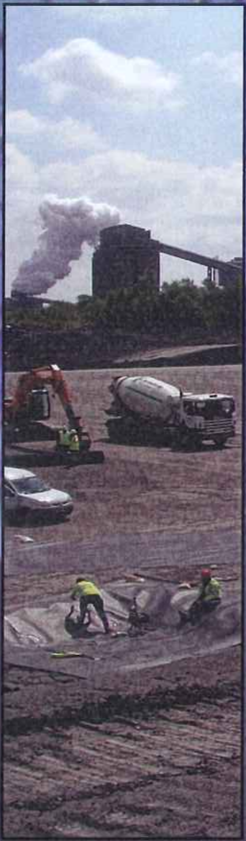



TerraConsult

August 2014
Report No 2067-R01

ROSSETT (ASTBURY) LANDFILL SITE

HYDROGEOLOGICAL RISK ASSESSMENT REVIEW

Prepared for

FCC Environment (UK) Ltd

ROSSETT (ASTBURY) LANDFILL SITE

HYDROGEOLOGICAL RISK ASSESSMENT REVIEW

August 2014

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DISCLAIMER

ROSSETT (ASTBURY) LANDFILL SITE

HYDROGEOLOGICAL RISK ASSESSMENT REVIEW

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1. INTRODUCTION

1.1 Background

This document, prepared by TerraConsult (South) Ltd (TCL) was commissioned by FCC Environment (UK) Ltd (FCC) to respond to two improvement conditions for the Rossett (Astbury) Landfill, near Wrexham.

Environmental Permit EPR/FP3839FP was consolidated into the latest version of the Permit in March 2014 by Natural Resources Wales and includes a series of improvement conditions designed to demonstrate that the appropriate management and monitoring controls are in place for the aftercare of the site. The Permit is in the name of WRG Environmental Ltd; a wholly owned subsidiary of FCC. There are two hydrogeological related improvement conditions, Improvement Conditions 4 and 7 contained within Schedule 1 Table S1.3 of the permit:

- IC4 – A review of the December 2003 HRA with a summary of all groundwater and leachate monitoring carried out since the December 2003 HRA;
- IC7 – A review of the surface water monitoring regime.

In order to prepare the risk assessment, the following documentation has been consulted

- Environment Agency (2003) Hydrogeological Risk Assessments for Landfills. LFTGN01
- Environment Agency (2003) Guidance on Monitoring of Landfill Leachate, Groundwater and Surface Water. LFTGN02
- Environment Agency (2011) Horizontal Guidance Note H1 - Annex J3. Additional guidance for hydrogeological risk assessments for landfills and the derivation of groundwater control levels and compliance limits.
- Environment Agency (2009) Hydrogeological Risk Assessment for Landfills Four Yearly Review Template

The assessment is also based on

- MJCA (2003) Hydrogeological Risk Assessment for Rossett Landfill Complex, Burton, Rossett. Ref: SH/DL/GD/2413/05
- MJCA (2009) Site Closure Plan - Rossett Landfill Complex. Ref: WRG/DL/JHP/1524/01
- FCC (2014) Environmental monitoring data

1.2 Site Location and History

The Astbury (Rossett) Landfill is located at Dark Lane, Burton, Wrexham, Clwyd, LL12 0AE, some 7km north west of Wrexham. The site is centred on National Grid Reference SJ 32747 56798.

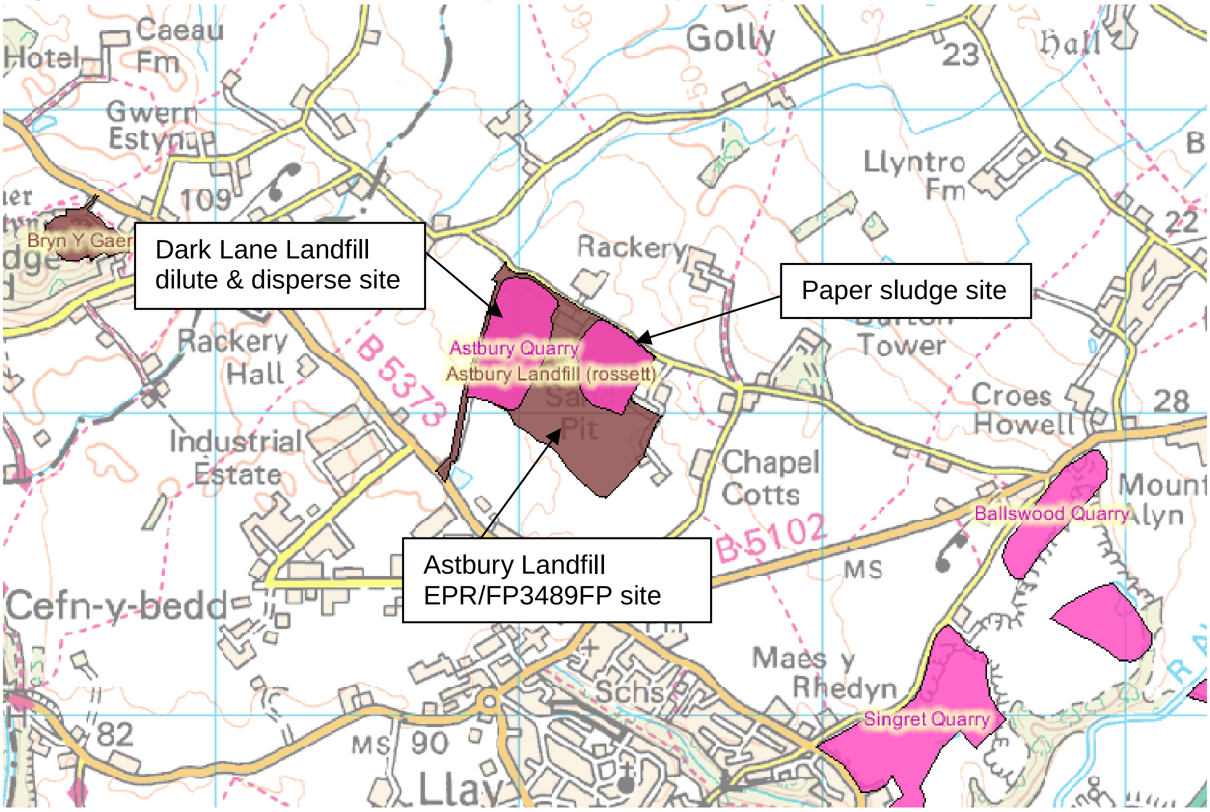
The site was originally licensed as Waste Disposal Licence L/84 issued on 17/08/1994 to reclaim the void space within the former Astbury glacial sand quarry. The licence was converted into EAWML37116 in September 1996, which was superseded by EPR/FP3894FP in September 2009.

The site was operated as a co-disposal landfill until June 2004 for the receipt of what is currently classified as hazardous, non-hazardous and inert wastes. From July 2004 the site was reclassified as a non-hazardous landfill. An application for a PPC Permit was prepared in 2003, however, the site ceased to accept wastes in 2005 before the end of the permit determination process. The landfill has since been fully capped, but has not entered formal "Definitive Closure". Monitoring and active emissions (*i.e.* landfill gas and leachate) management has continued to date as per the licence requirements.

There are two adjacent unlined landfill sites which were operated to the regulations of the time, and include a paper pulp landfill to the NE and the co-disposal Dark Lane landfill to the NW of the reviewed site (Figure 1). The paper pulp landfill was operated during the 1980's and the Dark Lane site was operated from 1974 to 1994. There is a further complication in that animal carcases are reported to have been buried at Yr Ackery Farm to the north of the Astbury Landfill site.

One of the primary factors which influenced the cessation of operations was from the limited engineering information from the earlier phases of the site's lifecycle whereby it is not possible to retroactively demonstrate the exact separation engineering details between the Astbury and the closed Dark Lane sites.

Figure 1 Site Location and Adjacent Astbury Quarry Landfills



2. REVIEW OF SITE CONCEPTUAL MODEL

2.1 Introduction

The Astbury landfill complex is located within glacial deposits with a generalised sequence of

- Clayey Till
- Upper Sand layer

- Intermediate Clay layer
- Lower Sand layer
- Basal clay unit

It is understood that the overlying clay layer was removed, and then the mineral was excavated into the upper sand of the glacial deposits terminating at the underlying intermediate glacial clay. It is because of the poor quality of the mineral beneath the clay layer and planning condition level limits that quarrying did not proceed through the intermediate clay. Schematic sections through the site are shown on Drawing SH/DL/10-03/11161.

2.2 Installation Design

The site has been designed and operated using the engineering standards of the time, and therefore the containment engineering has varied over the lifetime of the site from the first cell to be filled (Dark Lane Phase 1) in 1974, to the last cell to be engineered (Astbury Landfill, Cell 5) in 1998 as set out in Table 1. The site has therefore evolved from operating under the principals of dilute and disperse to fully engineered containment and active management from 1988. However, although active leachate management (without groundwater abstraction) is not possible for the Dark Lane and Paper pulp sites, leachate generation within these landfills is restricted as far as possible by the placement of a fully engineered cap.

Landfilling operations continued until 2005. The final containment engineering works were completed by 2009, when the LLDPE cap was in place. In addition to the capping works, restoration soils were placed and the surface profile re-contoured using inert materials to ensure that the correct pre-settlement contours are achieved.

Table 1 Engineering Standards

<table>
<tr><th>Engineering</th><th rowspan="2">Paper Pulp</th><th colspan="3">Dark Lane</th><th colspan="2">Astbury</th></tr>
<tr><th></th><th>Phase 1</th><th>Phase 2-4</th><th>Phase 5</th><th>Cells 1 - 2</th><th>Cells 3 - 5</th></tr>
<tr><th>Approx Dates</th><th>1980 - 1988</th><th colspan="2">1974 - 1988</th><th>1988</th><th colspan="2">1994 - 2005</th></tr>
<tr><td>Restoration</td><td>1m soil</td><td>1m soil</td><td>1m soil</td><td>1m soil</td><td>1m soil</td><td>1m soil</td></tr>
<tr><td>Cap</td><td>1m clay</td><td>1m clay</td><td>1m clay</td><td>1m clay</td><td>1mm LLDPE</td><td>1mm LLDPE</td></tr>
<tr><td>Drainage</td><td>None</td><td>None</td><td>None</td><td>no details</td><td>0.3m</td><td>0.3m</td></tr>
<tr><td>Basal Liner</td><td>None</td><td>None</td><td>Containment-unspecified</td><td>1m Eng clay</td><td>2mm HDPE
0.5m Eng Clay
0.1m BES</td><td>2mm HDPE
1m Eng Clay</td></tr>
</table>

n.b. sideslopes capped with LLDPE

2.3 Source Term

The volume of leachate within the site has historically been difficult to establish due to silting and the collapse of *in-waste* monitoring and abstraction wells. A significant proportion of the historic data where leachate levels are apparently reported as >2.5m above the base of the site are likely to be representative of the height of water above the base of an obstructed well and not the height of leachate acting on the base of the site.

A direct comparison of the 2005 - 2008 data with the 2013 - June 2014 data demonstrates that considerable efforts have been employed to reduce any backlog of leachate within the site and to ensure that monitoring data collected is representative.

Since the implementation of the leachate management works (including the reinstallation of new monitoring locations and completion of the capping works by 2009) the site has been able to demonstrate that leachate is under control and except for a limited number of outliers (of up to 2m) leachate is sustained at <1m above the base of the site (Figure 2 and Table 2).

However, the site was engineered with a 1m clay and HDPE liner was placed against the lower 4m of the sidewall of Cell 1 against the dilute and disperse area. The 1m clay liner was extended to a height of 9m above the base. The height of the HDPE sidewall liner is important as the leachate level improvement conditions 4 and 5 as referenced within Permit Table S3.1, requires that at least 1 metre's freeboard shall be maintained between the internal bund separating the non-engineered parts of the landfill.

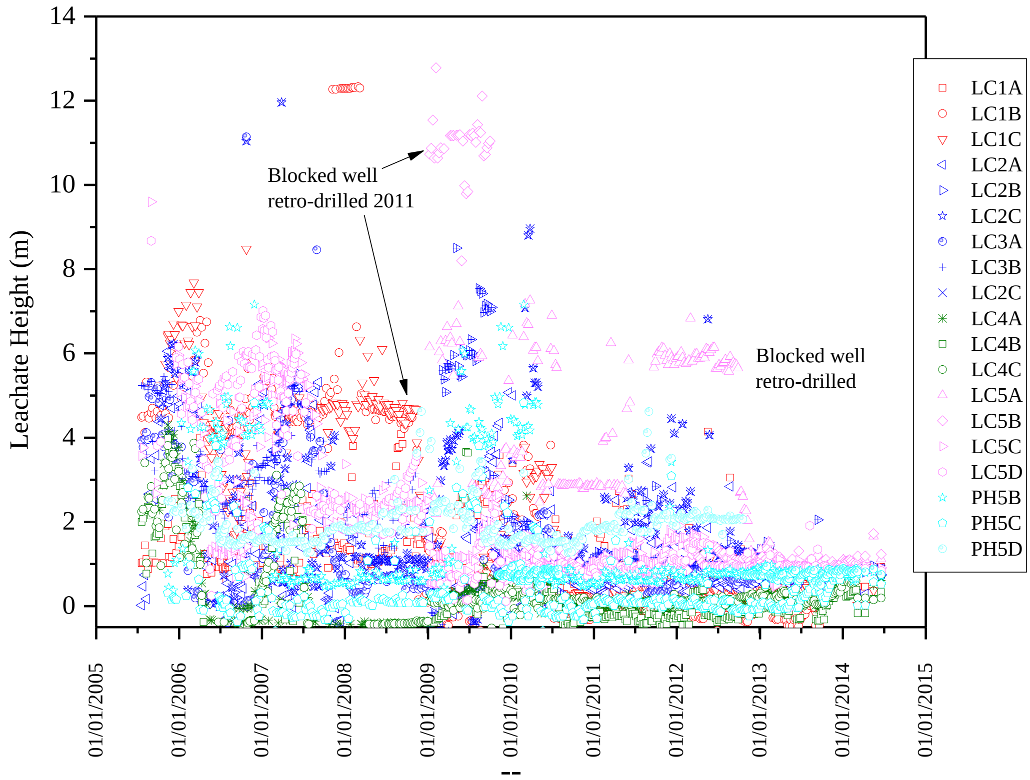
This freeboard would equate to maintaining a leachate head at no more than 3m above the base of the site. It is therefore proposed, that based on this principle, the compliance limit for leachate levels in the Astbury phase of the site be set at 71mAOD, based on the available basal information plus 3m.

It is recommended that the compliance limit for the Phase 5 (chambers PH5B, 5C & 5Dr) remains at 1m above cell base.

Table 2 Leachate Height (m above base)- Green shaded cells <1m, brown shaded >1m

	July 2005 - 2008					2013 - June 2014				
	min	10th%ile	median	85th%ile	max	min	10th%ile	median	85th%ile	max
LC1A	0.62	0.77	1.23	1.84	4.08	0.30	0.58	0.90	0.95	1.31
LC1B	0.09	4.12	4.60	5.53	12.33	replaced as LC1Br				
LC1Br	replacement monitoring point					0.00	0.00	0.16	0.82	0.88
LC1C	1.54	2.57	4.69	6.42	19.58	replaced as LC1Cr				
LC1Cr	replacement monitoring point					0.00	0.05	0.50	0.87	0.95
LC2A	-0.38	0.10	1.35	4.79	6.05	0.29	0.54	0.74	0.88	0.94
LC2Br	replacement monitoring point					0.66	0.76	0.87	0.95	2.05
LC2C	-0.02	0.20	1.15	4.15	11.96	replaced as LC2Cr				
LC2Cr	replacement monitoring point					0.82	0.87	0.90	0.93	1.42
LC3A	-0.44	0.19	1.63	4.77	16.82	0.20	0.52	0.84	0.90	0.99
LC3B	-0.36	1.85	2.98	4.86	20.93	replaced as LC3Br				
LC3Br	replacement monitoring point					0.53	0.79	0.87	0.92	1.17
LC3C	0.43	2.22	2.78	4.34	7.79	replaced as LC3Cr				
LC3Cr	replacement monitoring point					0.00	0.00	0.00	0.00	0.63
LC4A	-0.44	-0.43	-0.03	2.80	4.30	0.00	0.00	0.28	0.81	0.90
LC4B	-0.44	-0.28	1.78	2.82	3.98	0.00	0.00	0.12	0.35	0.76
LC4C	-0.44	-0.42	1.42	2.70	3.87	0.03	0.05	0.19	0.45	0.67
LC5Ar	replacement for damaged monitoring points					0.72	0.92	0.96	1.11	1.66
LC5Br						0.91	0.94	1.04	1.19	1.72
LC5C	0.69	1.41	2.64	5.41	9.60	0.00	0.65	0.86	0.94	1.11
LC5D	0.25	1.81	3.86	5.82	8.67	0.75	0.84	0.92	0.95	1.91
PH5B	replacement monitoring points					0.58	0.69	0.79	0.84	0.97
PH5C						0.00	0.00	0.33	0.77	0.88
PH5Dr						0.47	0.60	0.77	0.85	0.94

Figure 2 Leachate Height (m above base)



Leachate is monitored in five cells within the Astbury landfill and Phase 5 of the Dark lane landfill. The recent (2009 - 2014) monitoring data has been summarised in Appendix A, for the matrix and indicator substances (Tables A1 - A6), hazardous and non-hazardous metals (Table A2) and organic substances (Table A3). Time series plots for each cell have also been appended (Figures A1 - A6).

The leachate is a sodium bicarbonate based solution, with significant chloride, ammoniacal-N and dissolved organic matter (Table 3).

Potassium and magnesium are also significantly more concentrated with the leachate than expected in terrestrial waters. Neither potassium nor magnesium causes a risk to the environment except for their contribution towards the total salinity; however, they are useful indicator of influences on the water chemistry due to their mobility. The relatively low calcium and sulphate compared to other matrix ions and magnesium in particular is also consistent with a biologically active methanogenic regime whereby putrescible wastes are degrading and preferentially releasing the nutrients potassium and magnesium which are then not re-precipitated *in-situ*. Nitrate denitrifies to nitrogen under landfill conditions.

It is noted that whilst ammoniacal-N (Figure 3) and COD are primarily within the 700 - 1,500mg/l expected for the majority of methanogenic leachates, that sodium and chloride (Figure 4) are generally within the 2,000 - 4,000mg/l. Potassium at approximately 20 - 30% of sodium concentrations is also lower than the ~60% expected for municipal wastes. Such a set of observations can be consistent with either recirculation or the co-disposal of hazardous (formerly classified as special) wastes. Notwithstanding the above, the level of sodium chloride enrichment is significantly lower than expected for highly soluble hazardous wastes whereby chloride concentrations can increase to above 10,000mg/l.

