base of Cohesive Drift	Time to Peak Impact (Years)
Aromatic TPH C ₁₀ -C ₁₂	0.01	25	1.97	5.24x10 ⁻⁶	700
Aromatic TPH C ₁₂ -C ₁₆	0.01	5.8	0	2.38x10 ⁻⁶	1500
1,2-Dichloroethane	0.003	1120 - 35	0.25	0.00021	30
Dichloromethane	0.02	1140 - 30	0.064	0.00034	20

The results of the impact modelling using a constant source concentration suggest there is a low risk associated with dichloromethane reaching the receptor at a concentration likely to exceed the EAL. 1,2-Dichloroethane has a theoretical risk of impacting groundwater in excess of the EAL at the site boundary using a constant source, however if degradation of the source is considered the risk reduces dramatically.

The risk associated with the Aromatic TPH fraction C10-C12 appears from the modelling, to be significant using a steady state source, however degradation of the source renders this risk negligible. The risks associated with Aromatic TPH C12-C16 appear to be low from both simulations. The presence of an LNAPL source for the Aromatic TPH fractions is significant in that degradation of the source in solution is unlikely to occur unless this LNAPL is removed from the site.

The results of the impact modelling suggests that provided the LNAPL source of the Aromatic hydrocarbons is removed from the DiMe area there should not be a significant risk to controlled waters as a result of the residual levels of contamination.

6. Discussion and Conclusions

6.1 Summary

This report presents an assessment of the apparent risks to controlled waters receptors from contaminants within the ground and groundwater at the site of the former DiMe plant at Coed Darcy Urban Village.

The DiMe plant is a term used to describe the facility at the BP Llandarcy refinery where one of the final stages in the production of lubrication oils took place. A hot solvent blend of dichloromethane and 1,2-dichloroethane was used to extract waxy materials from the lubricating oil. The DiMe plant operated under pressure and gradual leakage, and occasionally larger scale spillages are understood from data made available to have occurred.

6.2 Conceptual Model

6.2.1 Source

The history of the processes and chemicals manufactured at the site appears to be reflected in the groundwater contamination found at the DiMe site. Spills and leaks of the principal substances used and produced in the DiMe plant appear to be distributed through the sequence of man-made and natural strata depending on their physical and chemical properties. The principal contaminants identified at the site which might impact controlled waters in future were considered to include:

- The DiMe Solvent composed of a mixture of 1,2-dichloroethane and dichloromethane; and
- Aromatic and Aliphatic Hydrocarbons including BTEX (lubricating oils and their hydrocarbon pre-cursors);

The contamination identified included a range of other substances which were considered of low significance. Within the categories of contaminants identified above a list of priority contaminants of concern were selected to reflect the highest risk substances to controlled waters. These substances were:

- 1,2-Dichloroethane;
- Dichloromethane;
- TPH Aromatic C10-C12; and
- TPH Aromatic C12-C16.

6.2.2 Pathway

A reappraisal of the geological units present at the site was conducted to determine the likely hydraulic units present between the source and potential receptors. The previous separation of the glacial drift deposits into two layers has not been carried into this report, although the general trend of increasingly cohesive nature with depth is in common with the previous (URS Ref. 1) interpretation. Three principal layers are considered to be present across the DiMe site:

- Made Ground and inconsistent Granular Drift;
- Cohesive Drift; and
- Bedrock including a weathered/fractured top layer.

The Made Ground and Granular Drift are considered to comprise the source layer, the Cohesive Drift is considered to act as a vertical pathway above the groundwater within the bedrock.

6.2.3 Receptor

The primary controlled waters receptor in relation to the DiMe contamination is considered to be the Secondary A Aquifer which is classified for the bedrock under the DiMe site. The appropriate receptor compliance point in relation to this receptor is considered to be the down-gradient boundary of the Coed Darcy site which is approximately 360m northeast of the DiMe site according to the groundwater flow direction. All other potential controlled waters receptors would be impacted by base flow from the groundwater and are located more than 360m from the DiMe area, and therefore the groundwater compliance point considered should be protective of all other controlled waters.

6.3 Risk Assessment Modelling

A complex risk assessment methodology has been developed to make use of the groundwater monitoring data available from the site over a long period of time. A level of predictive modelling was possible to assess whether the input parameters would reproduce realistic groundwater impacts similar to those monitored at the site. A complicating factor in predictive modelling is the presence of a depleting plume of dissolved contamination in the bedrock aquifer with 1,2-dichloroethane and dichloromethane thought to result from historical DNAPL migration from spills dating from when the site was operational.

In order to assess the potential future risks to groundwater an impact model was used to assess the current source concentrations impact at the chosen receptor point down-gradient of the site. This impact model effectively screened the contaminants for their reasonably plausible risks to receptors currently.

6.3.1 Model Results

6.3.1.1 Predictive Modelling

Little calibration of the models was carried out as the predicted concentrations in groundwater after 40 years (30 years of operation followed by 10 years since closure) in groundwater beneath the DiMe site were largely within the observed ranges. The rates of degradation of dissolved dichloromethane and 1,2-dichloroethane from literature appeared to be more rapid than appears prevalent at the DiMe site. However the groundwater impacts by DNAPL of these contaminants are likely to be still having a residual impact over and above the dissolved contaminants, therefore the parameterisation with more rapid literature rates of biodegradation applied are likely to be conservative. It should be noted that degradation of chlorinated solvents and justification for using degradation in the modelling is supported by natural attenuation indicators such as increased chloride and dissolved methane.

The predicted impacts from the Aromatic TPH fractions were negligible, which reflected reality, however the transport of these substances is retarded and no impact was likely over a period of 40 years. The predictive modelling was considered to effectively validate the parameters used in the following models.

6.3.1.2 Impact Modelling

The results of the impact modelling demonstrated that, of the priority contaminants considered, there were no discernible risks associated with dichloromethane or Aromatic TPH C12-C16. There were some potential risks associated with 1,2-dichloroethane and Aromatic TPH C10-C12 using a constant source which could be dismissed if consideration of source degradation is taken into account. As a result of the impact model no specific remediation targets were considered necessary for the contaminants of concern. There is however a requirement to remediate the

LNAPL source of hydrocarbon contaminants at the DiMe site as this was an assumption of the controlled water risk assessment.

6.4 Discussion

Relatively high concentrations of a number of organic contaminants have been recorded at the DiMe site, some of which are known to have significant residual sources (i.e. TPH fractions from LNAPL free phase on shallow groundwater). The ongoing risks relating to the main contaminants of concern at the DiMe site, the ones that provide the name of the site; 1,2-dichloroethane and dichloromethane, have been found through investigation and risk assessment to be low. This is primarily due to the physical and chemical behaviour of 1,2-dichloroethane and dichloromethane. These are relatively low molecular weight chlorinated hydrocarbons which were discharged by spills and leaks from the DiMe plant in large quantities. The mixture of DiMe solvents is predicted to have behaved as a DNAPL by virtue of their high specific gravity, penetrating the Cohesive Drift and discharging to the groundwater in the bedrock relatively rapidly (c.4 years). The result of these discharges impacted the quality of the groundwater in the bedrock with 1,2-dichloroethane and dichloromethane, up to the time when the plant was closed and decommissioned. The concentrations of 1,2-dichloroethane and dichloromethane subsequently dropped after the site was closed indicating that the main pathway for the DiMe solvent through the Cohesive Drift was likely to be as DNAPL. The residual sources of 1,2-dichloroethane and dichloromethane at the DiMe site distributed through the Cohesive Drift do not appear to present a significant on-going risk to controlled waters.