Table 3 Leachate Summary – Selected Matrix & Indicator Components (Average Concentration)

	Astbury Landfill					Dark Lane
	Cell 1	**Cell 2**	**Cell 3**	**Cell 4**	**Cell 5**	**Phase 5**
Ammoniacal-N (DWS 0.39mg/l)						
2001 - 2003	363	823	1,150	1,009	1,255	1,999
2003 - 2009	720	380	1,180	940	1,107	1,193
2009 – 2014	676	834	712	448	1,285	1,441
COD						
2003 - 2009	1,266	1,960	2,245	1,289	1,881	1,604
2009 – 2014	1,106	1,266	1,447	659	1,897	1,654
TOC						
2003 - 2009	385	240	772	447	628	423
2009 – 2014	323	418	460	188	671	514
Alkalinity						
2009 - 2014	4,974	5,616	5,918	3,627	8,269	6,858
Chloride (DWS 250mg/l)						
2001 - 2003	2,789	2,951	2,237	3,049	3,752	2,295
2003 - 2009	1,983	1,482	3,182	2,973	2,409	2,094
2009 – 2014	1,869	2,521	2,284	1,176	2,959	2,054
Sodium						
2001 - 2003	2,345	2,852	3,206	2,571	2,270	2,001
2003 - 2009	2,444	1,481	1,180	940	2,409	1,193
2009 – 2014	2,090	2,345	2,768	1,459	2,941	1,803
Potassium						
2001 - 2003	366	489	488	421	606	435
2003 - 2009	354	306	583	440	589	417
2009 – 2014	280	345	373	170	537	393
Calcium						
2001 - 2003	112	87	68	119	85	86
2009 – 2014	179	109	126	155	66	113
Magnesium						
2001 - 2003	149	193	137	163	183	127
2003 - 2009	120	98	109	115	128	132
2009 – 2014	96	93	96	66	118	94
Sulphate						
2001 - 2003	87	187	241	209	218	66
2003 - 2009	213	394	316	176	60	248
2009 – 2014	<40	<20	<40	<20	<40	<40

The leachate chemistry is generally consistent across the monitoring period from 2001 to 2014. There are no overall trends however outlier reported outlier points which are not sustained across successive monitoring events can occlude the actual underlying trends.

There is one cell (Cell 4) where there appears to be an indication that the leachate is depleting (Figure 5). This depletion is however a recent event and only apparent post 2010. It is not known if this is caused by or coincidental with the completion of the capping works.

Figure 3 Leachate Ammoniacal-N

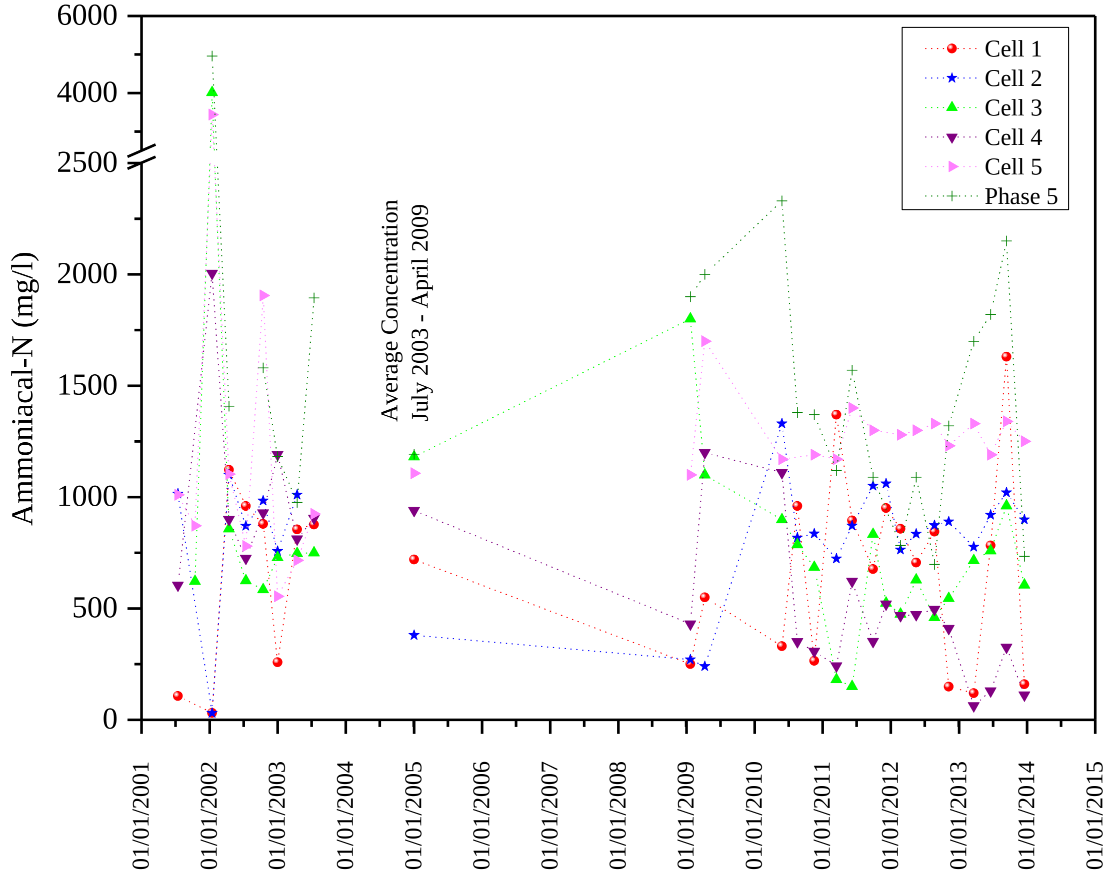


Figure 4 Leachate Chloride

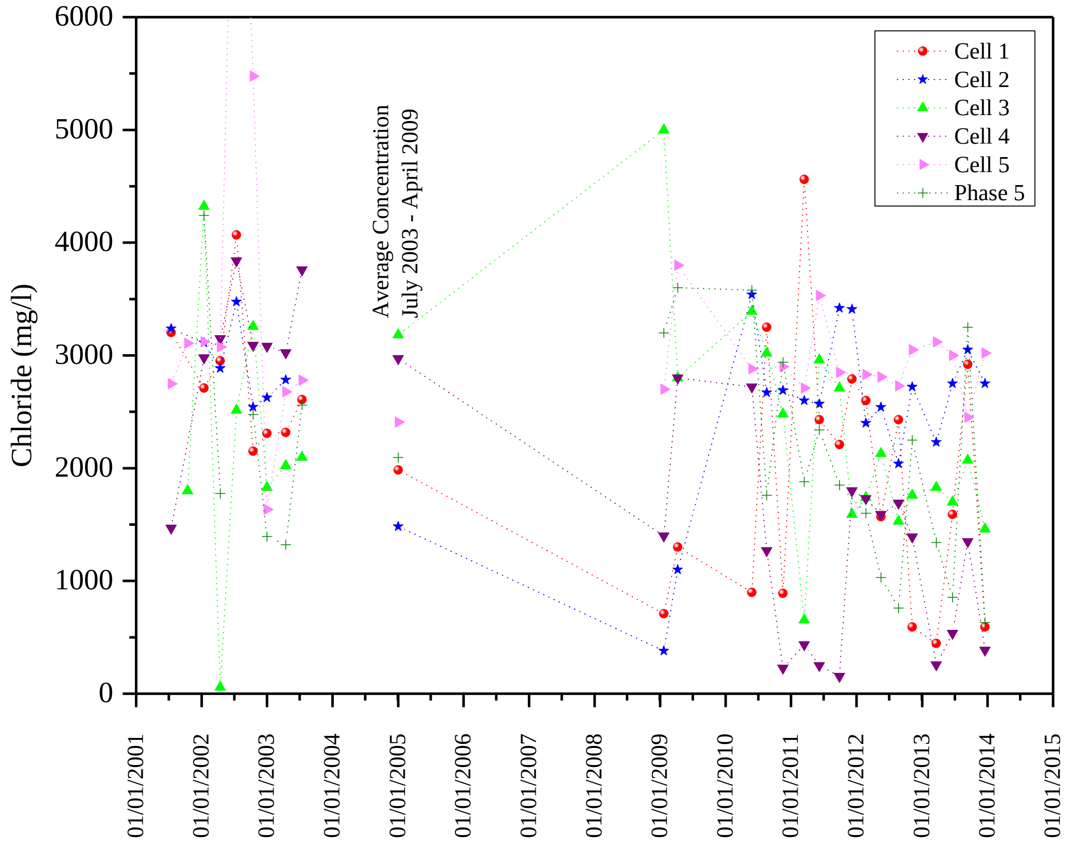
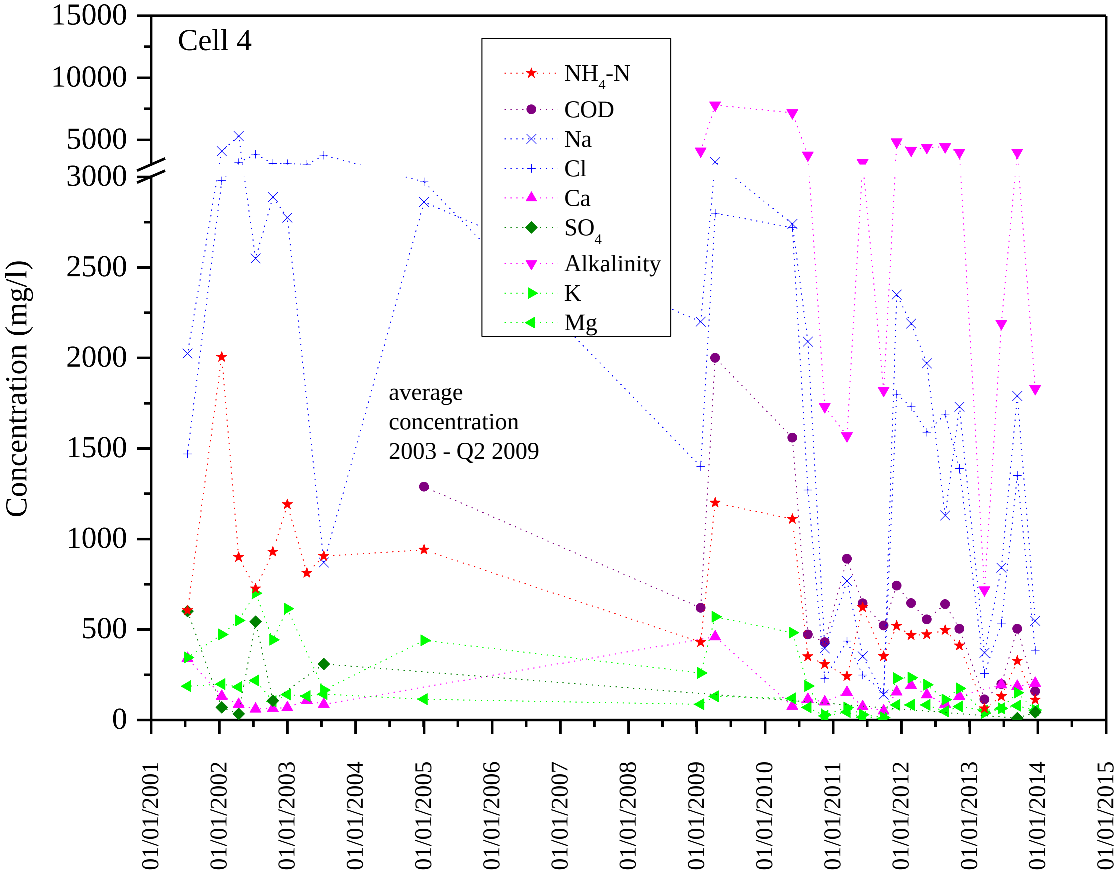


Figure 5 Cell 4 Leachate Matrix and Indicator Components



The hazardous and non-hazardous inorganic substances can be sub-divided into a number of categories, namely;

- the redox sensitive minor metals iron and manganese at >0.5mg/l (Appendix Table A3);
- the non-hazardous metals chromium, copper, nickel and zinc are typically at 0.01 - 0.6mg/l (Appendix Table A4); and
- the hazardous metals cadmium, mercury (and lead) are typically at <1µg/l (Appendix Table A4).

Iron and manganese are the only two metals which can give an indication of the state of the biochemical regime within the landfill. However, interpretation is made difficult as they also readily form colloidal forms with large molecular sized dissolved organic matter. Neither metals is however of environmental concern, except for later stages in a site's lifecycle when the landfill reverts from methanogenic and sulphate reducing conditions and sulphide minerals dissolve releasing soluble iron or manganese, which then re-precipitate on exposure to air.

Iron and manganese are also primary constituents of natural soils and their concentration varies dependent on air ingress, saturation levels and natural biological activity within the soil. In addition as the only mobile forms are associated with organic matter or colloidal forms within the landfill, these are subject to a higher degree of filtering than would occur for other dissolved metals. The quantity of iron and manganese within landfill leachate which can migrate into the environment is therefore inconsequential compared to the natural background levels even though leachate concentrations are typically at 1 - 3mg/l for iron and 0.1 - 1mg/l manganese.

Chromium, copper, nickel and zinc are non-hazardous metals ubiquitous within the environment. Chromium and zinc are a major component of many products and are generally chemically stable. Both metals readily complex with iron and concentrations within the ground are usually dependent on the iron-manganese redox regime and can be rapidly precipitated on exposure to air, oxygenated waters and soil.

Zinc is typically at 8 - 114µg/l and peaks at concentrations of 0.03 - 0.8mg/l which is significantly within its drinking water standard (DWS) of 3mg/l, whilst chromium typically at 40 - 119µg/l is generally only double the 50µg/l DWS. However, peak concentrations do range between 0.1 and 0.45mg/l.

Copper and nickel are more environmentally sensitive however concentrations are usually lower than for chromium and zinc. Copper is typically at 0.003 - 0.08mg/l with a single location (Cell 3) peaking outside of this range at 0.4mg/l. The copper is significantly below the 2mg/l DWS. Nickel is present within a tight concentration range of 0.03 - 0.15mg/l, which is in excess of the 0.02mg/l DWS.

Lead is reported at 0.1 - 3µg/l, with a single outlier at 11µg/l. Given that lead's DWS is 10µg/l, lead is not considered as significant within the leachate.

Mercury is reported as <0.01µg/l. Cadmium is also typically reported as below detection limits (<0.1µg/l), with the occasional outlier concentration reported at 0.3 - 0.5µg/l at all cells except for Cell 5, where a concentration of 6µg/l has been reported. This latter reported concentration approximates to the 5µg/l DWS. However, in similar landfill leachate scenarios, there can be false reporting of cadmium due to interferences with other ions in solution. Such a hypothesis is a reasonable assumption as concentrations in the following two analysis were below detection limits (<0.1µg/l).

Organic analysis is also undertaken on a routine basis. The primary constituents identified are the BTEX hydrocarbons (Tables A5 and A6). The BTEX substances are secondary breakdown products of natural organic matter within the landfill and are not primarily derived from primary waste inputs. The observed concentrations range from 3 - 75µg/l except for Cell 4, where benzene concentrations are higher at 0.26 - 0.65 mg/l (Table 4). Notably, the other BTEXs ethylbenzene and m,p-xylenes are more significant in Dark Lane Phase 5 at 0.1 and 0.17mg/l respectively than in Cell 4.

Table 4 Leachate Benzene (as µg/l)

Row Labels	CELL01	CELL02	CELL03	CELL04	CELL05	PHASEV
17/11/10	10	15	16	268	3	4
28/09/11	11	19	24	457	38	61
16/05/12	75	32	67	648	57	14
19/06/13	6	21	22	526	20	18

Other reported organic substances are typically low (Table 5). The phenolic compounds are soluble hydrolysis products which degrade rapidly within the environment. The most notable substance reported is a phthalate within Cell 4 and Phase V at 73µg/l and 151µg/l respectively. Bis(2-ethylhexyl)phthalate has known laboratory contamination issues from the vessels used within the laboratory and is unlikely to be present within the site's leachate.

Table 5 Other Reported Leachate Organic Constituents 2009 - 2013 (as µg/l)

Sample Point	CELL01	CELL02	CELL04	CELL05	PHASEV
Phenol			20		
2,4-Dimethylphenol		3	36		20
2-Methylphenol			9		7
4-Methylphenol			5		4
2-Methylnaphthalene			4		
Acenaphthylene			4		
Anthracene					1
Fluorene			2		
Phenanthrene			2		
1,2 Dichlorobenzene	1				
1,2,4-Trimethylbenzene	6	10	15		3
1,4 Dichlorobenzene			1		
bis(2-ethylhexyl)phthalate			73		151
Carbazole			2		
Dibenzofuran			2		

The volume of leachate within the site can be demonstrated as being brought under control during 2013 and 2014. The leachate is typical of a methanogenic leachate, albeit at the upper end range for a typical municipal landfill. There does not appear to be evidence of any special wastes which are reported to have been co-disposed at the site.

There are no significant unexpected contaminants within the site. Hazardous substances are limited and typically at or below detection limits. With regards to benzene and the other BTEX substances total concentrations are significantly below the 9,510µg/l reported in the 2003 Installation Design document. In addition, benzene, the most significant BTEX is localised to one location (Cell 4) and average concentrations across the containment cell are below the minimum modelled within the 2003 HRA (Table 6).

Table 6 Comparison Modelled Leachate Source Term with Modelled Parameters

Substance	Modelled			Leachate 2009 - 2013		Comments
	Min	Most Likely	Max	Mean	Max	
Ammoniacal-N	612	1150	2770	889	2,330,	Actual concentrations within modelled range
Chloride	1,390	2,850	4,850	2,144	5,000	
Boron	67	135	267	not reported in leachate		
	µg/l	µg/l	µg/l	µg/l	µg/l	
Chromium	60	210	330	74	446	Single outlier cell
Nickel	10^{-27}	160	240	37	135	Below modelled range
Benzene	86	173	345	52	648	Single outlier cell
Chloroform	27	53	107	not reported in leachate		
Mecoprop	27	54	105			

note - boron and organic substance concentrations modelled assuming minimum concentration is equivalent to leachate maximum (June 2003), with most likely and maximum assumed as twice and quadruple leachate maximum.

Leachate Infrastructure

FCC continually review the integrity of all the leachate extraction infrastructure as part of their ongoing monitoring regime, with field readings compared to known installation details.

Where field readings indicate that a leachate collection chamber appears to be failing through either silting or collapse, remedial works are immediately instigated.

A review of recent field depths and leachate levels, which has been reported to the Agency as part of the routine data submissions, would suggest that all of the current leachate collection chambers remain fit for purpose.

2.4 Pathways

The site is located within a former quarry which is located within a spur of glacial lacustrine deposits and surrounded by low permeability Glacial Till (Figure 6), which in turn is underlain by marl and mudstones of the Ruabon Marl Formation in the west and the Erbstock Formation to the west (Figure 7). The two bedrock formations are separated by the Paper Mill Fault, which underlies the superficial glacial deposits at the site. To the north of the site the upthrown Kinnerton Sandstone Formation underlies the superficial low permeability Glacial Till.

The Marl and mudstones which underlie the site will therefore form a hydraulic barrier beneath any residual glacial sediments, and the primary pathway will be via the residual glacial lacustrine and deposits beneath and adjacent to the site.

Figure 6 Site Geology (Extract from BGS Sheet 108 - Flint (Solid and Drift)

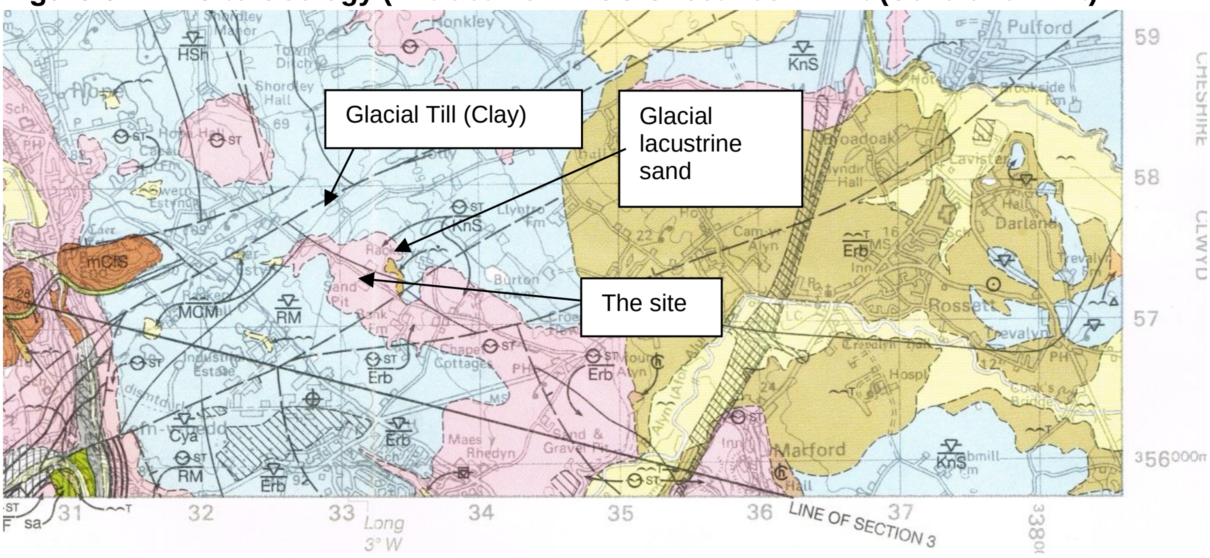
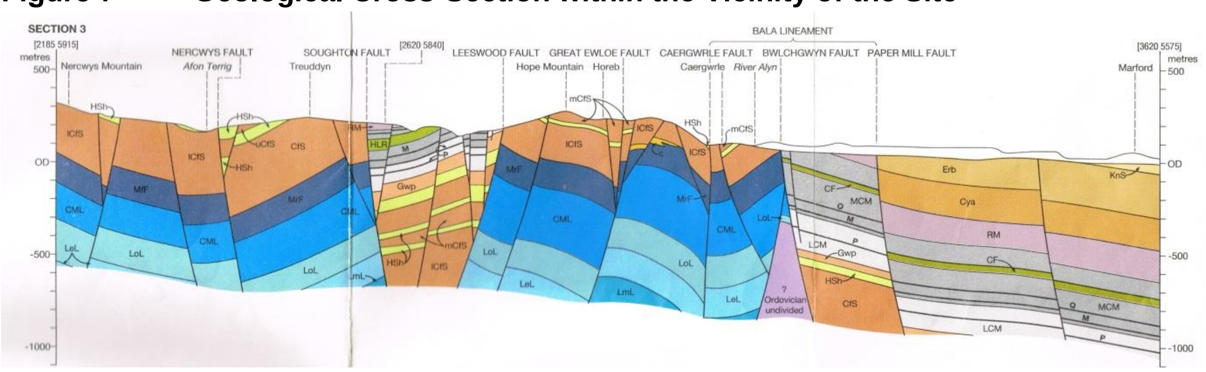


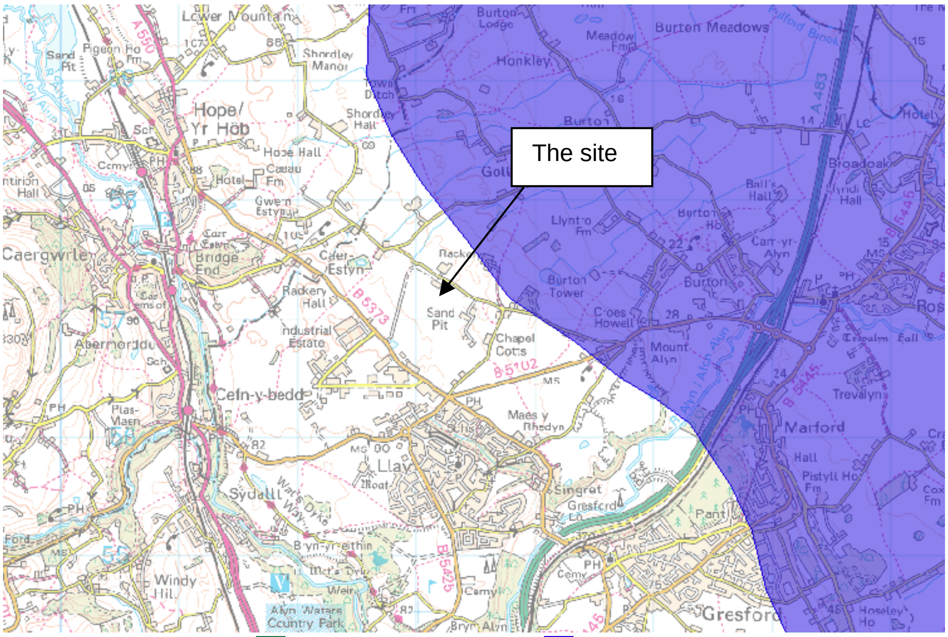
Figure 7 Geological Cross-Section within the Vicinity of the Site



RM- Ruabon Marl Fm, Erb - Ebistock Fm, KnS - Kinnerton Sandstone Fm

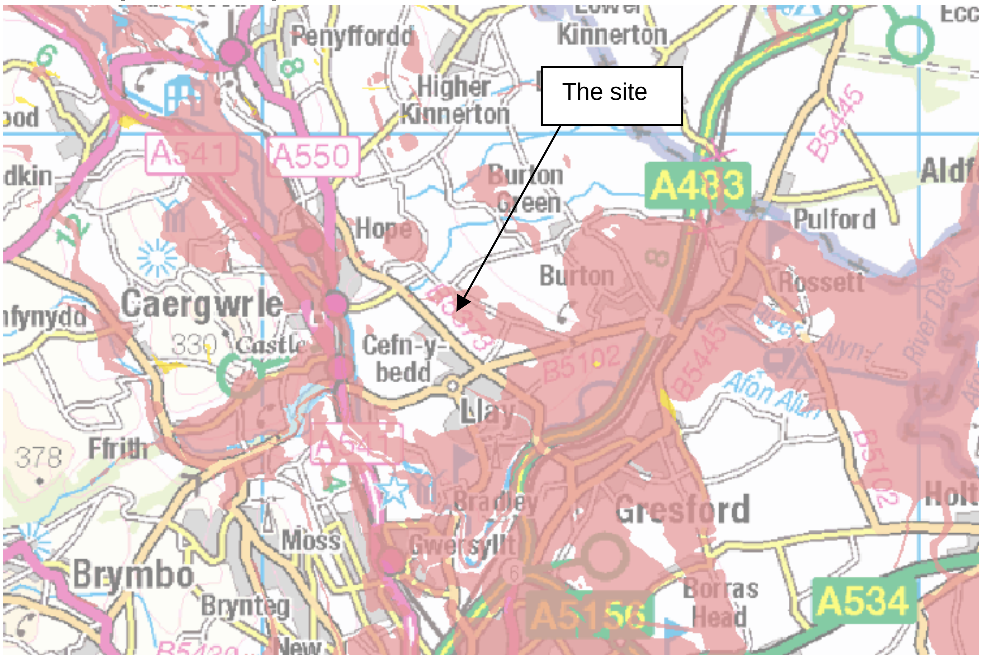
The site is not located within a designated source protection zone (Figure 8). However the remaining glacial lacustrine sand deposits are classified as a secondary aquifer. It should be noted that this superficial aquifer does not extend into the Glacial Till to the north, south or west of the site (Figure 6). The underlying marl and mudstone bedrock is also classified as a secondary aquifer, albeit that there are no associated source protection zones.

Figure 8 Source Protection Zones



Inner zone (Zone 1) Outer zone (Zone 2) Total catchment (Zone 3)

Figure 9 Superficial Aquifer Status



Key: Principal Secondary A Secondary B Secondary (undifferentiated) Unproductive

Previous site specific geological assessments have identified that the site is underlain by two glacial sand horizons, designated as the Upper Sand layer and the Lower Sand Layer.

These layers are separated by a 3 - 10m stiff clay horizon beneath both the dilute and disperse areas as well as the containment area cells. However, where the glacial sands extend to the east of the site, there is no definitive separation of the two sand layers.

The intermediate clay layer is acting as a natural geological hydraulic barrier between groundwater in the upper and lower sand layers with water levels differing between 4.8 and 6.7m in height between the upper and lower sand layers (Table 8).

Table 7 Glacial Deposit Description

Upper sand 22.5m @ EJ1 (SW) 4.0m @ BH6A (NW)	fine to coarse reddish brown and brown to orange silty sand with occasional fine to coarse gravel and fine to coarse coal fragments with occasional thin gravelly clay bands
Intermediate clay layer	stiff to brown or reddish brown laminated or gravelly clay (3 - 10m)
Lower sand 11.6m @ BH6 (NW)	interbedded sandy gravel, silt, sand and gravel, cobbles, silty sand and silty gravelly clay bands

There is a fall in groundwater levels from southwest towards the north and northeast of the site, this fall is coincidental for both the upper and lower sand layers (Table 8, Figure 10). It is likely that this fall in water level is related to the fall in topography from ~75mAOD at the northern perimeter of the site to less than 30mAOD to the northeast of the site. Such a fall in topography would result in a spring line and / or contributing to the base flow in the streams on top of the Glacial Till in the valley to the north of the site, such as the marsh area to the north of the site at BH06A, which is at an elevation of 65.9mAOD and groundwater is reported at 65.6mAOD. However, on a localised scale the presence of clay horizons prevents an accurate determination of groundwater flow on an individual basis.

Table 8 Groundwater Levels within Upper and lower Sands

Layer		EJ03	BH06
		Aug 07	Aug 07
Upper Sand	mAOD	68.41	65.37
Lower Sand	mAOD	63.59	58.64
Difference	m	4.82	6.73

A note in the conceptual model[1] states that:

> *"It has been agreed with the Environment Agency that the level of the base of the basal liner in the Astbury Landfill is 68.18mAOD".*

This statement is consistent with the dewatered groundwater level of 66.9 - 67.0mAOD during the construction of Cell 5 in 1998. The slow recharge indicates that the groundwater had been depressed to the base of Upper Sand - intermediate clay layer interface, whilst the surrounding landfill cell and the *in-situ* Glacial Till (formerly described as Boulder Clay) to the south of the site restricts recharge.

Groundwater levels have remained stable within the upper and lower sand layers for at least nine years and do not reflect any changes with respect to elevated leachate levels, dewatering or the reduction in leachate heads since capping of the site has been completed (Figure 10 and Figure 11).

[1] MJCA (2003) Conceptual model of the environmental setting and installation design of the Rossett Landfill Complex. report SH/DL/GD/2413/02, Paragraph 6.9

Figure 10 Groundwater Level

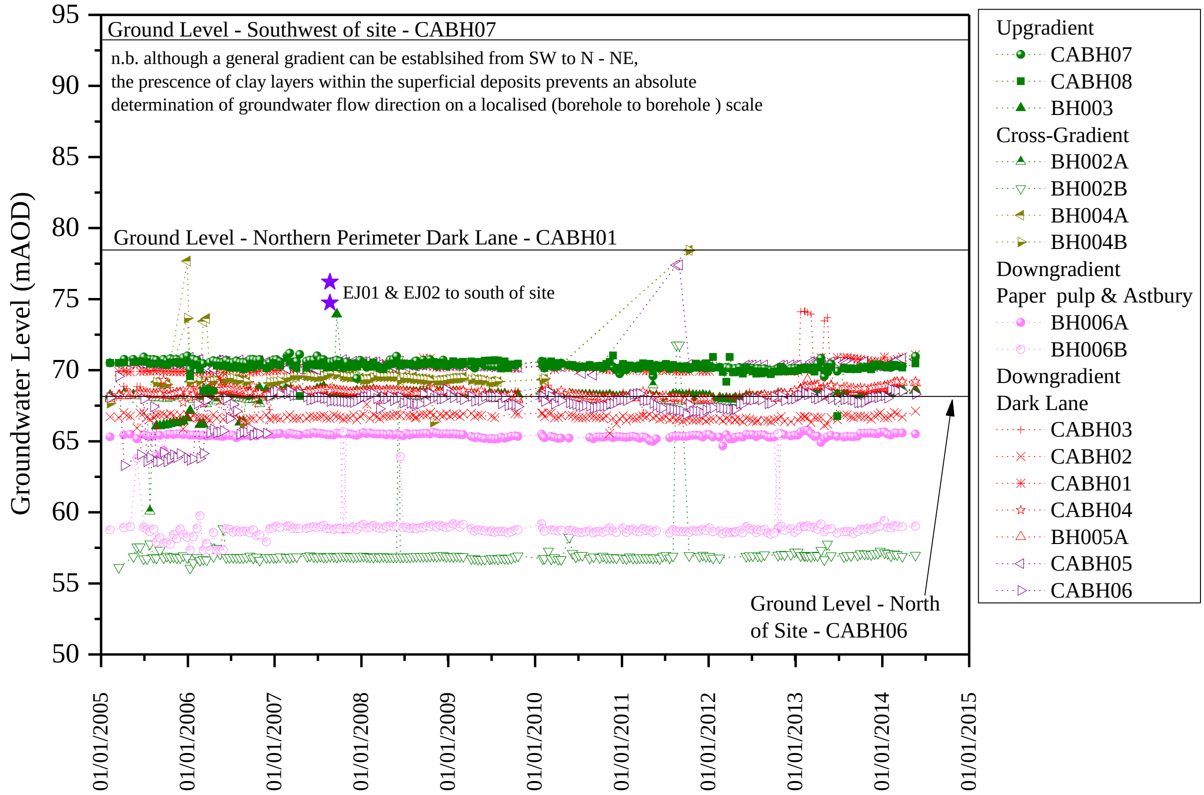
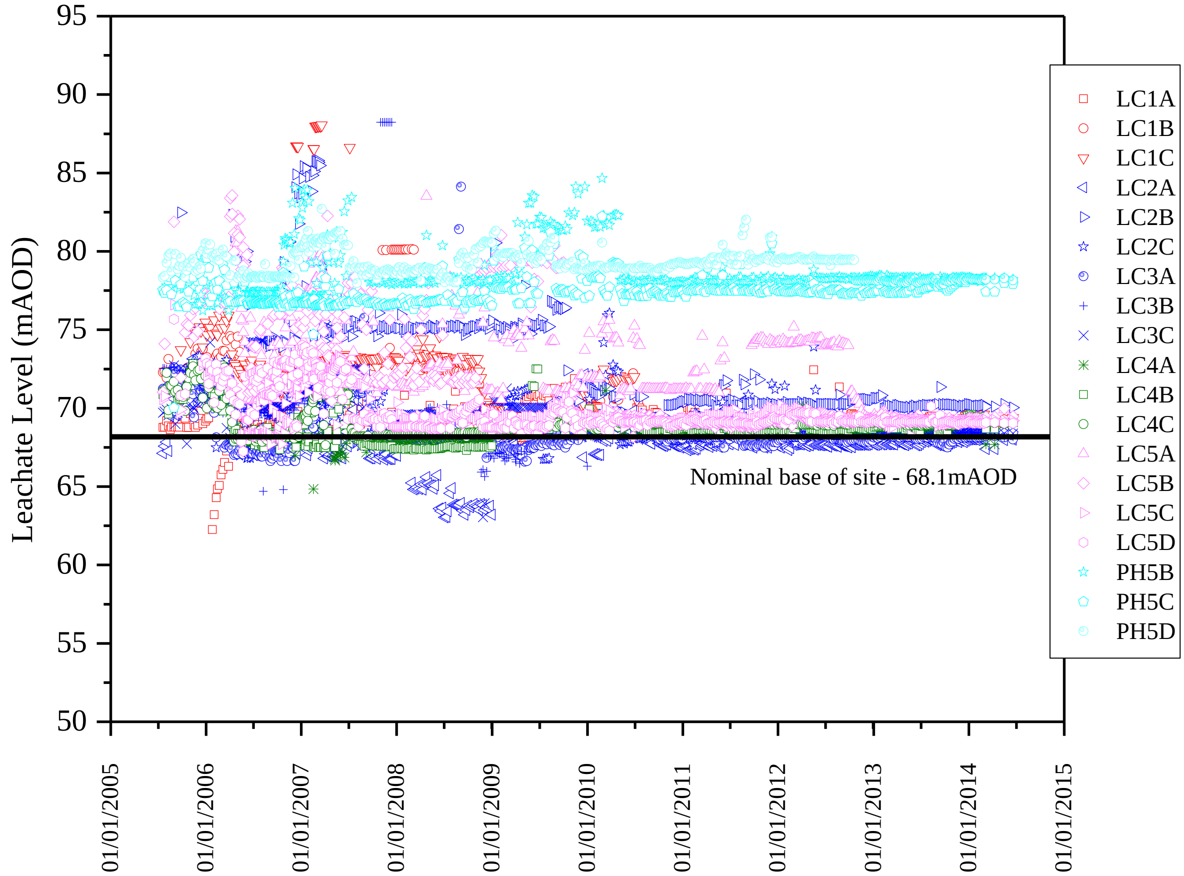


Figure 11 Leachate Level



However, given the current groundwater and leachate levels, it appears that there is to some extent a component of hydraulic containment at the site, whereby there is an equivalence of groundwater and leachate at approximately 67mAOD. Although difficult to quantify it is likely that there is a negligible hydraulic flux from the landfill as long as leachate levels are maintained under control from the Astbury landfill. However, such a conclusion cannot be extended to the Dark lane Phase 5 site, whereby the relatively higher base of the cell (~70mAOD) indicates that there could be a 4m unsaturated zone beneath the phase.

2.5 Receptors

There are three potential types of water receptors within the vicinity of a landfill, namely

- Groundwater principal and secondary aquifers;
- Surface water features, and aquifer baseflow contributions; and
- Abstraction points.

With regards to the Astbury Landfill, the underlying glacial sands are classified as a secondary aquifer. Surface water features within the immediate vicinity of the site appear to be surface water drainage channels which overlie the Glacial Till. It is likely that there is a baseflow contribution to these features from the glacial sand.

The surface water streams to the north of the site are tributaries of Pulford Brook, and the River Afon is located to the east of the site, both of which are tributaries of the River Dee. Water quality monitoring data held by the Environment Agency for the River Afon downstream of the site (at Gresford Lodge), indicates a very good to good water quality with respect to BOD (1.7mg/l), ammoniacal-N (0.09mg/l) and dissolved oxygen (103%) in 2009, which is indicative that the site has not had an adverse impact on the river. The water quality in Pulford Brook, some 5km downstream of the site has a higher BOD (2.7mg/l) and ammoniacal-N (0.51mg/l). However, the most likely cause for an increase in ammoniacal-N and the reduction in dissolved oxygen (70%) is due to its relatively smaller size, limited flow and the contribution from adjacent agriculture (nitrate levels are at 33mg/l). Therefore it appears that neither stream has been discernibly affected by the Astbury landfill.

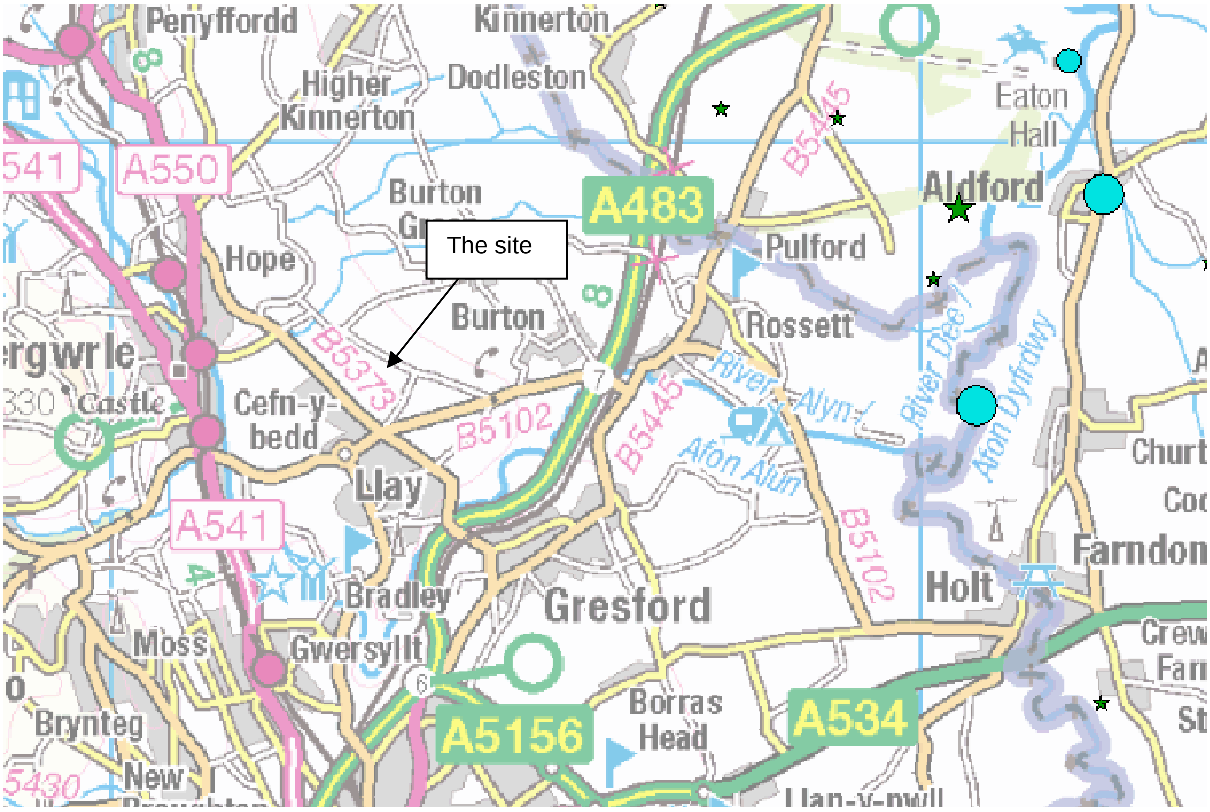
With regards to abstraction licences, there are no nearby (*i.e.* <7km) surface water or groundwater abstractions identified on the Environment Agency's website (Figure 12).