The risks relating to the other hydrocarbons have been represented using the fractions (Aromatic C10-C12 and C12-C16) which were considered the most likely to impact groundwater due to their high source concentration and physical and chemical properties. The risks of these to controlled waters were also found to be low but only on the assumption that the free phase LNAPL was removed from the DiMe area.

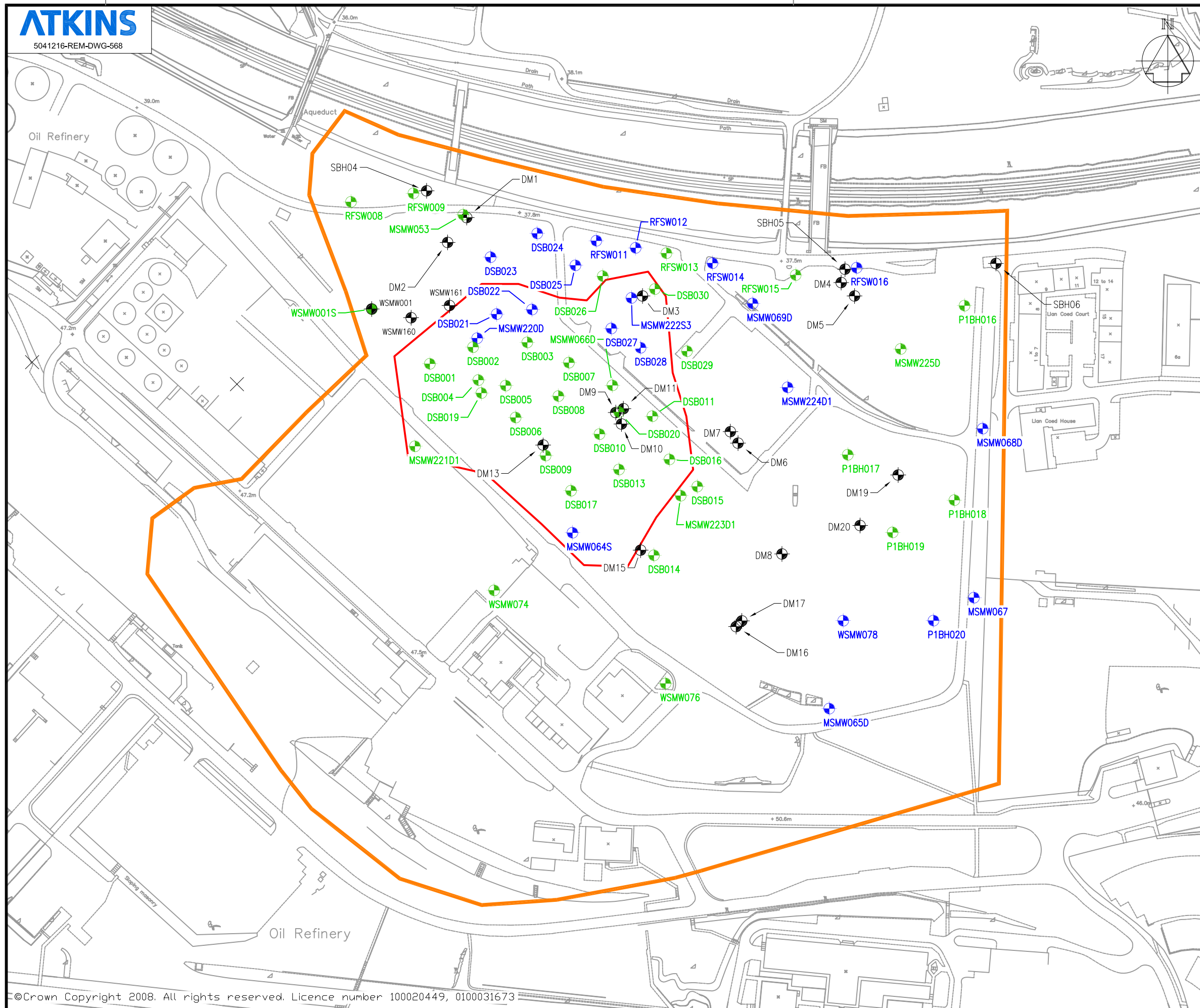
The main source of the Aromatic TPH fractions and other hydrocarbons at the site are the LNAPL's present sitting on top of the shallow groundwater. The presence of an LNAPL source is likely to generate an ongoing level of contamination for groundwater for a long period of time, i.e. providing a constant rather than declining source. A rise in perched water levels as a result of excessive infiltration could cause the LNAPL to rise to the ground surface water impacting controlled water receptors through surface water run-off. Therefore there is a need for removal/reduction of the free phase hydrocarbon LNAPLs from the Made Ground and shallow natural strata whatever the end-use of the site.

The conclusions of this report are open to interpretation on the basis of the level of recent groundwater monitoring data and the lack of recent ground investigations to test current soil source concentrations. A circumstantial case has been presented based upon sound principles of contaminant transport and the properties of the various contaminants considered. This case has been supported by attempting to validate the parameters used, in a predictive model.

The results of the risk assessment are, however, limited by the available monitoring data. Additional monitoring is proposed in order to provide additional justification of the assumed degradation rates adopted in this report. The findings of all monitoring will be reported separately as an addendum to this document.

7. References

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- 11 Kirk-Othmer Encyclopaedia of Chemical Technology. 4th ed. Volumes 1: New York, NY. John Wiley and Sons, 1991-Present., p. V5 (92) 1042



KEY:



ATKINS 2009 INSTALLATIONS



EXISTING INSTALLATION -
NOW DESTROYED



EXISTING INSTALLATION -
REMAINING IN-SITU



EXCLUSION ZONE



FORMER DiMe AREA

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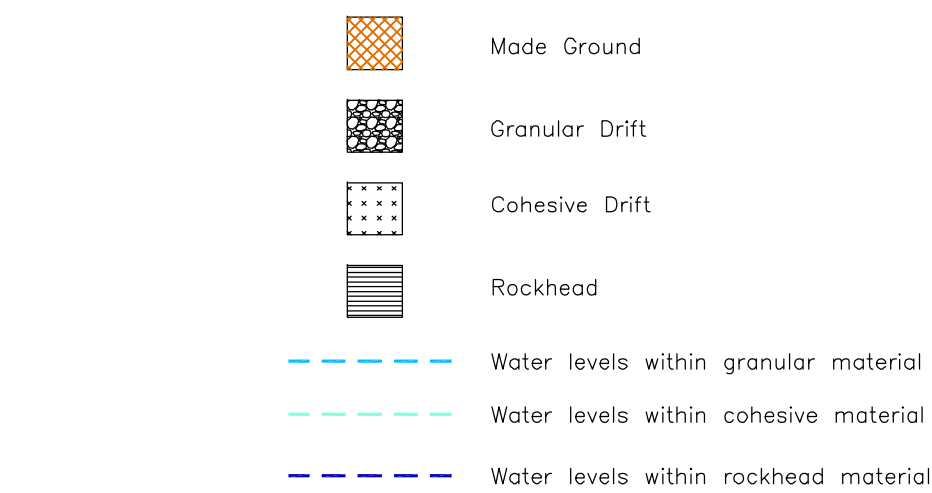
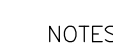
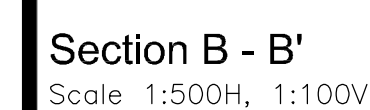
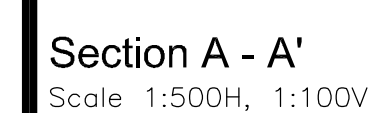
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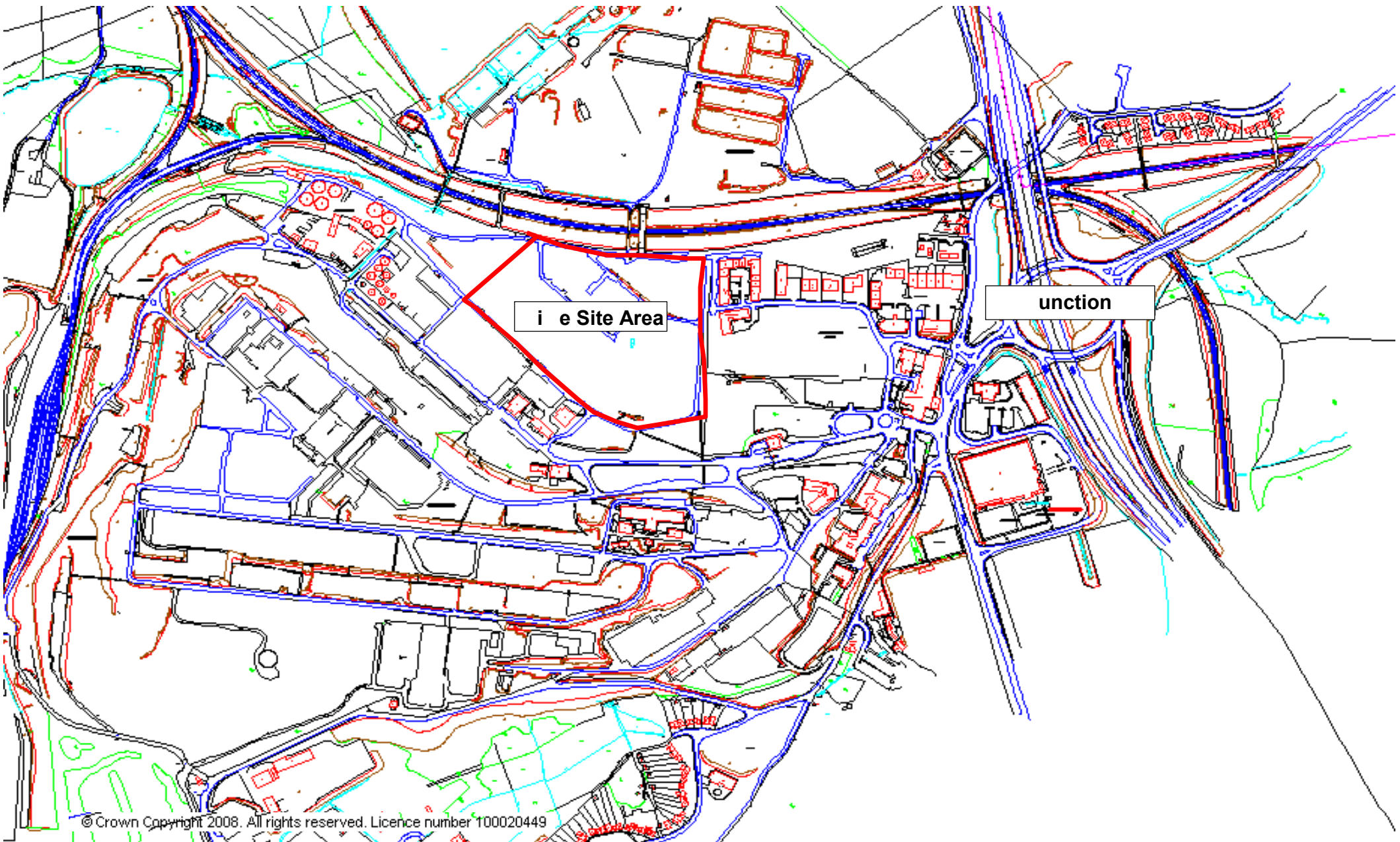