Table 9 Water Abstraction Licences (Located on Drawing SH/DL/10-03/11113)

Ref	Licence No	Use	Source	Dist	Dire	Location
1	24/67/9/0159	Mineral processing	Ruaborn Marl	On site	On site	
2	24/67/9/0146	Farming & domestic	Drift	1km	E	Cross-gradient
3	24/67/9/0065	Farming & domestic	Drift	1.5km	NE	Down-gradient
4	24/67/9/0164	Farming & domestic	Carb'Sandstone	1.3km	N	Cross-gradient
5	24/67/9/0175	Farming & domestic	Carb'Sandstone	1.3km	N	Cross-gradient
6	24/67/8/0069	Farming & domestic	Drift	1.5km	N	Cross-gradient
7	24/67/9/0123	Farming & domestic	Carb'Sandstone	2.3km	NNW	Cross-gradient
1	24/67/8/0052	Mineral washing	River Alyn	1.7km	SE	Upstream
2	24/67/8/0052	Mineral washing	River Alyn	1.7km	SW	Upstream
3	24/67/8/0086 #1	Spray irrigation	River Alyn	2km	ESE	Upstream
4	24/67/8/0084	Aquaculture	River Cedidog	2.3km	SW	Upstream
5	24/67/8/0086 #2	Spray irrigation	River Alyn	2km	E	Upstream
1	unlicensed		not stated	1.5km	ENE	
2	unlicensed		not stated	2.6km	NE	

n.b. reference numbers refer to groundwater, surface water and unlicensed type abstractions on drawing

Figure 12 Water Abstraction Licences



Groundwater Abstraction Size: Small, Medium, Large
Surface Water Abstraction Size: Small, Medium, Large

A further seven groundwater, five surface water and two unlicensed abstractions were identified within the Permit application (Table 9, Drawing SH/DL/10-03/11113). Only one groundwater abstraction was identified within 1km of the site, which is the former mineral washing abstraction licence for the Astbury Quarry. This license is no longer required followed the completion of mineral workings and the landfill operations.

There is only one potential abstraction point which could be considered as “at risk” from the landfill site, namely groundwater abstraction reference 3, which abstracts groundwater from the drift deposits (Table 9). However, this receptor is 1.5km to the NE of the site and ground levels are less than 25mAOD. It is therefore unlikely that the groundwater being abstracted is in hydraulic continuity with the Upper Sand layer which hosts the landfill.

For assessment purposes, the 2003 HRA considered the Upper Sand at the down-gradient boundary of the site (*i.e.* to the north of the paper pulp phase) as the primary receptor for modelling purposes.

Groundwater Quality

Groundwater quality is monitored in a series of locations to the south (upgradient), east (cross gradient) and north (downgradient) of the site. The monitoring programme is primarily focused towards the Upper Sands (Table 10), with a more limited dataset for the Lower Sands (Table 11). Monitoring locations are shown on Drawing WRG/DL/11-04/11952.

A summary of the 2009 - 2014 dataset is presented as time series graphs (Figures B1 - B17 in Appendix B along with additional summary data for the period 2009 - 2014 (Tables B1 - B4).

Table 10 Upper Sand Groundwater Matrix and Leachate Indicator Average Composition

	North Dark Lane					North	East		South		
	CABH 06	**CABH 03**	**CABH 01**	**CABH 04R**	**BH05 A**	**BH06 A**	**BH02 A**	**BH04 A**	**CABH 07**	**CABH 08**	**BH03**
Ammoniacal-N (DWS 0.39mg/l)											
2001 – 2003	3.5	0.4		52		0.4	9.1	0.3	1.5	0.5	0.4
2003 – 2009	0.7	0.5		140		0.7	9.2		2.9		
2009 – 2014	4.8	0.1	341	8	0.4	0.1	7.1	<0.2	1.1	0.2	0.1
COD											
2003 – 2009	125	27		746		25	101		190		
2009 – 2014	198	23				27	66	9	201	249	118
TOC											
2003 – 2009	38	7		69		7	9		21		
2009 – 2014	51	10				5	9	4	15	7	<6
Alkalinity											
2009 – 2014	219	713				251	472		560	638	615
Chloride (DWS 250mg/l)											
2001 – 2003	143	90		826		80	14	14	41	34	40
2003 – 2009	182	65		742		78	19		35		
2009 – 2014	188	108	902	29	70	63	14	17	26	25	20
Sodium											
2001 – 2003	75	67		459		80	17		31	30	
2003 – 2009	68	43		599		57	20		55		
2009 – 2014	66	77				38	19	12	25	29	26
Potassium											
2001 – 2003	254	1		48		30	17		4	4	
2003 – 2009	252	1		129		22	12		3		
2009 – 2014	298	1				28	13	1	3	4	2
Calcium											
2001 – 2003	101	132		219		161	339		192	127	
2009 – 2014	467	200				232	361	1,500	251	152	143
Magnesium											
2001 – 2003	31	25		54		45	50		77	65	
2003 – 2009	27	26		54		32	47		61		
2009 – 2014	22	26				30	57	24	72	80	64
Sulphate											
2001 – 2003	152	108		40		104	550	67	27	126	
2003 – 2009	239	78		293		101	472		55		
2009 – 2014	257	384				90	531		36	95	75

Table 11 Lower Sands Groundwater Matrix and Leachate Indicator Components - Average Concentration

	North			East	
	CABH02	**BH05B**	**BH06B**	**BH02B**	**BH04B**
Ammoniacal-N					
2001 – 2003	0.9	0.7	0.3		0.3
2003 – 2009	0.7		0.5		1.6
2009 – 2014	0.9		0.4	9.2	0.2
COD					
2003 – 2009	125		22		53
2009 – 2014	23		26		
TOC					
2003 – 2009	38		4		9
2009 – 2014	4		4	<6	
Alkalinity					
2009 – 2014	410		226	130	
Chloride					
2001 – 2003	67	1,453	106		16
2003 – 2009	73		175		18
2009 – 2014	92		229		17
Sodium					
2001 – 2003	17		24		12
2003 – 2009	17		42		11
2009 – 2014	17		80		
Potassium					
2001 – 2003	2		3		1
2003 – 2009	2		7		1
2009 – 2014	2		3		
Calcium					
2001 – 2003	140		149		109
2009 – 2014	272		248		
Magnesium					
2001 – 2003	30		31		19
2003 – 2009	34		36		25
2009 – 2014	38		33		
Sulphate					
2001 – 2003	49		84		71
2003 – 2009	40		78		63
2009 – 2014	40		78		

Groundwater recharge and flow directions are generally correlated to topography and the exposure of sand layers. There is a topographical fall from south to north into a valley feature between Yr Ackery and Ackery Farms to the north of the site. The topographical fall also intersects the groundwater table in the Upper Sand layer. Glacial Till is also exposed to the south and west of the site, whilst the sand extends to the east of the site. Groundwater flow is therefore expected to be from the south and southeast towards the northeast.

The groundwater system appears complex because of a combination of off-site influences in addition to the landfills themselves. This is complicated further because of the variable nature of the glacial deposits which includes clay layers which will lead to local influences. Notwithstanding the above conclusions can be drawn as to the impact of the Dark Lane and Astbury landfill sites on groundwater quality.

Landfill leachates can be classified into a number of substance types based on their relative concentration compared to terrestrial waters, which can be broadly described as

- Organic degradation indicators (*e.g*. ammoniacal-N, COD and TOC);
- Matrix ions (*i.e*. enriched in Na, Cl, K, Mg, HCO_3);
- Trace components, including hazardous and non-hazardous metals and organics.

It is the presence of both the organic degradation indicators and the type of matrix ions which can be used to identify the actual impact of a site on groundwater. Although informative as to the water quality, the trace hazardous and non-hazardous substances have limited potential as pollution plume indicators.

At the site, the leachate is an ammoniacal-N, COD bearing sodium chloride enriched with secondary potassium and magnesium. It is the presence of all of these components which identify whether a leachate plume has been released from the site and whether the associated impact is acceptable. In isolation these substances can be used individually to identify locations of concerns, however, interpretation must be based on greater details to distinguish landfill form non-landfill osurces. The three most useful substances for screening the groundwater are ammoniacal-N (Figure B1), chloride (Figure B2) and potassium (Figure B3).

At the following locations ammoniacal-N, chloride and potassium are elevated:

- Ammoniacal-N (>2mg/l): CABH01, CABH04R, BH02A, CABH06, CABH07
- Chloride (>100mg/l): CABH01, CABH04R, CABH06, BH06B
- Potassium (>10mg/l): BH02A, CABH06, BH06A

In general, there has been limited change in groundwater quality and no distinct increasing trends indicative of a continuing sustained dispersion plume. However, short term peaks in concentration have been observed and the locations identified above are discussed in more detail in the context of potential landfill and non-landfill influences.

Up-gradient and Cross-Gradient Locations

CABH07 is an up-gradient location on the south west corner of the site adjacent to Dark Lane Phase 5. Groundwater quality is relatively stable and unchanged for the inorganic parameters. The groundwater is a calcium bicarbonate solution with limited sodium chloride (<40mg/l). Ammoniacal-N varies on a cyclic pattern in association with the COD. Ammoniacal-N ranges from <0.2mg/l to 3.3mg/l, with COD fluctuating between 57 and 490mg/l (Figure B16). At the adjacent CABH08, COD has been reported at 1540mg/l, although it is expected between 25 and 125mg/l (Figure B17). The COD is also in this range (*i.e*. 120mg/l) at BH03 on the southeast corner of the site.

To the east of the site, there is negligible chloride in the groundwater BH02A (Figure B5) and BH04A, at <20mg/l, however, ammoniacal-N is enriched at ~9mg/l at BH02A and BH02B. Calcium sulphate at 360mg/l and ~500mg/l respectively in BH02A, is also inconsistent with an ammoniacal-N enriched landfill leachate as the sulphate would be expected to be reduced to sulphide and the calcium precipitated to <250mg/l as $CaCO_3$.

Groundwater at BH02A does however differ from that at the other up-gradient locations in that there was a spike in ammoniacal-N (26mg/l, COD (181mg/l) and magnesium (114mg/l) which occurred between spring 2011 and 2012. Chloride peaked at 34mg/l and potassium at 26mg/l during this period.

Such a groundwater pattern is inconsistent with landfill leachate seepage and it is therefore concluded that the ammoniacal-N and associated dissolved organic matter is not derived from the Astbury Landfill site. Although not confirmed it is noted that the site is surrounded by pasture and manure could be a primary off-site organic source.

Downgradient

There appears to be three conclusions that can be drawn with regards to the northern monitoring locations.

1) There is evidence of a leachate influence at two adjacent locations (BH04R and CABH01, Figures B14 and B6 respectively) on the northeast perimeter of the Dark Lane site.
2) There is a significant potassium and organic influence at CABH06 to the north of Yr Ackery Farm
3) There is a minor, if not depleting trend in chloride at BH06A associated with a higher than expected potassium concentration (25±5mg/l) to the north of the Paper pulp and Astbury Quarry sites and downgradient to the east of CABH06

The association of chloride and ammoniacal-N at CABH01 and CABH04R is indicative of an influence of seepage from the dilute and disperse Dark lane landfill site. This plume contains ammoniacal-N, potassium, chloride and dissolved organic matter (*i.e*. COD). However, ammoniacal-N does not appear to have migrated to CABH03, BH05A, BH05B, which indicates that there is a limited seepage zone through which a leachate plume is migrating.

There is a limited dataset for CABH01 to draw conclusions regarding historical trends, however current (2014) monitoring data indicates that ammoniacal-N is 340±50mg/l in association with chloride at 902±208mg/l (Figure B10).

There is a larger dataset for BH04R (Figure B14) which indicates that between 2004 and 2014 there has been a significant reduction in concentrations of:

- ammoniacal-N from 366 to 8mg/l (in 2014)
- chloride from 1,692 to 30mg/l (in 2014)
- potassium from 224 to 38mg/l (in 2008)

Such a reduction could be consistent with the depletion of the original leachate source and is an indication that the pollution potential of the dilute and disperse landfill continues to reduce. It is noticeable that any influence from the Dark Lane site is not observable in the off-site monitoring locations downgradient.

The groundwater chemistry at CABH06 located to the north of Yr Ackery Farm and the centre point of the combined landfills is more complex. This location is the most difficult location to interpret. The groundwater is uncharacteristically dominated by potassium, with concentrations sustained in the 250 - 425mg/l range. This is the same concentration range as found with the leachate monitoring data. However chloride at 50 - 280mg/l at CABH06 is diluted between 10 and 50 times leachate concentrations of 2,500mg/l (Figure B15). Such a distribution pattern is impossible for a leachate plume and hence must be caused by an alternative non-landfill source.

Elevated COD, TOC and ammoniacal-N in association with the elevated potassium are potential geochemical indicators of a nearby organic based source, and is consistent with that expected following the burial of carcases, such as that identified for Yr Ackery within

Section 4.9 of the2003 Environmental Settings and Design of the Rossett Landfill Complex document. It is also noted that "an abundance of manure in the ground" is also identified which could readily cause a sustained background in ammoniacal-N of 0.2 - 3mg/l, as well as be the source of the spike in ammoniacal-N (to 16mg/l) and COD to 427mg/l in October 2011, whilst the upward trend in both COD and TOC from 2013 could be associated with seasonal rainfall patterns and soil moisture conditions.

Such a short duration plume (*i.e*. 1 year) is unlikely to be associated with the long term seepage and dispersion from a landfill site, as the source would be sustained for several decades, hence a non-landfill source is expected.

BH06A and BH06B monitor the upper and lower sands to the north of the paper pulp and Astbury landfill site. This is the primary monitoring location down-gradient of the site. Geochemically the groundwater in both sand layers are calcium based groundwaters. Ammoniacal-N is at less than 0.5mg/l in both layers, whilst potassium and magnesium concentrations are at a steady state between 20 and 50mg/l without showing upwards trends. This concentration is slightly above that expected for most terrestrial groundwaters, but would only be of concern if part of a sustained upwards trend.

There is one significant difference between the two layers, namely within the Upper Sand at:

- BH06A chloride is demonstrating a slight downwards trend from 106 to 64mg/l

whilst in the Lower Sand layer:

- BH06B, chloride has increased from 205 to 417mg/l between 2004 and 2014

Relating this chloride to landfill leachate is difficult because there is not an associated increasing ammoniacal-N trend. In contrast to chloride ammoniacal-N appears to be depleting from ~3.5mg/l to <0.4mg/l.

In addition, the chloride appears to be associated with calcium and not sodium, whilst bicarbonate (*i.e*. alkalinity) is depleting whilst chloride is increasing. Given that landfill leachates contain significant sodium bicarbonate, then when the ammoniacal-N, potassium and magnesium are also considered, it is highly unlikely that the groundwater at BH06A and BH06B is affected by landfill leachate.

Hazardous and Non-hazardous substances

The down-gradient hazardous and non-hazardous metal concentrations are below drinking water limits (Appendix B Tables B3 and B4).

Cadmium and mercury are below their respective drinking waters standards (DWS) of 5µg/l and 1µg/l between 2009 and 2014. Occasional positive determinations have been made however; cadmium has remained below 1µg/l and mercury below 0.04µg/l on all occasions during this period. Lead has similarly been reported below 1µg/l (<10% of the 10µg/l DWS)

Chromium is the primary non-hazardous metal within the groundwater. However the highest concentrations of 49µg/l and 65µg/l have been identified in the up-gradient CABH07 and cross-gradient BH02A respectively. Immediately down-gradient of the site at CABH03 and CABH02 chromium is present in the range 13 - 31µg/l. The DWS (50µg/l) is therefore only exceeded up-gradient of the site.

Copper and nickel are below 10µg/l except for two locations, the first is CABH06 where copper is reported at 23 - 48µg/l and nickel is reported at 13 - 20µg/l (*i.e*. equivalent to the Ni

DWS). This location is considered as influenced by carcass burials. The second location BH06B does not contain elevated copper, but nickel has been reported at 5 - 15µg/l. Such a concentration range is not environmentally significant.

Zinc is also present at CABH06 at up to 112µg/l and at BH02A at 60µg/l, all other determinations at <20µg/l, which is insignificant, compared to the 3mg/l DWS. The highest concentrations reported for ring are likely to be associated with changing iron and manganese redox changes whereby oxide minerals go through periods of reduction and dissolution, followed by re-oxidation and co-precipitation within the ground. It is noted that these two locations do contain variable ammoniacal-N an indicator that there is likely to be variable redox conditions within the ground.

Groundwater Chemistry Summary

The groundwater at the Astbury landfill complex appears to be largely unaffected by landfill leachate. Although there is an influence from the Dark Lane dilute and disperse site on the NE perimeter, any off-site migration does not appear to have impacted on groundwater off-site to the north, east or south of the complex.

Occasional spikes in ammoniacal-N have occurred in off-site locations. However, these are not sustained and therefore inconsistent with landfill leachate seepage. However, the most significant impact on groundwater chemistry is from an off-site source which is influencing groundwater chemistry at CABH06 to the north of Yr Ackery Farm. This influence is inconsistent with the site's landfill leachate chemistry, however, it does contain constituents which would be present within a landfill leachate and on a superficial level could be misidentified as being of landfill leachate origin.

Surface Water Monitoring Data

Surface water run-off from the landfill is managed via perimeter channels which are monitored at various points around the site and the discharge (Drawing WRC/DL/11-04/11952. SW06 and SW01, monitor the surface water on the south (SW06) and west of Dark lane, before discharging from the NW corner of the site at SW01.

Surface run-off from the Astbury site is monitored at SW05, on the southeastern corner of the site, and SW02 after the settlement pond on the northern perimeter of the site. Surface water from these two locations is channelled to SW04 at the northeast part of the site, before discharging at SW03.

Previously water used for mineral dewatering was also discharged via the streams which form tributaries to Pulford Brook.

A summary of the monitoring data is presented in Appendix C and Table 12.

The discharge points from the site are under 80m in altitude and are likely to be classified as either a Types 3, 5 or 7 water (*i.e.* >50mg/l alkalinity as calcium carbonate). The type of water is important for identifying the Environmental Quality Standards the discharge will be classified against.

Given the topography of the site, it is likely that the surface water discharges form the head waters of two stream systems which flow northwards and form tributary streams to Pulford

Brook. However, there will be additional contributions to the streams from the surrounding pasture land, which could also affect water quality.

H1 Guidance Annex d, identifies a "Good" for Types 3,5 and 7 waters as 0.6mg/l ammoniacal-N and 5mg/l BOD. The surface water achieved this standard during the 2009 - 2014 period, although previously there has been difficulties achieving this standard (Table 12). Chloride levels at <100mg/l from 2003 will not detrimentally affect water quality.

Hazardous and non-hazardous substances analysed demonstrate that boron is below EQS and DWS limits of 2mg/l and 1mg/l respectively. Pesticides (*e.g*. mecoprop) are at 1% of the EQS and other solvents, aromatics and pesticides monitored are below detection limits (Appendix C, Table C2).

Table 12 Surface Water Monitoring Data Summary (Average Concentrations) and Relevant Limits Set for SW02

	SW6	SW1	SW5	SW2	SW4
pH (pH units)					
2001 – 2003		8.3		8.3	
2003 – 2009		8.3		8.4	
2009 – 2014	7.7	8.3	7.4	8.1	7.8
Limit				**>6 - <8.5**	
Conductivity (µS/cm)					
2001 – 2003		0.9		1.2	
2003 – 2009		0.7		0.5	
2009 – 2014	326	556	414	778	867
Ammoniacal-N (mg/l)					
2001 – 2003		0.30		0.98	
2003 – 2009		4.16		4.31	
2009 – 2014	0.22	0.7	0.01	0.53	0.04
Chloride (mg/l)					
2001 – 2003		50		209	
2003 – 2009		42		76	
2009 – 2014	12	20	13	65	566
Sulphate (mg/l)					
2001 – 2003		85		146	
2003 – 2009		91		217	
BOD (mg/l)					
2001 – 2003		5.0		3.0	
2003 – 2009		3.3		2.4	
2009 – 2014	8.6	2.2	2.1	4.6	2.1
Limit				**10**	
COD (mg/l)					
2009 – 2014		39		50	67
Boron					
2009 – 2014				0.26	0.09

The surface water discharged from the site is generally of a good quality with little likelihood of a potential to impact on water quality.

However, it is noted that within the permit decision document, that a cautionary note was included because of limitations to the understanding of the volume of groundwater contributing to the surface water discharge and the quality of such water to adequately determine its off-site impact.

Such an impact should be based on the ongoing surface water management arrangements and water sources.

3. HYDROGEOLOGICAL RISK ASSESSMENT

3.1 Numerical Modelling

3.1.1 Justification for Modelling Approach

The site was modelled by MJCA in 2003 using LandSim 2[2]. The LandSim model[3] developed on behalf of the Environment Agency by Golder Associates is the preferred model for assessing risks to groundwater from landfill sites by each of the UK's Environment Agency bodies. The LandSim model is a Monte Carlo simulator, which is a probabilistic simulator to assess contaminant migration from a source through a barrier system which underlies the potential polluting source, vertically through an unsaturated zone beneath the barrier, and a saturated pathway before entering an aquifer.

The Monte Carlo Simulator allows for a stochastic approach to be taken for the model. Stochastic models allow a range of values to be input for each parameter. The model then selects a value for each parameter when running a simulation. Thus the model overcomes difficulties associated with deterministic models which take a single value for each parameter when a series of end member scenarios are run without understanding how each parameter interacts or their relative importance.

The model also performs multiple simulation runs and the simulation programme compiles the results as a statistical probability of a particular result occurring. When the results are statistically combined, the likelihood of each of the 'worst-case' parameters occurring simultaneously can be compared with the general case which is actually expected to happen. The impact of each of these cases and that of intervening probabilities can then be compared with relevant EQS to determine if the risk is acceptable.

The model also predicts timescales that any potential impact is likely to occur over. This includes factoring in whole lifecycle factors such as active or passive engineered controls and the polluting lifespan of the contaminant source.

The site was modelled twice, the first using LandSim to assess the containment areas and the second model based on spreadsheet calculations was also presented for the unlined areas. However, the model conclusions presented were targeted towards the containment areas under the assumption that the containment area was physically separated from the uncontained areas.

The site was modelled assuming post-dewatering recovered groundwater levels would increase to the base of the liner. Consequently the site was modelled assuming that the HDPE liner within the Astbury landfill was a single liner, with 1m of engineered clay acting as the unsaturated zone. Where HDPE was not present, the site was modelled without a liner.

A vertical pathway was not modelled and the Upper Sands were modelled as the aquifer pathway to a point at the edge of the Paper Pulp site.

[2] (MJCA 2003) Hydrogeological Risk Assessment for Rossett Landfill Complex, Burton, Rossett. Ref: SH/DL/GD/2413/05
[3] Golder Associates (UK) Ltd (2003) LandSim. Landfill Performance Simulation by Monte Carlo Method. *Environment Agency R&D Publication 120*

3.1.2 LandSim Model Parameterisation

The only containment engineering works carried out after the 2003 Permit application was capping works as all basal liner and drainage layer construction was completed at that time. Therefore all physical (*i.e*. engineering-based) parameters are unchanged since the 2003 assessment.

The site was modelled within LandSim assuming a liner pathway through Dark lane Phase 5 and Astbury Cells 1 -5 to a point at the edge of the site. The Paper Pulp site and the uncontained cells were therefore not considered within the LandSim model.

Table 13 LandSim Model Parameters (MJCA, 2003)

Parameter	units	Distr	Phase 1 (Astbury Landfill)	Phase 2 (Dark Lane Phase 5)
Infiltration	mm/yr	Nor	145.59 sd14.35	145.59 sd14.35
Cell	m			
width		S	250	200
length		S	426	100
Base Area	ha	S	10.65	2
Top area	ha	S	10.65	2
Leachate Head	m	Tri	0.01-1.2-6.3	
Liner Type			**2mm HDPE**	**None**
HDPE				
Pin Holes		Tri	0-25-25	N/A
Holes		Tri	0-5-5	
Tears		Tri	0-0.1-20	
Unsaturated Zone			**Mineral Component of EBS modelled as unsaturated zone**	
Length	m	S	1	1
Moisture			0.025	0.025
Conductivity	m/s	Log Tri	10^{-11}-10^{-10}-10^{-9}	10^{-11}-10^{-10}-10^{-9}
Dispersion	m		0.1	0.1
Density	kg/l		2	2
Aquifer pathway	**m**		**Upper Sand Layer**	
Length	m	Unif	220-450	450-560
Width	m	Single	250	200
Mix Zone	m	Uni	2-7	2-7
Porosity			0.2	0.2
Regional Gradient		Tri	0.003-0.005-0.007	0.003-0.005-0.007
Hydraulic Cond	m/s		2.66×10^{-6} - 1.23×10^{-5}	2.66×10^{-6} - 1.23×10^{-5}
Dispersivity	m			
Longitudinal		Uni	45 - 56	45 - 56
Transverse		Uni	4.5 - 6.5	4.5 - 6.5
Density	kg/l	Uni	1.37 - 1.81	

Average leachate concentrations are below that modelled, and therefore the leachate can be considered as a generally weaker solution than that modelled in the 2003 assessment (Table 14). However, there are the occasional of localised instances whereby the maximum concentration within the leachate is slightly above that modelled. The leachate chemistry is therefore consistent with that modelled in 2003.

Table 14 Comparison Modelled Leachate Source Term with Modelled Parameters

Substance	Modelled			Leachate 2009 - 2013		Comments
	Min	Most Likely	Max	Mean	Max	
Ammoniacal-N	612	1150	2770	889	2,330,	Actual concentrations within modelled range
Chloride	1,390	2,850	4,850	2,144	5,000	
Boron[1]	67	135	267	not reported in leachate		
	µg/l	µg/l	µg/l	µg/l	µg/l	
Chromium	60	210	330	74	446	Single outlier cell
Nickel	10^{-27}	160	240	37	135	Below modelled range
Benzene	86	173	345	52	648	Single outlier cell
Chloroform	27	53	107	not reported in leachate		
Mecoprop	27	54	105			

Note[1] - boron and organic substance concentrations modelled assuming minimum concentration is equivalent to leachate maximum (June 2003), with most likely and maximum assumed as twice and quadruple leachate maximum.

The second approach taken was a mathematical expression (Equations 1 and 2) of the attenuation capacity of the upper Sand beneath the Dilute and Disperse area of the Dark Lane site to calculate an attenuation factor and the distance required to meet an appropriate Environmental Assessment Limit (EAL).

$$Attenuation\ Factor\ = \frac{(Leachate\ concentration - groundwater\ concentration)}{Distance\ between\ the\ landfill\ boundary\ and\ the\ borehole} \qquad \text{Equation 1}$$

$$Distance\ \frac{(Leachate\ concentration - EAL)}{Attenuation\ Factor} \qquad \text{Equation 2}$$

The approach taken used groundwater concentrations at CABH03 and CABH04R as the basis for the calculation as set out in Table 7 and Table 8 of the 2003 HRA respectively. CABH03 is 25m down-gradient of the site and the latter is 16m down-gradient of the site.

3.2 Emissions to Groundwater

Since the withdrawal of Environment Agency Landfill Technical Guidance LFTGN01[4] and its replacement by H1 Guidance Technical Annex J3[5] and GP3[6], there has been a change in the approach to considering appropriate receptors for hazardous substances with regards to the practicalities of assessing direct discharges of hazardous substances to groundwater.

This policy change is in part due to the practicalities of assessing unsaturated zone concentrations above an aquifer body and consideration of the quantity of a hazardous substance, which although the concentration may be above minimum reporting values (MRVs), there is minimal associated volume.

[4] Environment Agency (2003) Hydrogeological risk assessments for landfills and the derivation of groundwater control and trigger levels. LFTGN03

[5] Environment Agency (2011). Additional guidance for hydrogeological risk assessments for landfills and the derivation of groundwater control levels and compliance points. Horizontal guidance Note H1 - Annex J3

[6] Environment Agency (2013) Groundwater protection: Principles and practice (GP3)

3.2.1 LandSim Assessment - Hazardous Substances

The 2003 LandSim assessment predicted that there would not be a breakthrough of hazardous substances at concentrations above minimum report values into the aquifer (Table 15).

Table 15 LandSim Assessment Model Maximum (95th Percentile) Hazardous Substance Predictions (2003 HRA)

Parameter	Base UZ	Base UZ	Edge of Site	EAL
	Astbury	Dark Lane		
	µg/l	µg/l	µg/l	µg/l
Benzene	0.003	$3x10^{-6}$	$8x10^{-8}$	1
Chloroform	0.04	0.002	$2x10^{-4}$	0.1
Mecoprop	$3x10^{-10}$	$6x10^{-19}$	$3x10^{-21}$	0.04

3.2.2 LandSim Assessment - Non-hazardous Substances

The non-hazardous substance boron and nickel were predicted to be below their respective EAL (*i.e*. their DWS). The most likely (50th percentile) chromium concentration was predicted at 13µg/l, which is 26% of the DWS. However, although the maximum concentration was predicted at 65µg/l, at the edge of the site (Table 16) the time taken to reach the compliance point was 400,000years.

The most likely predicted chloride concentration was similarly below the EAL, with the maximum concentration above the EAL. The 2003 HRA predicted a most likely concentration of 4mg/l, with the maximum at 179mg/l for the current point in time (*i.e*. 2014) downgradient of the Astbury site.

Ammoniacal-N was the most significant pollutant predicted by the model with a most likely concentration peaking at 108mg/l and maximum at 523mg/l. Attenuation was however significant and breakthrough to an edge of site monitoring point is not predicted until approximately 2,500years through the engineered liner system.

Table 16 LandSim Assessment Model Maximum (95th Percentile) Non-hazardous Predictions (2003 HRA)

Parameter	Edge Site	Edge Site	EAL
	Most Likely	Maximum	
	µg/l	mg/l	µg/l
Ammoniacal-N	108	523	0.39
Chloride	242	1,020	250
Boron	0.1	0.5	1
Chromium	13	0.065	0.05
Nickel	0.2	0.003	0.02

3.2.3 Dilute and Disperse Area Analytical Solutions

The dilute and dispersion area was modelled for two monitoring locations and were used to calculate (using Equations 1 and 2) an expected distance until compliance was achieved for leachate constituents (Table 17).

The calculations indicate a distance in the order of 16 - 25m from the edge of the dilute and disperse site until compliance would be achieved, except for three constituents' chloride, nickel and chromium.

It is noted that for the three most sensitive substances, the distance varies dependent on the monitoring location used in the calculation. For example, nickel is expected to meet its EAL within 25m at BH04R, but could require up to 200m for the calculations based on BH03 data.

In contrast, chloride and chromium were calculated to meet their EAL within 25m at BH03. However, at BH04R, a distance of 69m for chloride and 250m for chromium would be required.

Table 17 Estimated Distance to Meet an EAL from the Edge of the Dark Lane Site

Parameter	Concentration				Attenuation Factor		Maximum Distance to Meet EAL	
	Leachate	BH03	BH04R	EAL	BH03 (25m)	BH04R (16m)	BH03	BH04R
	mg/l	mg/l	mg/l	mg/l	mg/l/m	mg/l/m	m	m
Ammoniacal-N	235-940	0.2 - 0.7	28 - 72	0.39	9 - 38	12 - 54	25	19
Chloride	500 - 2,000	22 - 144	619 - 1,155	250	19 - 72	11 - 53	24	69
Boron	7 - 27	0.5 - 2	0.9 - 3.5	1	0.3 - 1	0.4 - 1.5	26	18
Nickel	0.07 - 0.26	0.001 - 0.2	0.02 - 0.09	0.02	0.001 - 0.002	0.003 0.01	200	23
Chromium	0.02 - 0.09	0.002 - 0.05	0.003 - <0.05	0.05	0.0008 - 0.002	0.0008 - 0.003	16	250
Mecoprop	0.01 - 0.08	0.0001 - 0.0005	0.1 - 0.4	$4x10^{-5}$	0.0006 - 0.003	0.0009 - 0.005	25	16
Toluene	2.7 - 11	0.005 - 0.02	0.06 - 0.2	0.004	0.1 - 0.4	0.2 - 0.7	25	16
2,4- Dimethly phenol	0.1 - 0.4	0.002 - 0.008	0.06 - 0.02	0.0005	0.004 - 0.01	0.006 - 0.02	26	17

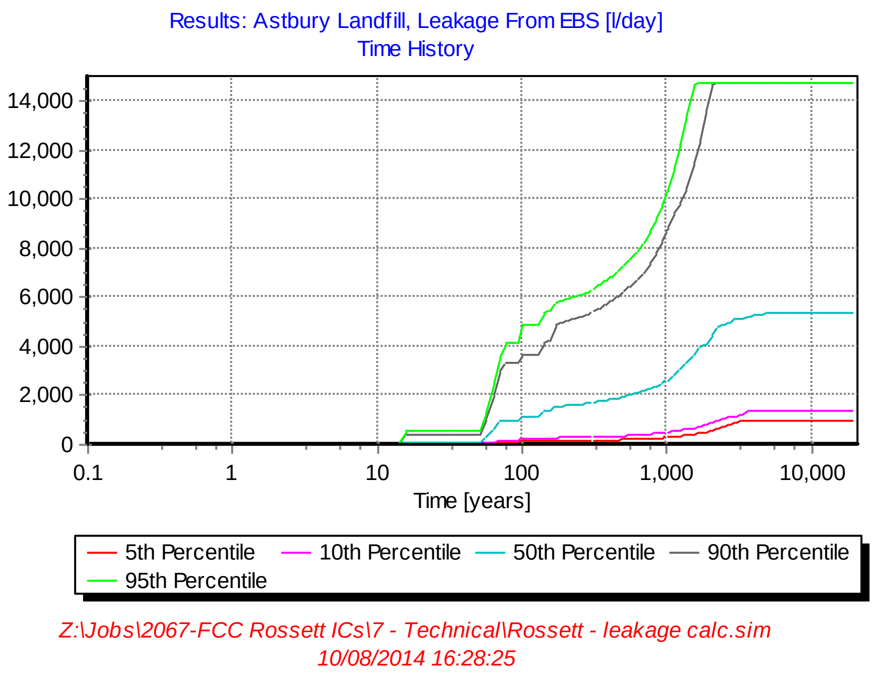
3.2.4 Comparison of Model Conclusions and Recent Monitoring Data

The groundwater and surface water monitoring data collected between 2009 and 2014 are consistent with the conclusions drawn within the 2003 hydrogeological risk assessment. Leachate seepage has not led to an impact on the groundwater system, except where previously identified during the previous assessment immediately down-gradient of the Dark Lane dilute and disperse cells.

Notwithstanding the above, a longer term potential impact was identified from the previous assessment. However, such an impact was due to the time taken for the retarded dispersion fronts for ammoniacal-N and chloride to reach the edge of the site. Monitoring data, such as from BH04R does indicate that any impact is likely to be limited, and of a short term duration, within the Upper Sand layer given the rapid depletion in concentrations that can be observed (Figure B14).

It should be noted that the highest concentrations were predicted based on the minimum aquifer flow of 0.12m^3/day beneath the containment cells. Such a flow is negligible when compared to an expected seepage volume of 0.6m^3/day at the current point in time before increasing to 14m^3/day following the degradation of all of the artificial liner components (Figure 13).

Figure 13 LandSim Predicted Leakage Rates through EBS



The LandSim model does not take into account the actual leachate seepage volume when calculating contaminant mixing within the groundwater; therefore for substances which have limited attenuation within the liner (*i.e*. chloride and ammoniacal-N) when LandSim recalculate an aquifer concentration it artificially concentrates a higher than physically possible concentration. In the case of this assessment, for simulations based on the lower aquifer conductivities and the associated 95th percentile predictions, concentrations will be increased by a factor of 5 (0.6m^3/day mixed into 0.12m^3/day aquifer flow) whilst synthetic liners are intact, increasing to 117 times (14m^3/day mixed into 0.12m^{3}day aquifer flow).

Given that chloride would be expected to be released during the initial 5 - 100 years, then a dilution of 6 would be appropriate recalculation, which would reduce the maximum (95th percentile) concentration from 1020mg/l to 204mg/l, which is below the 250mg/l DWS.

Ammoniacal-N release is slower and breakthrough is unlikely until after 1,000years, when the flux would be based on a higher flow of >14m^3/day, whereby a maximum concentration of 523mg/l would be reduced to 4.5mg/l, which is consistent with the background concentration identified up-gradient of the site.

Chloride or ammoniacal-N are therefore unlikely to cause a detrimental impact on the groundwater system or prevent any of the current uses of the groundwater, *i.e*. as spray irrigation. Similarly, the groundwater flux volume which could contain the highest concentrations of constituents would be rapidly diluted on exposure at the surface and therefore would not detrimentally contaminate the surface water system.

3.3 Review of Technical Precautions

The site was engineered to the standards of the time and therefore basal engineering and leachate control varies across the site. However, as far as possible leachate is managed on two levels, namely

- leachate generation is minimised by an engineered cap which prevents the ingress of rainfall; and
- the volume of leachate within the site is minimised as far as possible by actively abstraction leachate where a basal liner is present.

All sustainable technical precautions have therefore been implemented.

4. IMPROVEMENT CONDITIONS

This report has been prepared to address two improvement Conditions IC4 (requiring an updated hydrogeological risk assessment review) and IC7 regarding surface water.

IC4 has been addressed in Sections 2 - 3 and 5 of this document, with additional commentary below. IC7 (Surface Water) is addressed in this Section.

4.1 Improvement Condition 4 - Groundwater Monitoring Schedule

The groundwater monitoring schedule is based on a hydraulic direction from southwest towards the northeast. Groundwater flow in this direction is in part influenced by the topography and a potential spring line at about 68mAOD and the interface between the glacial sand and till formations.

There are two up-gradient locations (CABH07 and CABH08) at the southwest and southern (BH03) corners of the site and two cross-gradient locations BH04A/B and BH02A/B to the east of the site. Where there are dual depth response zones, monitoring points “A” are located in the Upper Sand and point s suffixed “B” are located in the Lower Sand.