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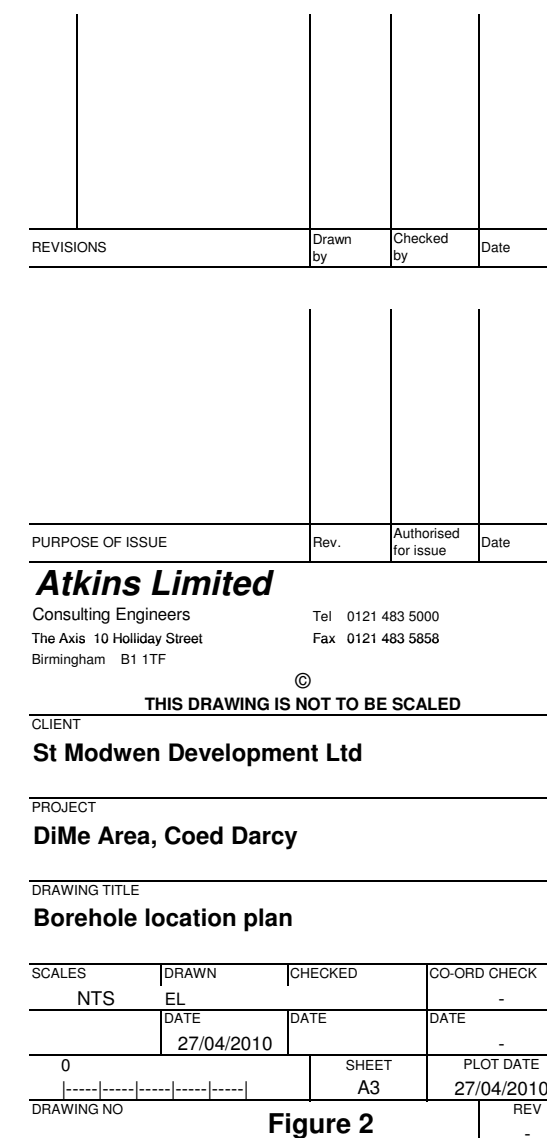
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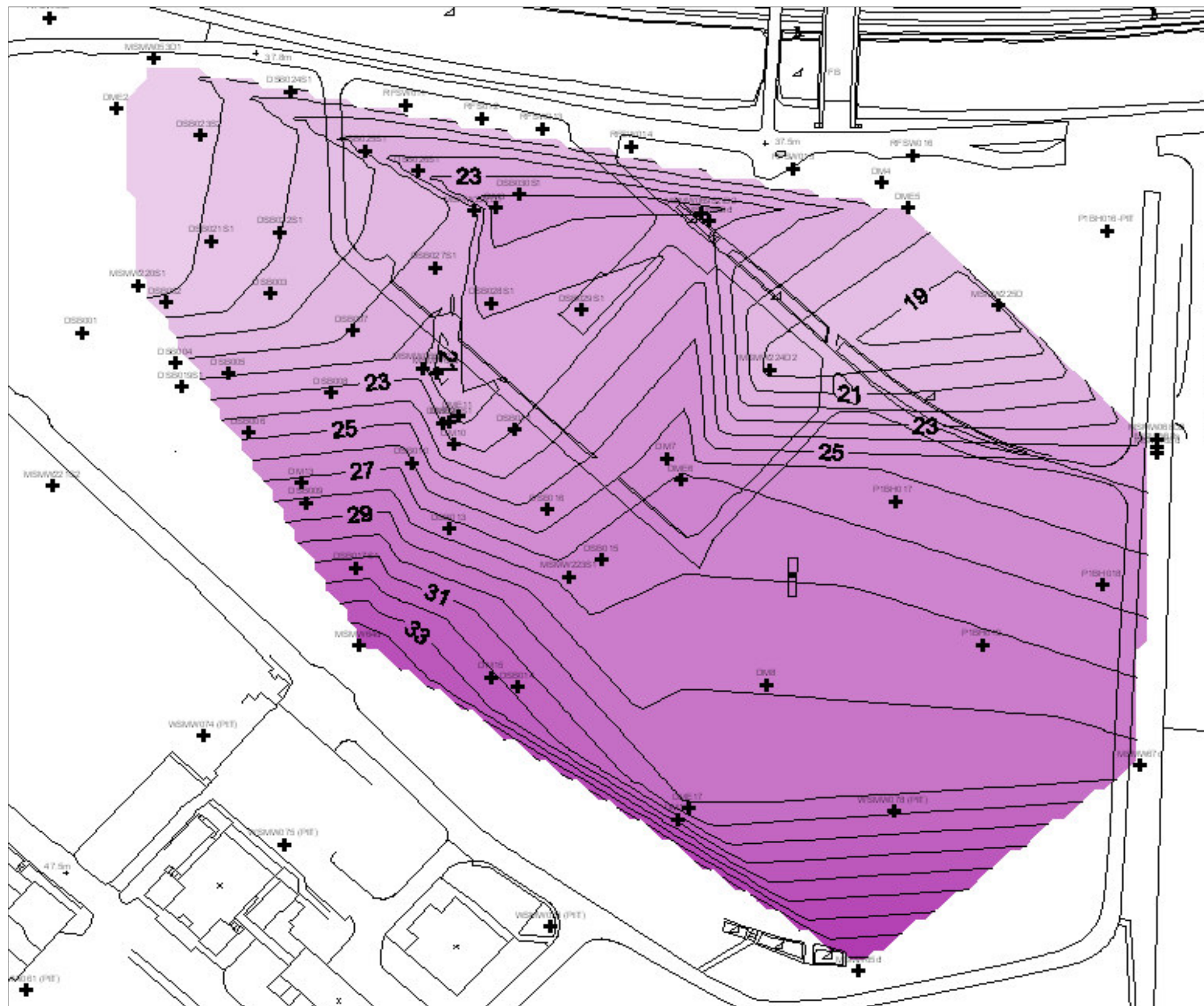
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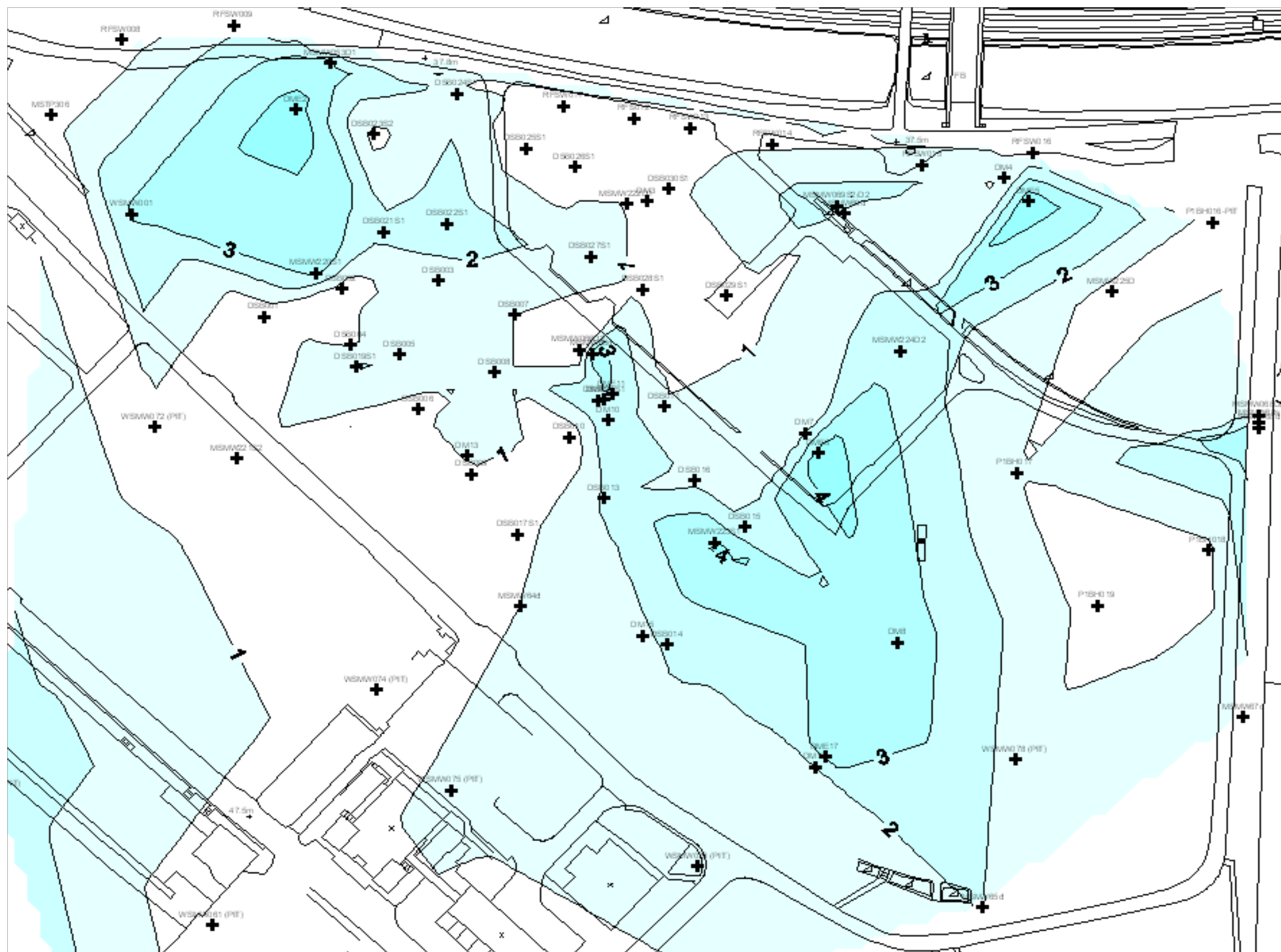
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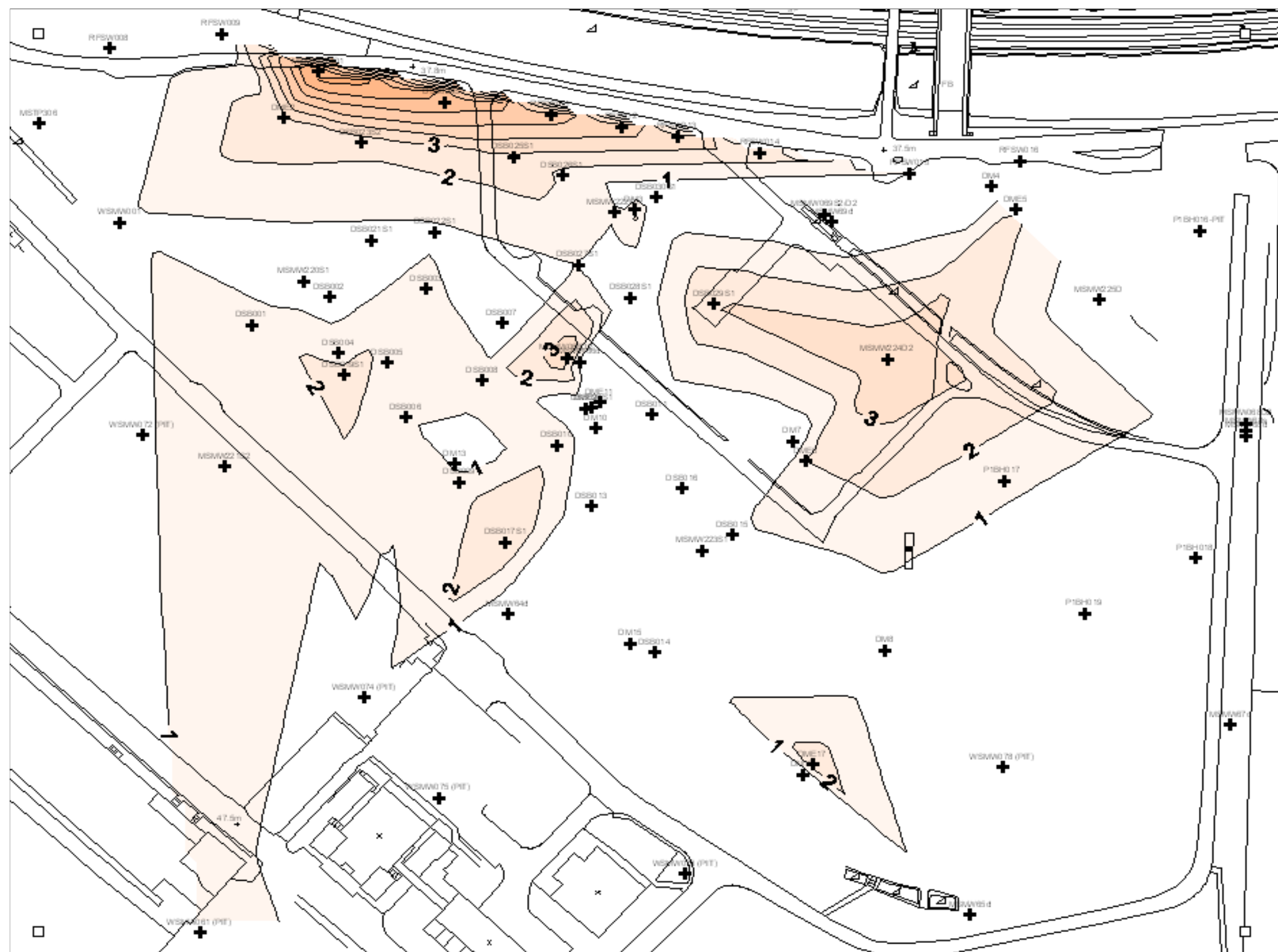