The majority of the monitoring locations are targeted towards the north eastern flank of the site on the down-gradient perimeter of the site, as well as between 100 and 200m from the site.

Five locations CABH03, CABH02, CABH01, CABH04R, BH05A/B are located along the flank of the Dark Lane dilute and disperse site at spacing’s of between 65 and 106m.

There are a further three locations at approximately 90m (CABH05) and 195m (CABH06) and 115m (BH06A/B) which are placed to intercept any dispersion plumes from the site. CABH05 and BH06A/B are located perpendicular to the north eastern perimeter of the Dark Lane and Astbury landfill/Paper Pulp sites respectively. CABH06 is located perpendicular to the interface between the Dark Lane and Astbury landfill sites.

Given that the site is located within the Upper Sand layer and there is a 3 - 10m clay barrier between the upper and lower sands which forms a hydraulic barrier between the two sand layers, then the ongoing monitoring programme should be prioritised towards the upper sand layer.

The key monitoring points are the line of monitoring points which monitor the north eastern perimeter of the Dark Lane site, as these monitor the duration and the extent of any potential pollution plumes emanating from the dilute and disperse site. .

With regards to the Astbury and paper pulp sites, monitoring should continue at BH02A and BH04A to determine if there is lateral leachate seepage from either Cell 4 or the Paper Pulp site. BH02A would also monitor a north easterly flux from Cell 4 and Cell 3.

BH06A is ideally located to monitor a down-gradient flux from both sites, as it is likely that groundwater flow which is at ~68mAOD on the perimeter of the site is some 15m below ground level reduces to ~65mAOD at BH06A, which is at ~0.3m below ground level. Ground level then reduces rapidly to <25m AOD, therefore groundwater flow would be influenced by where the topography intersects the groundwater table. Given that BH06A is located within a valley feature, groundwater flow is likely to be channelled towards the existing borehole which is towards the centre of the valley.

The monitoring data also indicates that the source at Yr Ackery is also influencing BH06A, albeit to a lesser degree than for CABH06. Given that there does not appear to be an influence from any of the Astbury landfill's, then it is unlikely that an additional monitoring point to the west of BH06A would provide useful additional information as to pollution migration. Groundwater flow from the northwest corner of the site is also directly towards BH06A, therefore there is similarly no advantage in locating an additional monitoring point to the east of BH06A.

BH06A is located within a marsh area and it is likely that this marsh is caused by a combination of near-surface surface clay and a spring line. This marsh area drains in an easterly direction to the surface water course downstream of the north eastern discharge from the site. It is therefore recommended that this surface water channel is monitored immediately before the confluence with the stream in order that a larger potential sphere of influence is monitored than at BH06A alone. Monitoring should be undertaken based on the groundwater suite and frequencies, for the newly designated location SW08 (Table 21).

The current groundwater monitoring based on a quarterly schedule is based on LFTGN02 which requires that leachate and groundwater are monitored on at least a 6-monthly schedule during the aftercare period of a landfill site's lifecycle.

The monitoring schedule includes a comprehensive suite of leachate indicator substances which can be used to define the degradation state of the leachate and whether the site is undergoing active biodegradation (*i.e*. alkalinity, BOD and ammoniacal-N) or reverting to a lesser reduced regime (*i.e*. TON, sulphate, Fe and Mn). The suite also includes the mobile ions which are preferentially concentrated within leachates compared to terrestrial waters (*i.e*. COD, Na, K, Mg, and Cl) as well as trace hazardous and non-hazardous substances.

A comprehensive list of leachate indicators is still required in order to distinguish the influence of off-site sources within the groundwater.

There are therefore no additional substances which are recommended to be included within the monitoring programme.

Permit Limits are not simple to determine for the Astbury landfill complex because of the background influences, which can be demonstrated to have an influence on groundwater chemistry. Reference levels are however proposed for ammoniacal-N and chloride at two downgradient locations CABH04R and BH06A (CABH03 is up/cross-gradient and influenced by off-site sources).. These reference levels should be used as the basis for discussion when evaluating the impact on the groundwater system on either the receipt of data or as part of annual monitoring reviews.

The assessment levels (Table 18) are based on a combination of the background concentration (*e.g*. 3mg/l ammoniacal-N at CABH07), the DWS, or a steady-state concentration observed in the monitoring data. The data is presented graphically in Figure 14 and Figure 15, and use analytically discernible increases above the existing dataset (*i.e*. UKAS accredited laboratories quote precision levels of no less than 10%). This increase is shown graphically on Figure 14 and Figure 15, which can also be used on a routine basis to determine whether there is an ongoing increasing trend which would warrant further investigation by the site operators with respect to advising on any proposed changes to the active leachate management controls at the site.

Table 18 Proposed Monitoring Reference Levels

Location	Substance	Reference Level	Source
CABH04R	ammoniacal-N	10mg/l	110% of recent peak concentrations (Figure 14)
BH06	ammoniacal-N	3mg/l	Background concentration at upgradient CABH07 (Figure 14)
CABH04R	chloride	250 mg/l	Drinking water standard (Figure 15)
BH06	chloride	250mg/l	Drinking water standard (Figure 15)

Although reference levels have been proposed, care should still be taken as other off-site sources have been identified which contribute ammoniacal-N, potassium and other potential leachate indicators to the groundwater geochemical system.

It is not proposed that limits are set for additional substances within the groundwater monitoring schedule, because leachate migration will be defined by the major elements in solution, where they can be distinguished from background effects and not the trace non-hazardous and hazardous substances. The trace substances are at relatively low concentrations in the leachate, and it would require the displacement of all of the groundwater flow by leachate, before these substances could be distinguished from the background effect.

Such a displacement would be evident in the matrix / major element chemistry, and at lower mixing rates, the monitoring programme would be monitoring a combination of the natural background fluctuation in combination with the analytical precision and accuracy of the analysing laboratory. Therefore setting Permit Limits for other substances, such as Cd, Hg, Cr, Cu, Ni and organic constituents would provide no useful information on the performance of the landfill's management controls and likely result in a number of 'false positives' where there can be no actionable means in response to an apparently elevated laboratory result.

Figure 14 Groundwater Ammoniacal-N Reference Levels

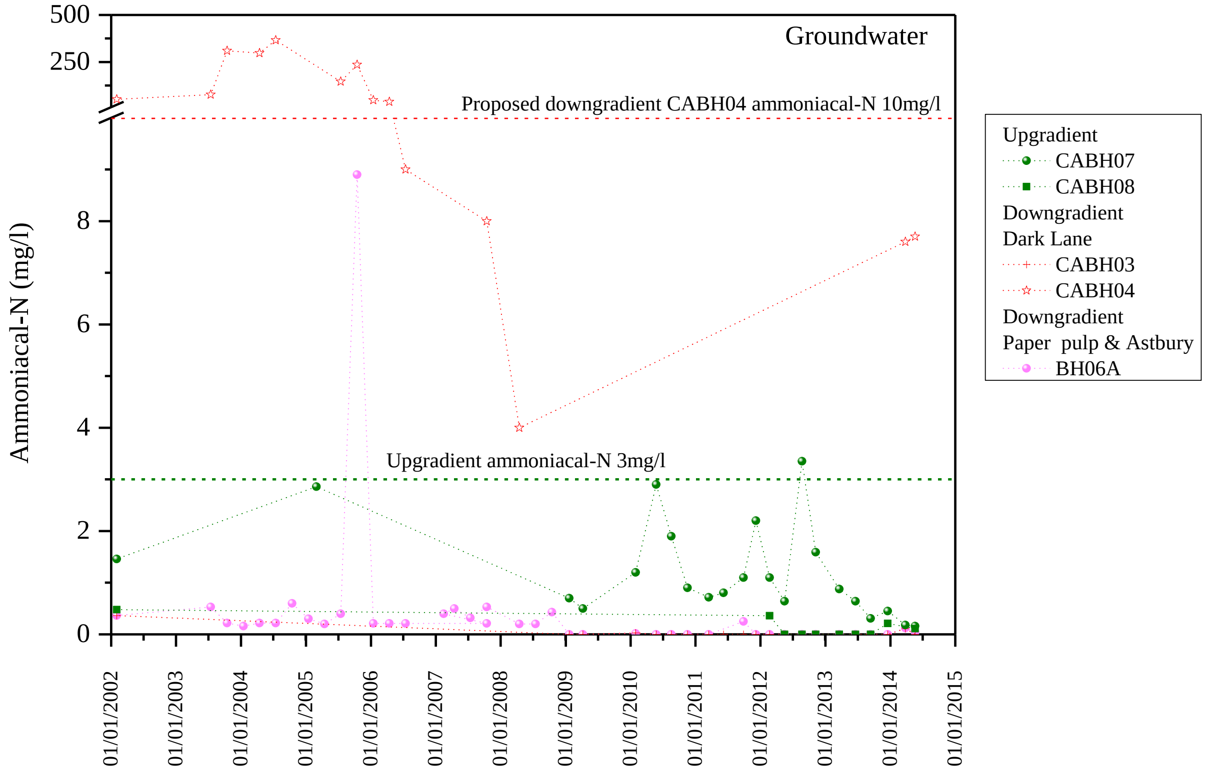
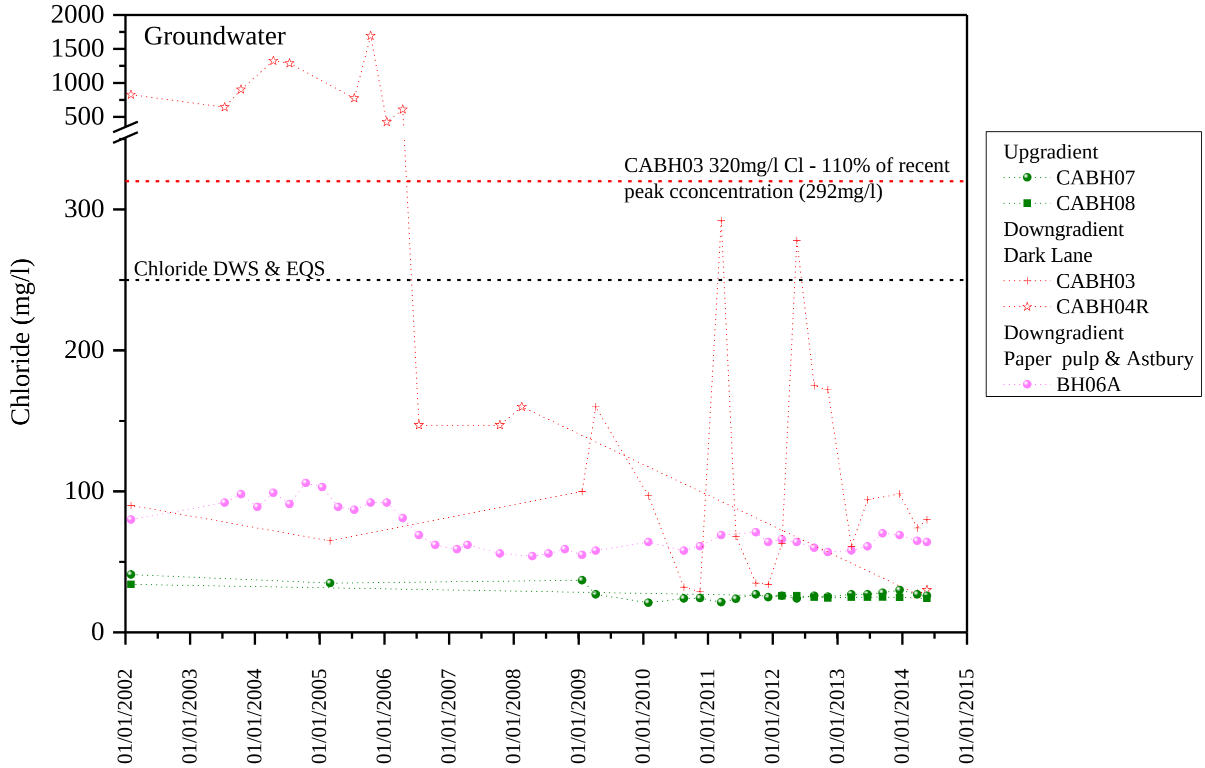


Figure 15 Groundwater Chloride Reference Levels



Groundwater Monitoring Infrastructure

The groundwater boreholes at the site have been assessed against their original construction detail to determine if they remain fit for the purpose of groundwater sampling at the site. The current field depth of each borehole has been measured and this depth compared to the response zone (if known) in each borehole. The response zones have been taken from Table 2 of the 2003 ESID Report (ref: MJCA, SH/DL/GD/2413/02) and the review presented in Appendix D.

The majority of the boreholes appear to retain a significant depth of their response zone, and historic data suggests that these boreholes continue to recharge sufficiently to allow a suitable sample to be obtained. Borehole BH04A/B appears to have been lost. Borehole BH06A does appear to have silted up beyond the response zone but continues to recharge sufficiently to allow routine samples to be obtained. It is recommended that this borehole be de-silted at the earliest opportunity.

Three of the boreholes reviewed (BH02B, BH05B and CABBH05) appear to have failed, with significant silting observed in boreholes BH02B and BH05B, and borehole CABBH05 appears to have been installed to shallow and is consistently reported as dry. however, it is noted that BH02B and BH05B have response zones in the Lower Sand which is hydraulically separated from the Upper Sand layer, the primary groundwater receptor for the site. A recommendation has been made that monitoring is targeted towards the Upper Sand, the horizon in which a developing pollution plume could be identified.

4.2 IC7 - Surface Water

Improvement Condition IC7 states that:

"The operator shall submit to Natural Resources Wales for written approval, a review of the surface water monitoring regime at the site. The review shall include, but not be limited to the following:

- *A review of the suitability of the surface water monitoring locations;*
- *A review of compliance limits and assessment levels; and*
- *An investigation to determine if the activities at the site have impacted upon the quality of adjacent surface water systems."*

During 2013 and 2014 surface water is being monitored at four locations around the perimeter of the site and at the discharge points (as shown on Drawing Environmental Monitoring Plan, dated No 2010), namely:

1. SW01 - Site discharge into northern watercourse
2. SW02 - Site discharge into north eastern water course
3. SW04 - Eastern transfer ditch between SW05 and before SW02
4. SW05 - Southwest corner balancing pond and transfer ditch
5. SW06 - South western surface water run-off perimeter interception and transfer ditch
6. SW07 - South western corner perimeter ditch

Only two of these locations SW01 and SW02 are important for monitoring the impact of the site on the environment, as they are located at the discharge point. These points are immediately prior to the minor road (Dark lane) which forms the northern boundary of the site. The discharge is culverted under the minor road before forming the headwaters of tributary streams to Pulford Brook approximately 2.5km to the northeast of the site (Figure 16). All other surface water monitoring points are within the site boundary and are located on the surface water run-off interception channels.

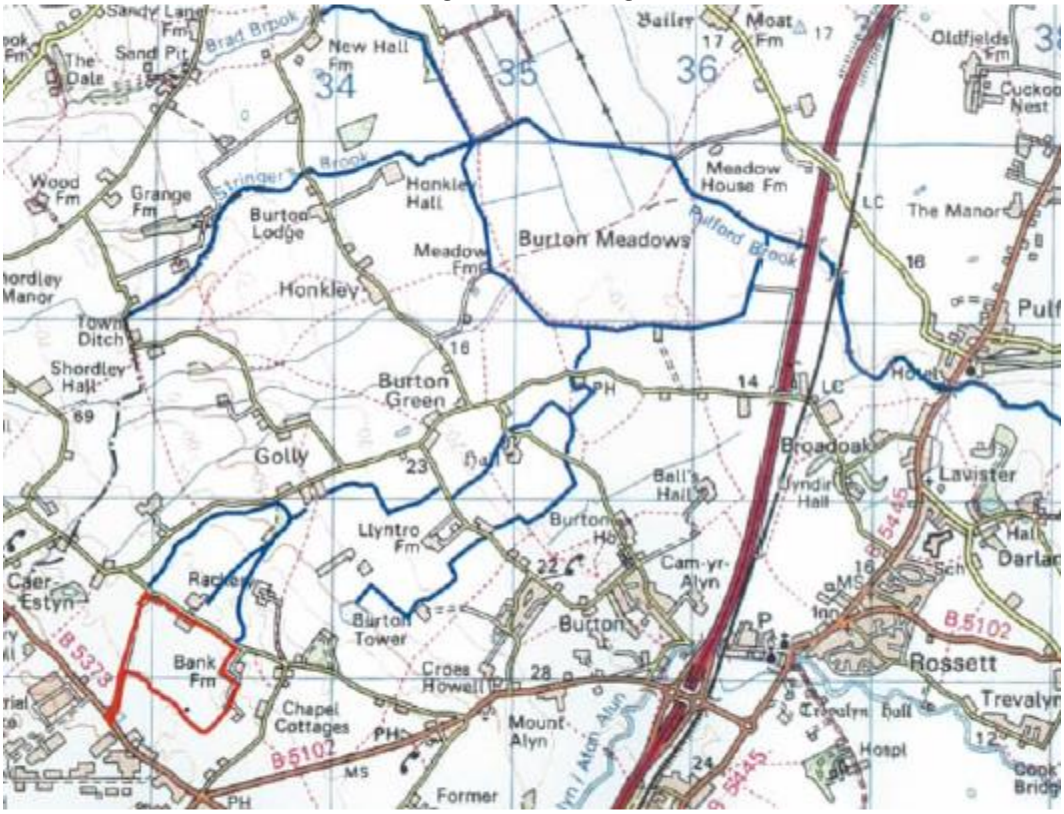
The surface water interception ditches are essentially ephemeral streams, which are dry for the majority of the year. Consequently there is a limited amount of monitoring data, however, the limited dataset also indicates that any impact is short term and there is no sustained impact on surface water quality. Surface water discharge is no longer significant since groundwater management and abstraction ceased when mineral washing associated with the quarry ended.

A seventh surface water location SW08, has been proposed in response to IC4 (Hydrogeological assessment) and discussed in Section 4.1.

7. Surface channel adjacent to BH06A/B marsh area

This monitoring point is intended to target a spring line to the north of the site below the Paper Pulp landfill and hence will identify if there is a potential baseflow contribution through the glacial sands which could impact on surface water quality.

Figure 16 Surface Water Discharge - Receiving water courses



Extract from MJCA Drawing SH/DL/10-03/11122

The receiving surface water channels flow downhill through pasture land and are primarily identifiable by woodland which follows the streams and are likely used as field boundaries.

The primary purpose for monitoring the discharge into the surface water is to ensure that leachate outbreaks which could be intercepted by the perimeter channels is not being released from the site and that the water quality is of a standard which does not cause concern for animals in the adjacent pasture.

Given the location of the site relative to the receiving streams and the topography, there is not an upstream contribution to the flow. However, there are five potential contributions to the surface water courses, namely:

1. the site discharge
2. surface water run- off from Dark Lane
3. surface water run-off from the adjacent farms and pasture
4. surface water run-off from the property on the eastern boundary of the site
5. baseflow where the surface water channels intercept groundwater.

The review of groundwater monitoring data has identified that there are potential organic sources within the vicinity of the site which could contribute to the water chemistry in the receiving streams. Such a contribution could also be in excess of that from the site, such as for periods when manure may be temporarily located in proximity of the stream and releasing ammoniacal-N and organic matter. Caution should also be taken when interpreting surface water monitoring data to exclude road run-off, local herbicidal and pesticide applications as well as anoxic conditions which develop in stagnant water, following the accumulation of vegetation such as leaf accumulation.

It is considered that surface water monitoring should be targeted to the point where surface water is discharged from the site in order to screen out off-site influences. However, care should still be taken where there is stagnant water. It is therefore recommended that the other on-site monitoring points are removed from the routine schedule. However, this does not prevent additional investigations being undertaken if an adverse change in the discharge is being undertaken.

The site is not currently causing an adverse impact on surface water quality downstream of the site. There has been insufficient flow from the northern perimeter monitoring point SW01 to enable a sample to be taken.

Surface water at SW02 and SW04 are both below the limits set for SW02. The surface water would also be classified as being of a “high” quality with respect to ammoniacal-N and BOD. There is only a good quality classification for the other parameters where there is not a distinction between Good and High quality standards.

Surface water should continue to be monitored at the point of discharge from the site to target the type of substances which could affect downstream water quality or those constituents within the landfill which could adversely impact on water quality. The substances within the leachate which could cause an impact on surface water are the primary matrix components and suspended solids. Significantly these are also the components which could adversely impact the receiving water on a combination of toxicological, eutrophication and smothering of the stream base reasons.

Table 19 Surface Water SW02 and SW04 Quality Monitoring 2014

	pH	EC	SS	NH_4-N	BOD	Cl	B	Mecoprop	Dieldrin	Chloroform	Toluene
		µS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	µg/l	µg/l	µg/l	µg/l
SW02											
26/03/14	8.0	1060	21	0.20	4.5	78	0.25	0.06	<0.01	<1	<1
24/04/14	7.5	981	50	0.30	7.8	81	0.28	<0.02	<0.01	<1	<1
20/05/14	8.2	591	7	0.02	2.2	84	0.25	0.16	<0.01	<1	<1
24/06/14	Dry										
Limit	**6 - 8.5**		**60**	**none**	**10**	**none set**					
SW04											
26/03/14	7.9	561	33	0.07	2.1	20	0.07	<0.02	<0.01	<1	<1
24/04/14	7.7	1070	8	0.03	<2.0	54	0.19	<0.02	<0.01	<1	<1
20/05/14	7.7	1100	14	0.01	<2.0	65	<0.02	0.05	<0.01	<1	<1
24/06/14	7.7	1260	12	0.04	2.1	84					
Environmental Quality Standard for "Good" standard Classification (for Type 3,5 7 water)[7]											
Annual Mean	*6 - 9			0.6	5	250	1	18	0.01		50
95th percentile	*6 - 9			0.6	5	250	1	187	0.01		380

*For high standard pH to be between pH 6 as 5th and pH9 as 95th percentile concentration
for good standard pH >5.2 as 10th percentile (no equivalent upper limit

The setting of Permit Limits for suspended solids and BOD is the most effective mechanism to ensure that benthic and other organism are protected downstream of the site.

The permit already requires that the parameters in Table 22 are monitored. Given the results collected to date, it is unlikely that the boron or the specific organic substances monitored will provide meaningful data as to leachate outbreak or the releases from the site.

The data indicates that boron is below sensitive concentrations within the discharge, whilst the most likely source of the herbicides and pesticide is the post-landfilling application at or in the vicinity of the site. Toluene is a component of diesel and petrol fuels and although it is a useful marker for fuel spillages, vehicle movements at a closed landfill are minimal and therefore the potential impact is negligible.

Neither group of contaminants are markers of leachate outbreak and are likely to be caused by post-landfilling applications (including off-site). .

5. REQUISIT E SURVELLIANCE

5.1 Introduction

The monitoring schedules within the Permit are presented in Table 20 for leachate, Table 21 for groundwater and Table 22 for surface water. There are at least 3 monitoring locations within each hydraulically contained landfill cell.

Groundwater and surface water schedules, along with the leachate suite are discussed in Section 4.

[7] Environment Agency (2010) H1 Environmental Risk Assessment - Annex (d) - Surface Water discharges (basic)

5.2 Leachate, Groundwater and Surface Water Monitoring Schedule

Table 20 Leachate Monitoring Schedule (as per Table S3.1 and S3.8 of Permit EPR/FP3894FP)

Monitoring Point	Parameter	Limit	Frequency
Leachate Extraction Points LC1Br, LC1Cr, LC1A LC2A, LC2Br, LC2C LC3A, LC3Br, LC3r LC4A, LC4B, LC4C	Leachate Height	At least 1m freeboard shall be maintained between the internal bund separating the non-engineered parts of the site Equivalent to 71mAOD	Quarterly
PH5B, PH5C, PH5D		1 m above cell base	
Abstraction chamber in Astbury Cells 1, 2, 3, 4, 5 Dark Lane Phase 5	pH, EC, Temp Cl, SO_4, alkalinity, NH_4-N, TON, TOC, BOD, COD Ca, Mg, Na, K Fe, Mn Cd, Hg, Pb Cr, Cu, Ni, Zn oil/hydrocarbons	none set	Annually
Abstraction chamber in Astbury Cells 1, 2, 3, 4, 5 Dark Lane Phase 5	Hazardous Substances Monitoring point base	none set	Once every 4 years

Table 21 Groundwater Monitoring Schedule (as per Tables S3.4 and S3.10 of Permit EPR/FP3894FP)

Monitoring Point	Parameter	Limit	Frequency
CABH04R	Ammoniacal-N Chloride	10mg/l 250mg/l	Quarterly
BH06A	Ammoniacal-N Chloride	3mg/l 250mg/l	Quarterly
CABH04R BH06A	Water Level pH Electrical Conductivity Boron Mecoprop Toluene Dieldrin Chloroform	None set	Quarterly
Up-gradient Locations CABH08, CABH07, BH03,	Water level pH Electrical Conductivity Ammoniacal-N Chloride	None set	Quarterly
	Alkalinity, Sulphate Calcium Sodium, Potassium Iron, Manganese Chromium, Copper Nickel, Zinc Lead Base of monitoring point	none set	Annually
Cross-gradient BH02A, BH04A, CABH03 Down-gradient CABH03, CABH02, CABH01 CABH04R, CABH05, CABH06 BH05A, BH06A SW08 (refer to Section 4.1)	Water level pH Electrical Conductivity Ammoniacal-N Chloride	None set *n.b. limits set for CABH04R and BH06A for Cl & NH_4-N)	Quarterly
	Alkalinity, Sulphate Calcium Sodium, Potassium Iron, Manganese Chromium, Copper Nickel, Zinc Lead Base of monitoring point	none set	Annually
	Hazardous substances detected in leachate (or a full screen if monitoring data suggests an increase in contamination	None set	Every two years

Table 22 Surface Water Monitoring Schedule (as per Tables S3.3 and S3.9 of Permit EPR/FP3894FP)

Monitoring Point	Parameter	Limit	Frequency
SW02	Suspended solids BOD pH Ammoniacal-N Electrical Conductivity Visible oil or grease	60mg/l 10mg/l >6 - <8.5 None set None set none set	Monthly
SW02	Chloride Boron Mecoprop Toluene Dieldrin Chlorofrom	None set	Quarterly
SW04	Suspended solids BOD pH Ammoniacal-N Electrical Conductivity Visible oil or grease	None set	Monthly
SW04	Chloride Boron Mecoprop Toluene Dieldrin Chlorofrom	None set	Quarterly
SW01	pH Electrical conductivity Suspended solids Ammoniacal-N Chloride Visible oil and grease	None Set	Monthly
Existing Points Recommended to be removed from Permit			
SW01, SW03, SW05, SW06	pH Electrical conductivity Suspended solids Ammoniacal-N Chloride Visible oil and grease	None Set	Monthly

6. RECOMMENDATIONS

A series of recommendations have been made from the assessments and data evaluation undertaken within this review in response to the requirements of Improvement Conditions 4 and 7.

These recommendations can be summarised as

1. The leachate level Permit Limit should be set at 71mAOD for monitoring locations within the Astbury landfill site;
2. The leachate level limit should be set at 1m above the base for Phase 5 of the Dark Lane site;
3. No change to the leachate or groundwater parameter analysis is required;

4. No change to the leachate infrastructure are required as a result of this review;
5. New groundwater control limits are proposed in Section 4.1;
6. No changes to the current groundwater monitoring infrastructure are proposed.
7. It is proposed to remove Surface water monitoring points SW03, SW05, SW06 and SW07 from the routine monitoring schedule.
8. A new monitoring location SW08 has been proposed, as an off-site point to monitor any groundwater contribution to surface water chemistry downgradient of the site;
9. Surface water Permit Limits should be retained for the discharge from the site;

7. CONCLUSIONS

The Astbury landfill does not have a discernible impact on the down-gradient hydrogeological system. However, there is a discernible influence from the adjacent dilute and disperse landfill site. This older site was operated to the regulations of the time and closed prior to the introduction of the Groundwater and Landfill Directives or the Environmental Permitting Regulations.

The Groundwater Directive can be demonstrated as being complied with for the containment cells.

All reasonable active (*i.e*. leachate management) and engineered controls have been implemented and any backlog of leachate within the site has been removed. The site has therefore entered a stabilisation phase of its lifecycle and leachate quality will be monitored on a routine schedule to assess the depletion of the source term until active controls are no longer required.

All landfill influences are restricted to a narrow zone (<30m) down-gradient of the Dark Lane site. No impact from either of the sites can be confirmed at 100m down-gradient of the landfill complex. However, at such a distance there is an off-site source containing three potential landfill indicators (*i.e*. potassium, ammoniacal-N and organic matter). Notably this list does not contain chloride the primary landfill indicator identified at perimeter locations down-gradient of the Dark lane site, and up-gradient of the off-site source.

Monitoring and active management of the on-site leachate should be continued to allow the ongoing assessment of any contaminant plumes from the dilute and disperse site and to confirm that a pollution plume was not generated from the containment areas before the leachate could be demonstrated as being brought under control.

Revised compliance limits have been determined for the Astbury phase cells, as specified in Table S3.1 of the site Permit. The current interim limit, as specified within the Permit is set at a 1m freeboard between the internal bund separating the non-engineered parts of the landfill. Based on this principle a limit of 71mAOD has been determined and will be implemented following approval of this report.