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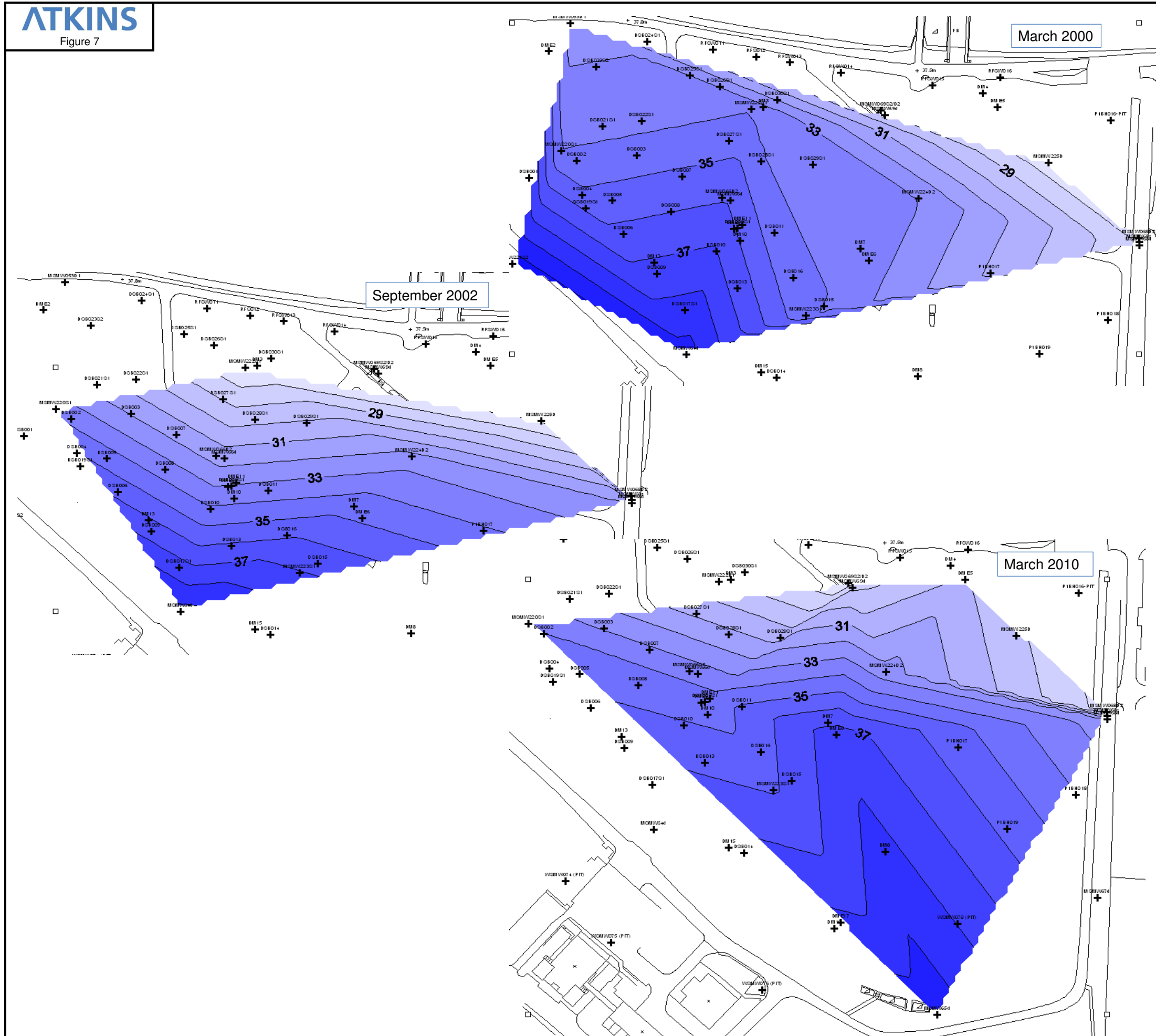
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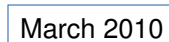
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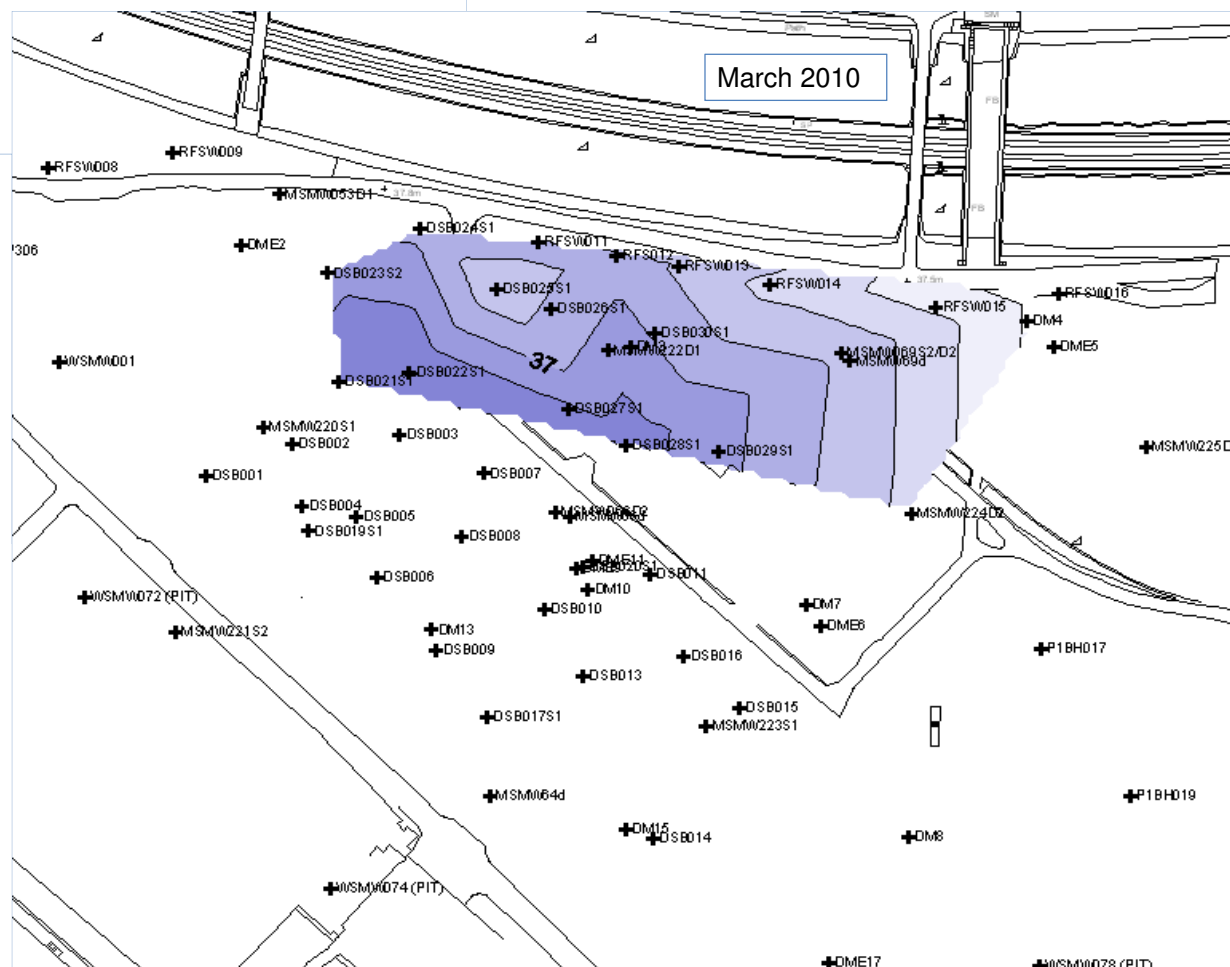
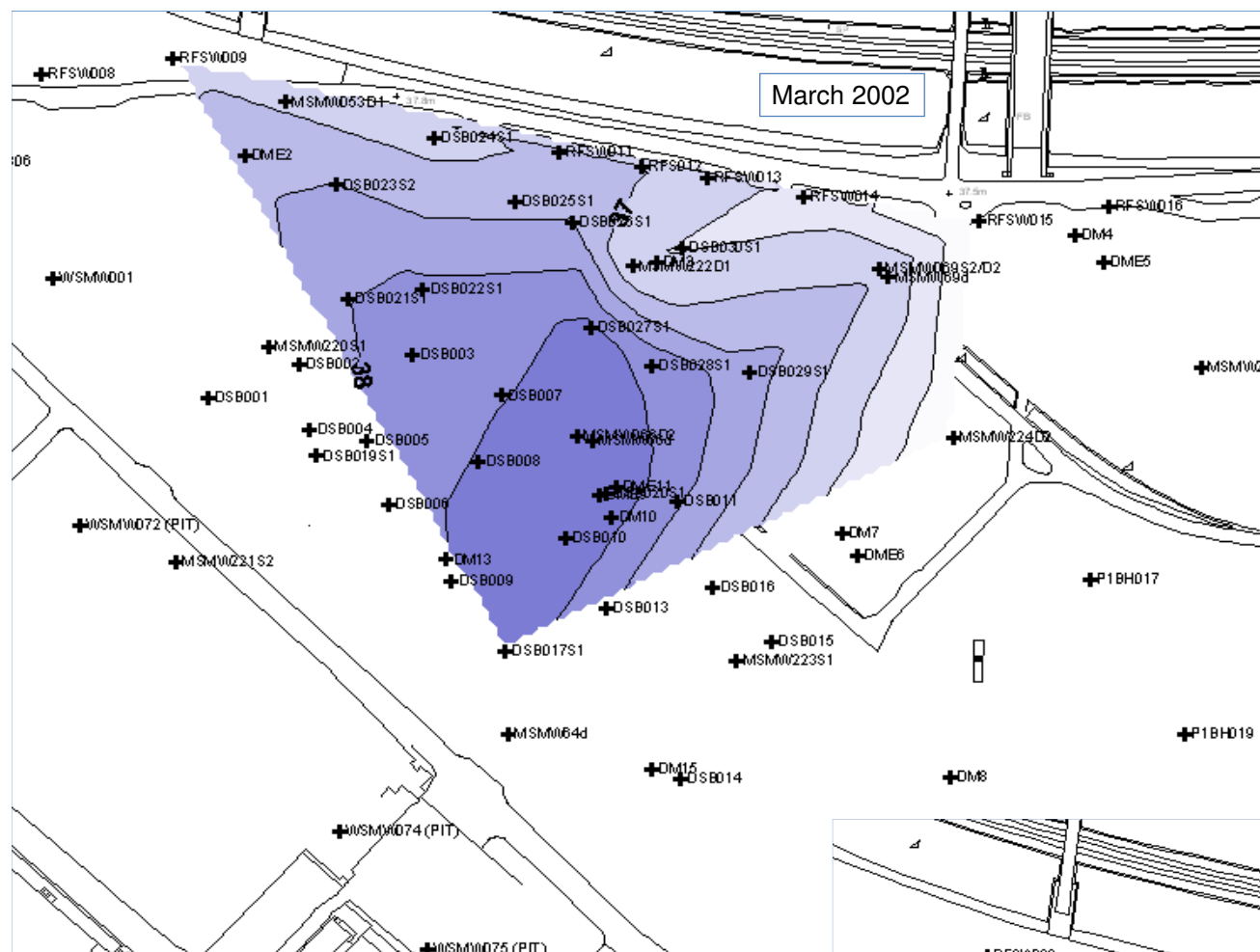
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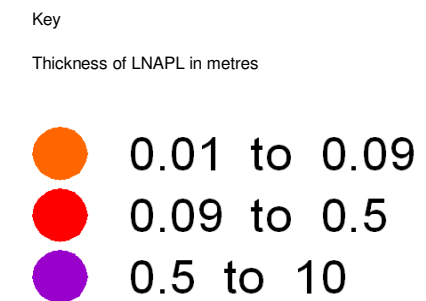


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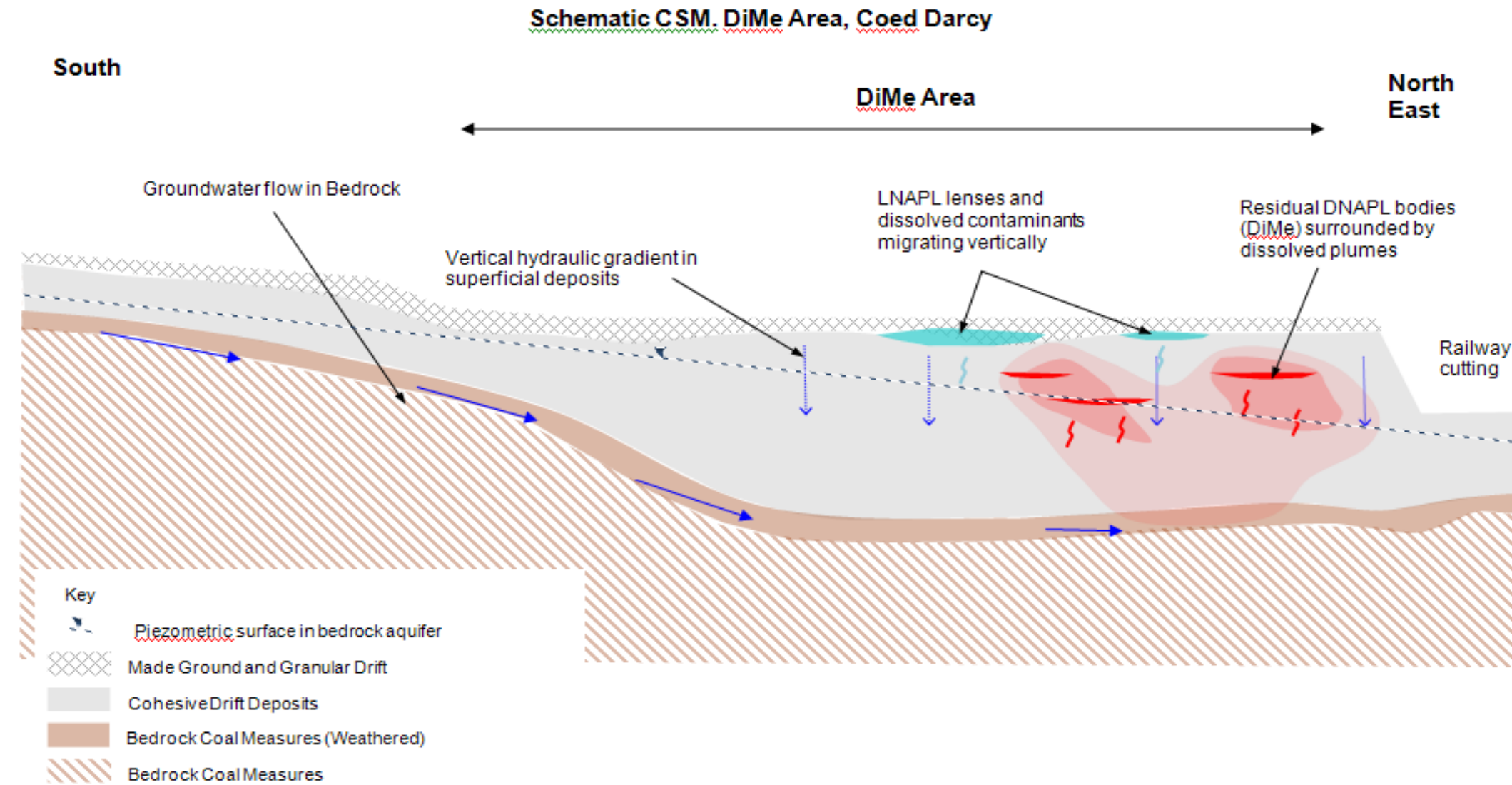


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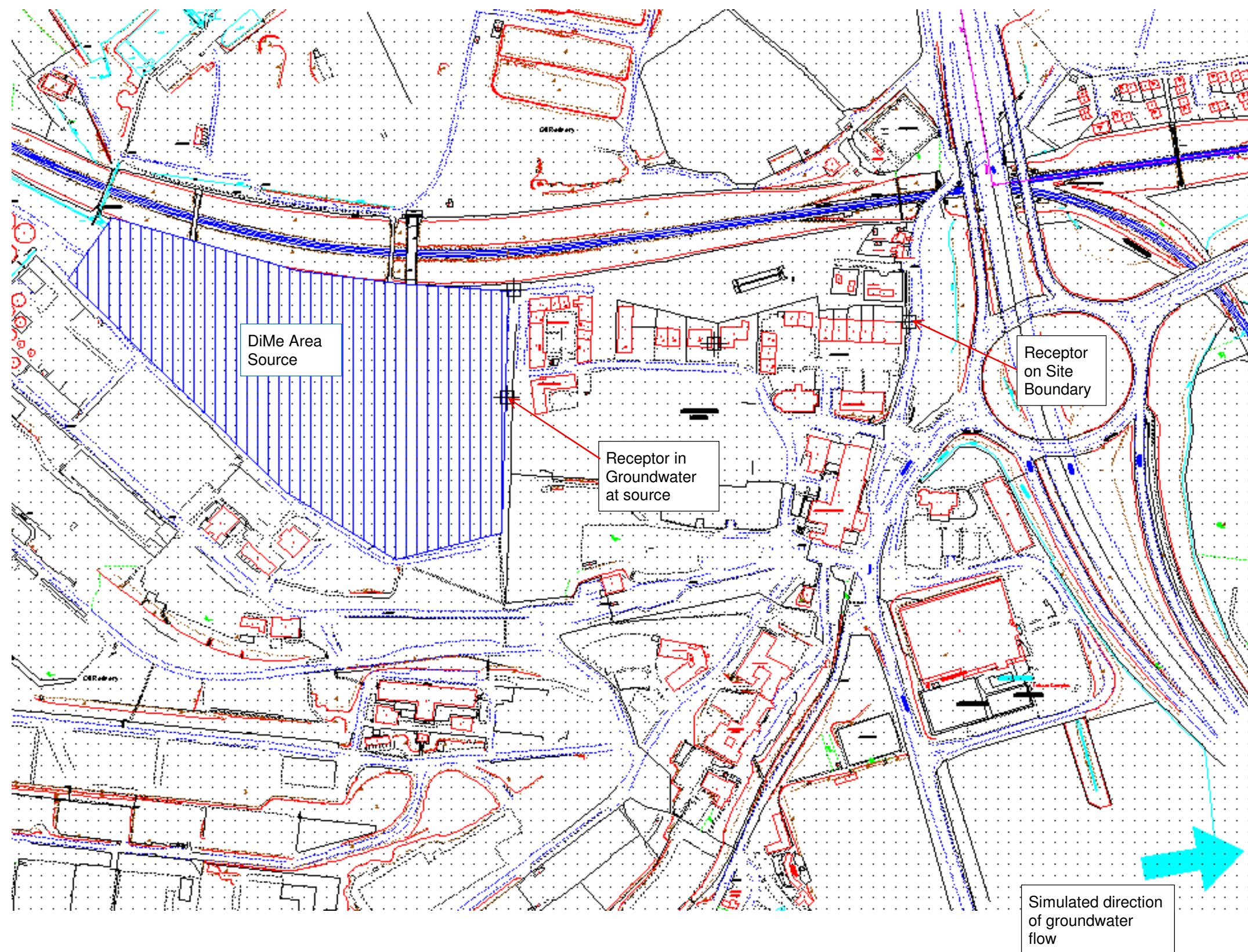


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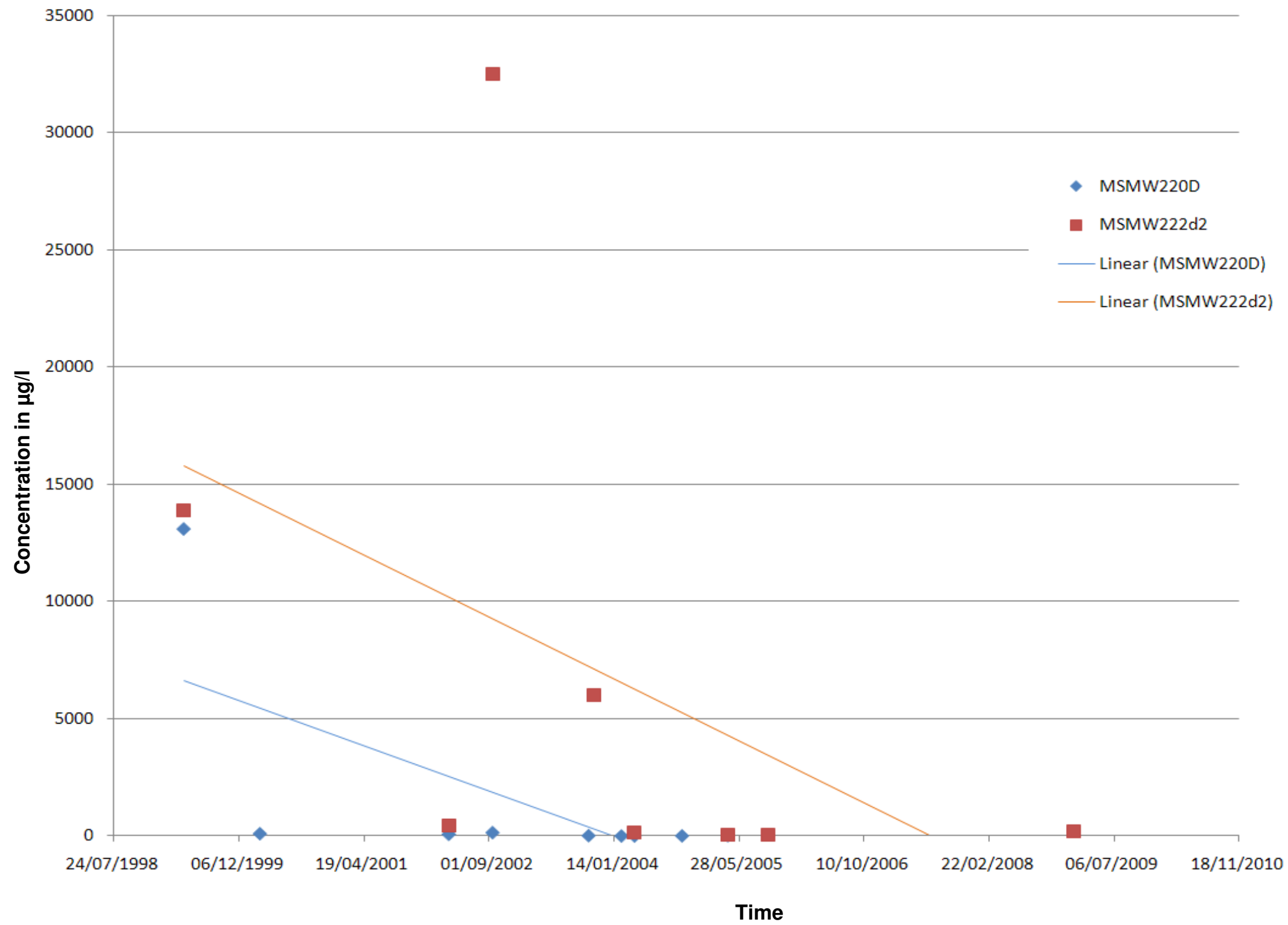


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Boreholes

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Appendix A Borehole Logs, DiMe Area