Appendix A

Leachate Monitoring Data

Figure A1 Cell 1 Leachate Matrix and indicator Components

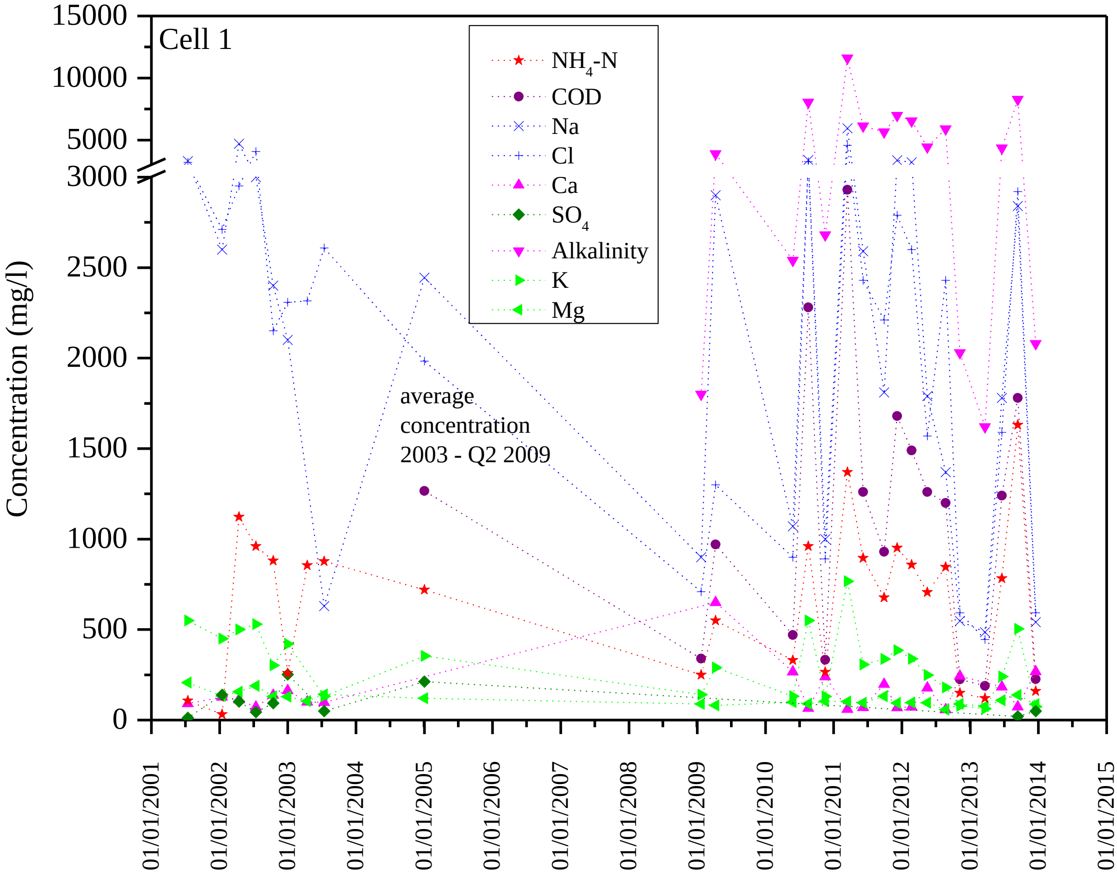


Figure A2 Cell 2 Leachate Matrix and indicator Components

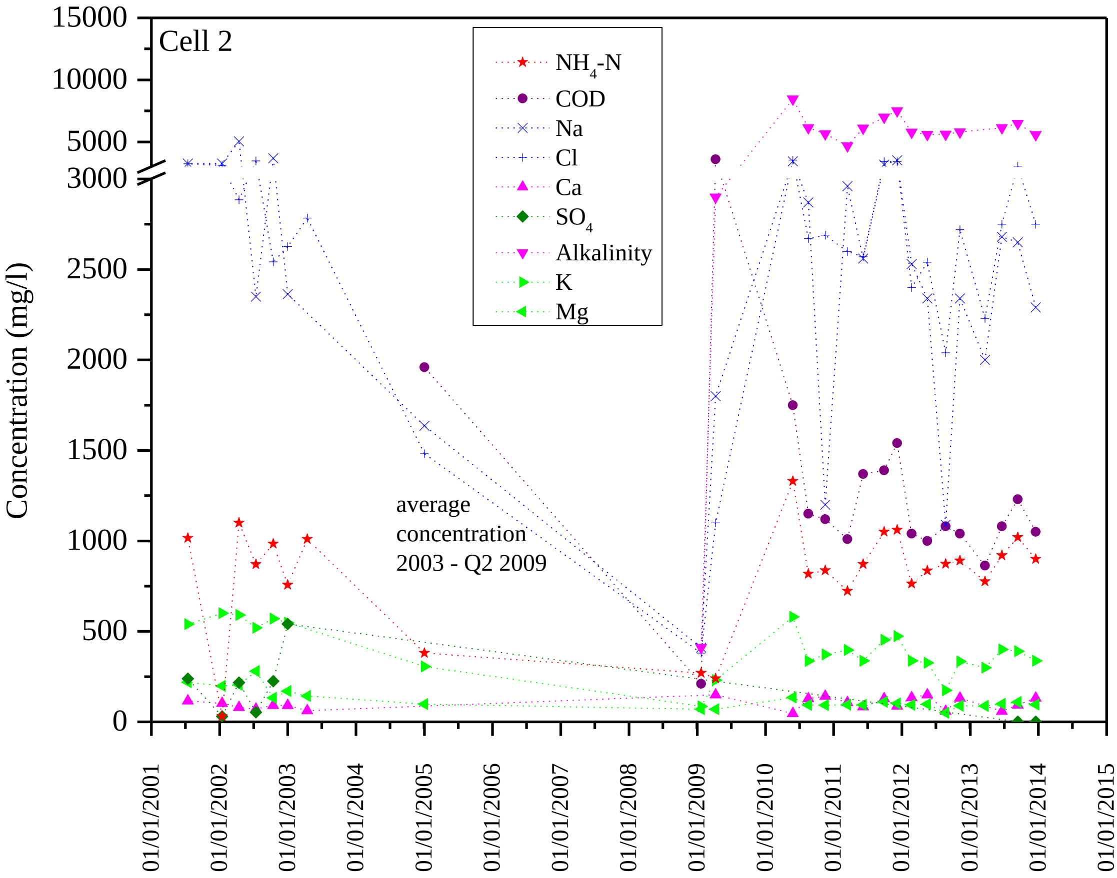


Figure A3 Cell 3 Leachate Matrix and indicator Components

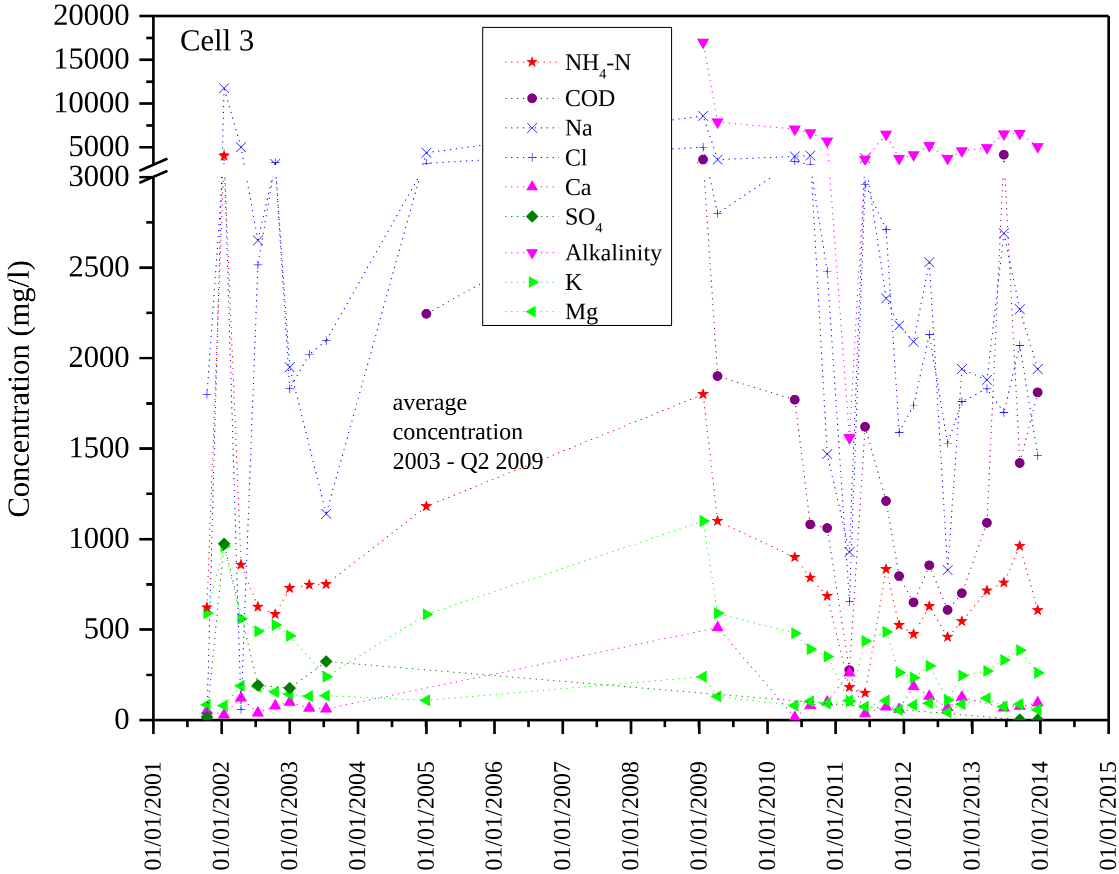


Figure A4 Cell 4 Leachate Matrix and indicator Components

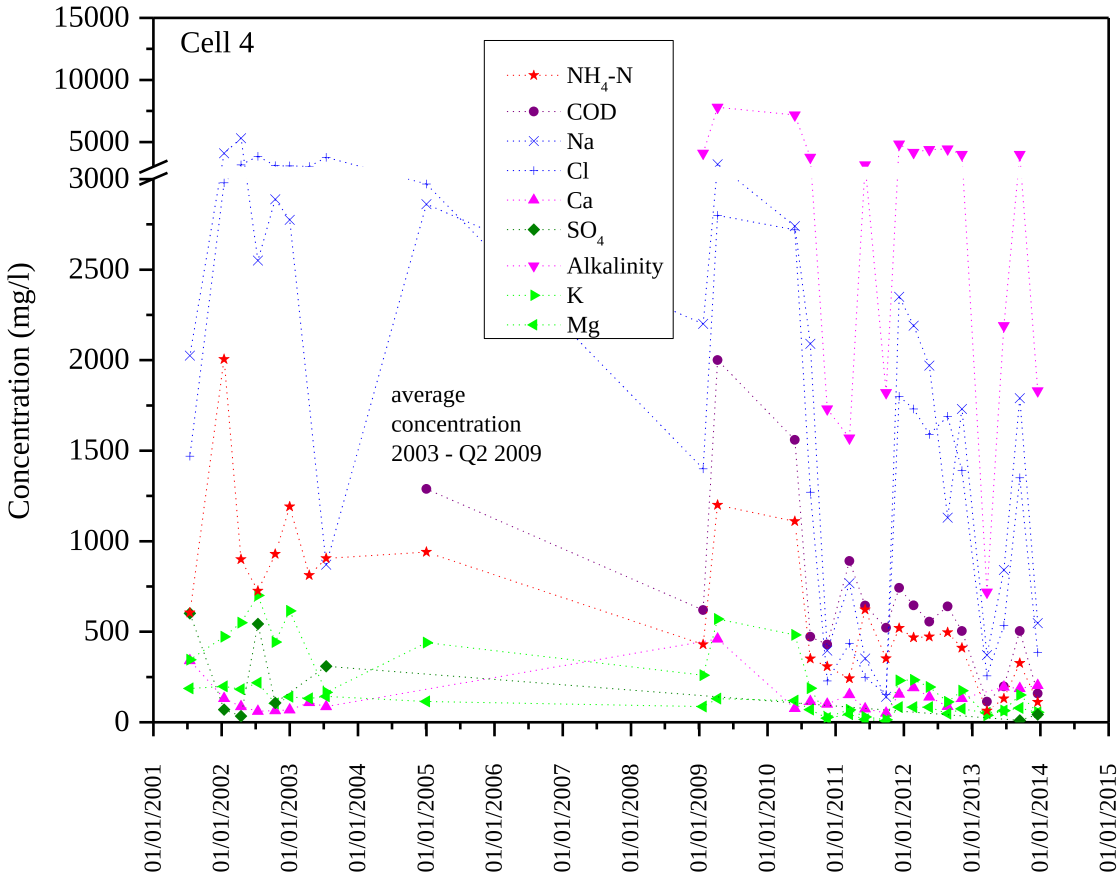


Figure A5 Cell 5 Leachate Matrix and indicator Components

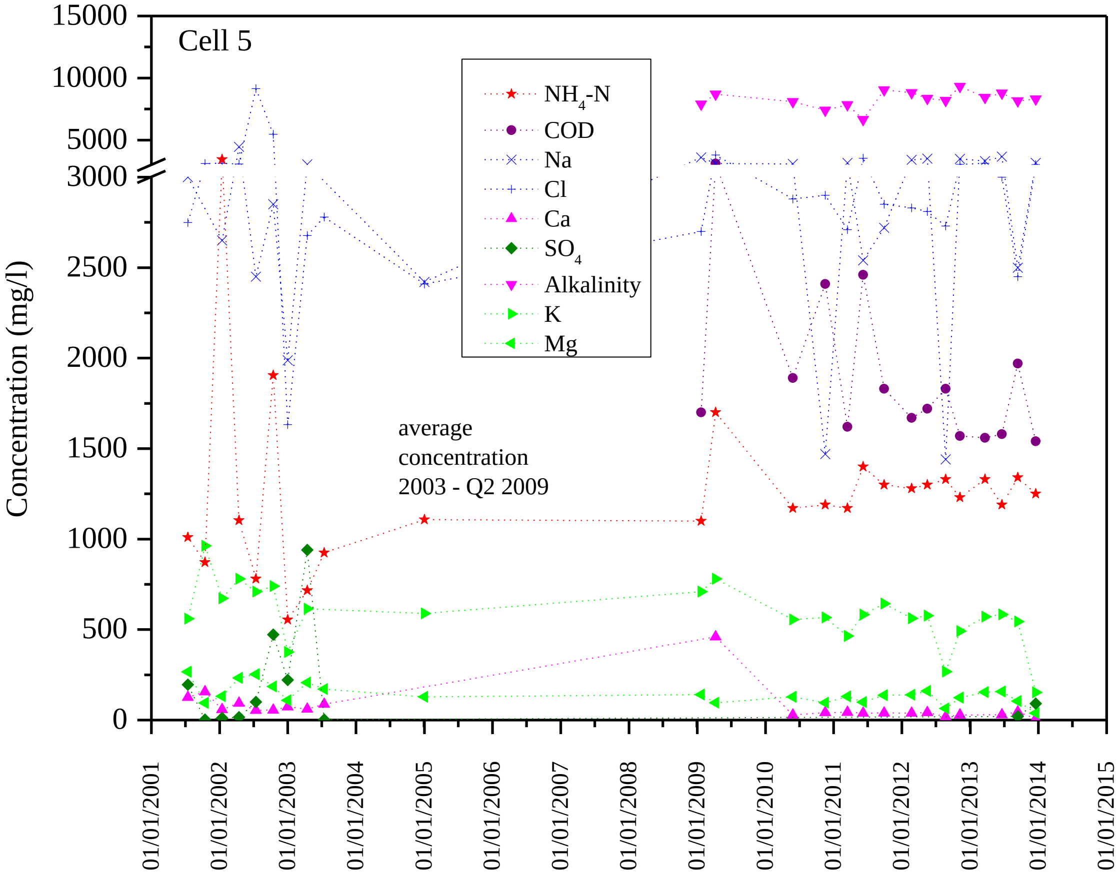


Figure A6 Phase 5 (Dark Lane) Leachate Matrix and indicator Components

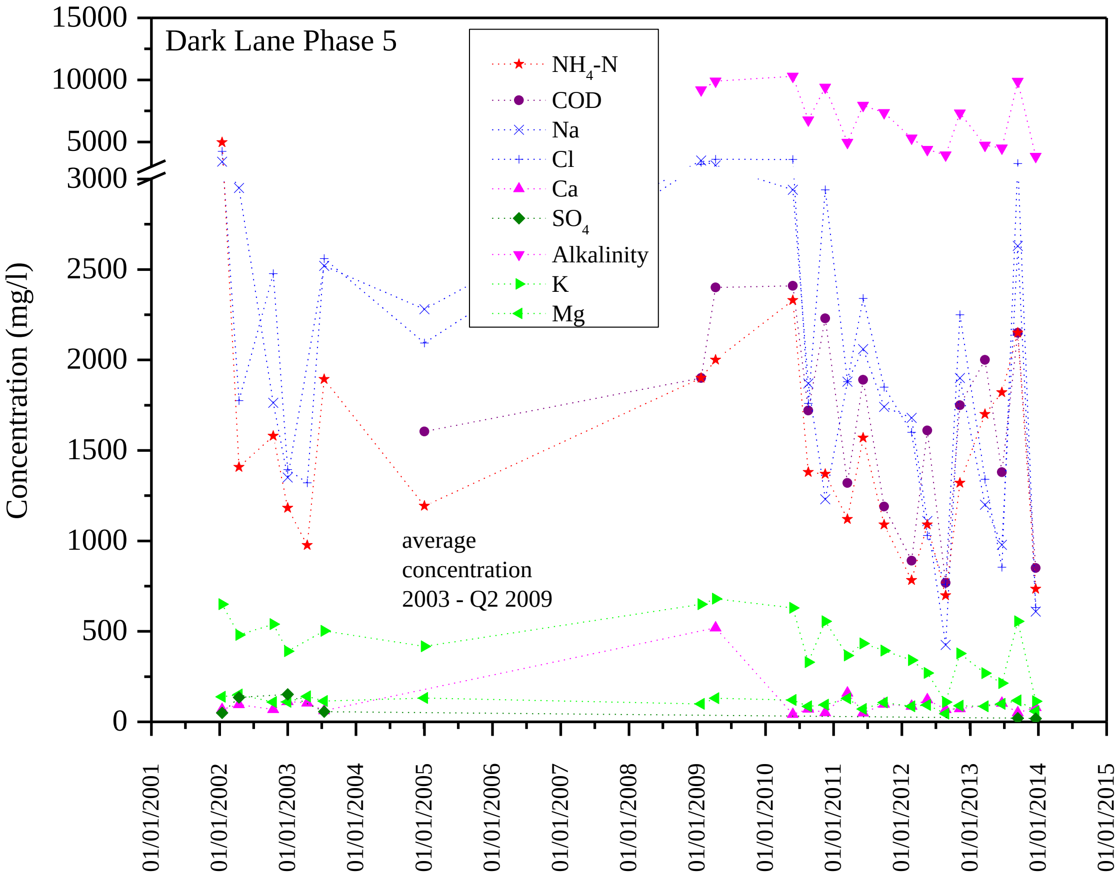


Table A1 **Leachate Salinity and Organic Indicator Components (2009 - 2014)**

Sample point	pH (Lab)		Conductivity (uS/cm)		NH_4-N (mg/l)		COD (mg/l)		BOD (mg/l)		TOC (mg/l)	
	Ave	Max	Ave	Max	Ave	Max	Ave	Max	Ave	Max	Ave	Max
ASCELL01	7.8	9.1	11,953	25,800	676	1,630	1,106	2,930	51	101	323	952
ASCELL02	8.1	9.1	14,553	20,200	834	1,330	1,266	3,600	45	65	418	1,240
ASCELL03	8.1	9.1	14,700	35,000	712	1,800	1,447	4,150	43	92	460	1,300
ASCELL04	7.9	9.2	8,712	18,000	448	1,200	659	2,000	31	80	188	620
ASCELL05	8.2	9.3	19,333	22,000	1,285	1,700	1,897	3,100	64	121	671	940
ASPHASEV	8.2	9.4	15,653	24,000	1,441	2,330	1,654	2,410	73	121	514	828

Table A2 **Leachate Matrix Ions (2009 - 2014)**

Sample point	Ca (mg/l)		Mg (mg/l)		Na (mg/l)		K (mg/l)		Cl (mg/l)		Alkalinity (mg/l)	
	Ave	Max	Ave	Max	Ave	Max	Ave	Max	Ave	Max	Ave	Max
ASCELL01	179	650	96	138	2,090	5,950	280	767	1,869	4,560	4,974	11,600
ASCELL02	109	150	93	135	2,345	3,520	345	580	2,521	3,540	5,616	8,450
ASCELL03	126	510	96	240	2,768	8,600	373	1,100	2,284	5,000	5,918	17,000
ASCELL04	155	460	66	130	1,459	3,200	170	570	1,176	2,800	3,627	7,800
ASCELL05	66	460	118	161	2,941	3,660	537	780	2,959	3,800	8,269	9,320
ASPHASEV	113	520	94	130	1,803	3,500	393	680	2,054	3,600	6,858	10,300

Table A3 **Leachate Minor Ions (2009 - 2014)**

Sample point	SO4 (mg/l)		TON (mg/l)		Iron (mg/l)		Mn (µg/l)		Zn (µg/l)	
	Ave	Max	Ave	Max	Ave	Max	Ave	Max	Ave	Max
ASCELL01	<40	50	<1	<1	1.3	5.0	318	969	44	113
ASCELL02	<20	<20	<1	3	1.0	2.8	99	212	43	210
ASCELL03	<40	<40	<1	6	3.4	14.0	44	119	113	747
ASCELL04	<20	42	<1	26	1.5	8.8	196	398	21	73
ASCELL05	<40	91	<1	3	1.2	4.6	67	252	24	74
ASPHASEV	<40	18	<1	18	1.0	2.5	110	252	8	28

Table A4 **Leachate Hazardous and Non-hazardous Metals (2009 - 2014)**

Sample point	Cd (µg/l)		Hg (µg/l)		Pb (µg/l)		Cr (µg/l)		Cu (µg/l)		Ni (µg/l)	
	Ave	Max	Ave	Max	Ave	Max	Ave	Max	Ave	Max	Ave	Max
ASCELL01	<0.1	0.39	<0.01	<0.01	0.7	2.1	119	388	21	70	49	135
ASCELL02	<0.1	0.46	<0.01	<0.01	0.6	2.7	85	154	19	49	31	93
ASCELL03	<0.1	0.48	<0.01	<0.01	2.1	11.0	107	446	75	423	34	99
ASCELL04	<0.1	0.25	<0.01	<0.01	0.1	0.3	40	92	3	6	29	122
ASCELL05	<0.1	5.90	<0.01	<0.01	0.5	1.7	49	178	17	51	35	106
ASPHASEV	<0.1	0.37	<0.01	<0.01	0.2	0.9	46	106	4	12	42	153

Table A5 **Leachate BTEX Substances (2009 - 2014)**

Sample Point	Benzene (ug/l)		Toluene (ug/l)		Ethyl Benzene (ug/l)		m,p-xylene (ug/l)		o-xylene (ug/l)	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
ASCELL01	6	75	2	2	3	14	4	12	2	8
ASCELL02	15	32	3	5	14	25	8	21	3	8
ASCELL03	16	67	1	3	6	11	2	9	1	8
ASCELL04	268	648	1	15	36	91	1	21	4	14
ASCELL05	3	57	3	10	40	55	6	58	3	27
ASPHASEV	4	61	5	35	11	102	17	166	7	82

Table A6 **Leachate Other Aromatic Hydrocarbons (2009 - 2014)**

Sample Point	Naphthalene (µg/l)		1,2,4-TMB (µg/l)		sopropylbenzene (µg/	
	Min	Max	Min	Max	Min	Max
ASCELL01	5	44	5	6	2	5
ASCELL02	3	22	9	12	6	7
ASCELL03	6	11	3	5	1	6
ASCELL04	23	721	7	31	5	11
ASCELL05	10	146	16	31	3	20
ASPHASEV	4	8	3	26	2	3

Appendix B

Groundwater Monitoring Data

Figure B1 Groundwater Ammoniacal-N

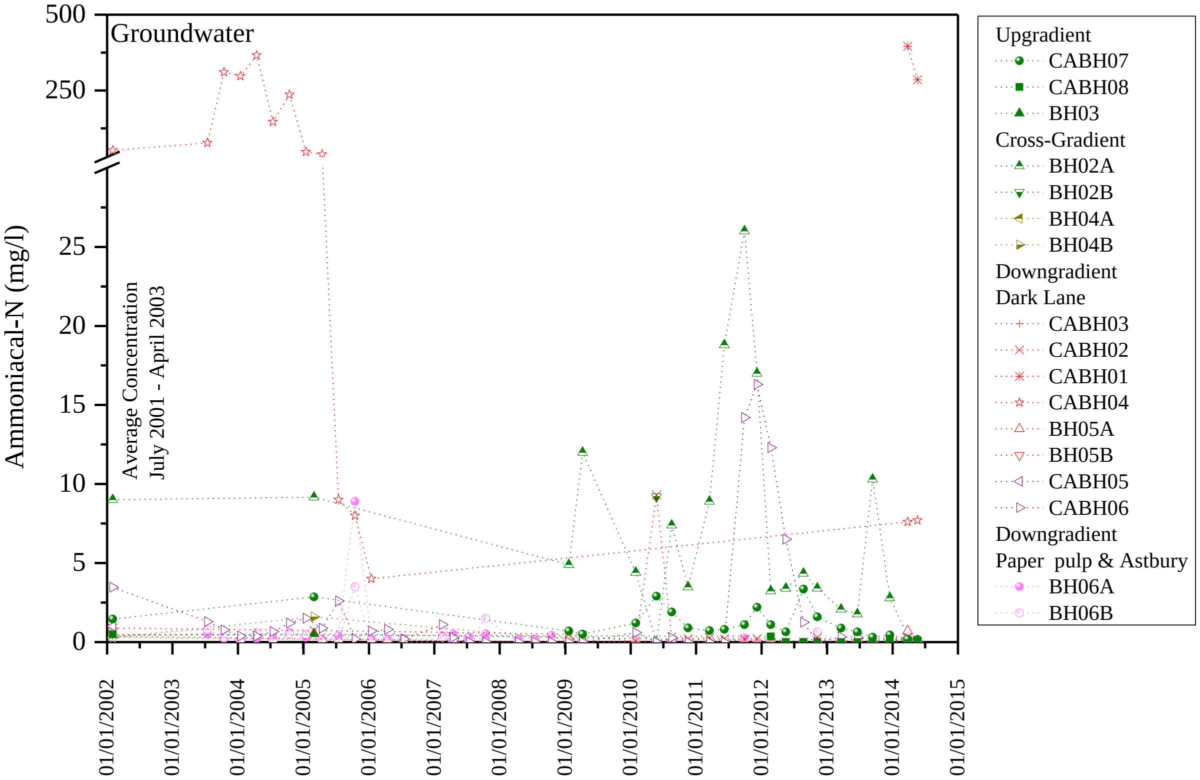


Figure B2 Groundwater Chloride

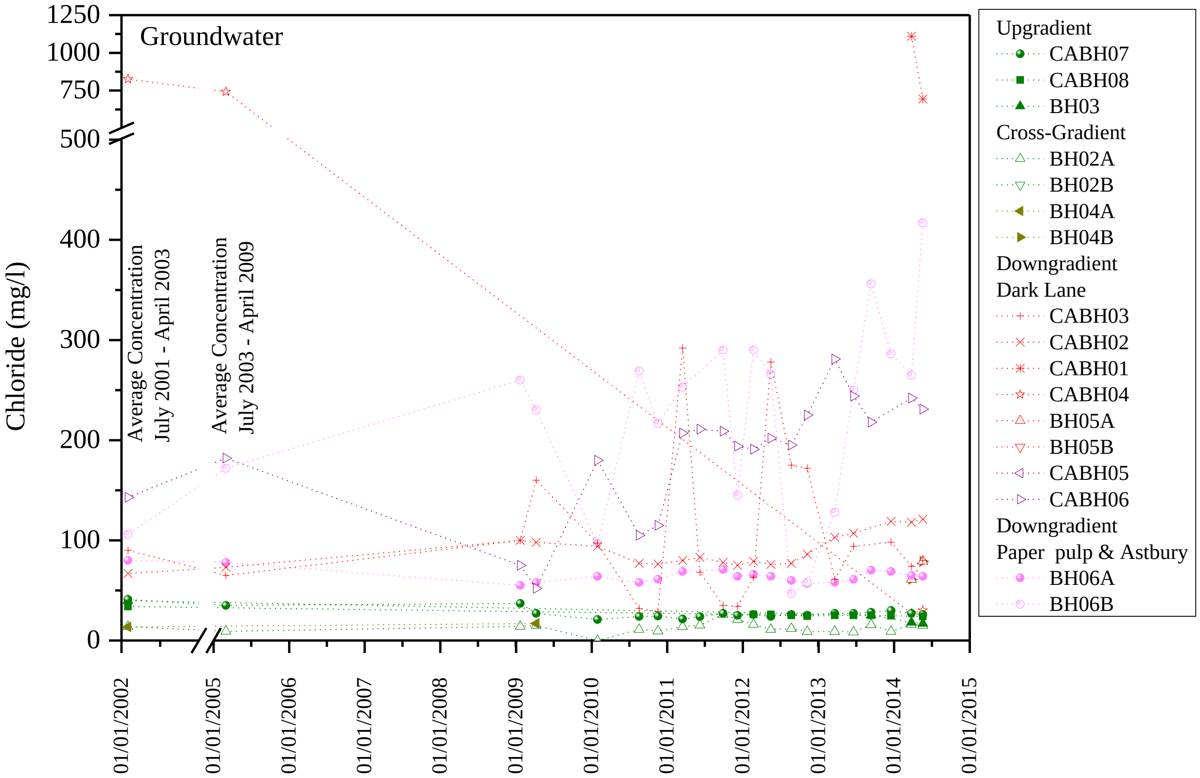


Figure B3 Groundwater Potassium

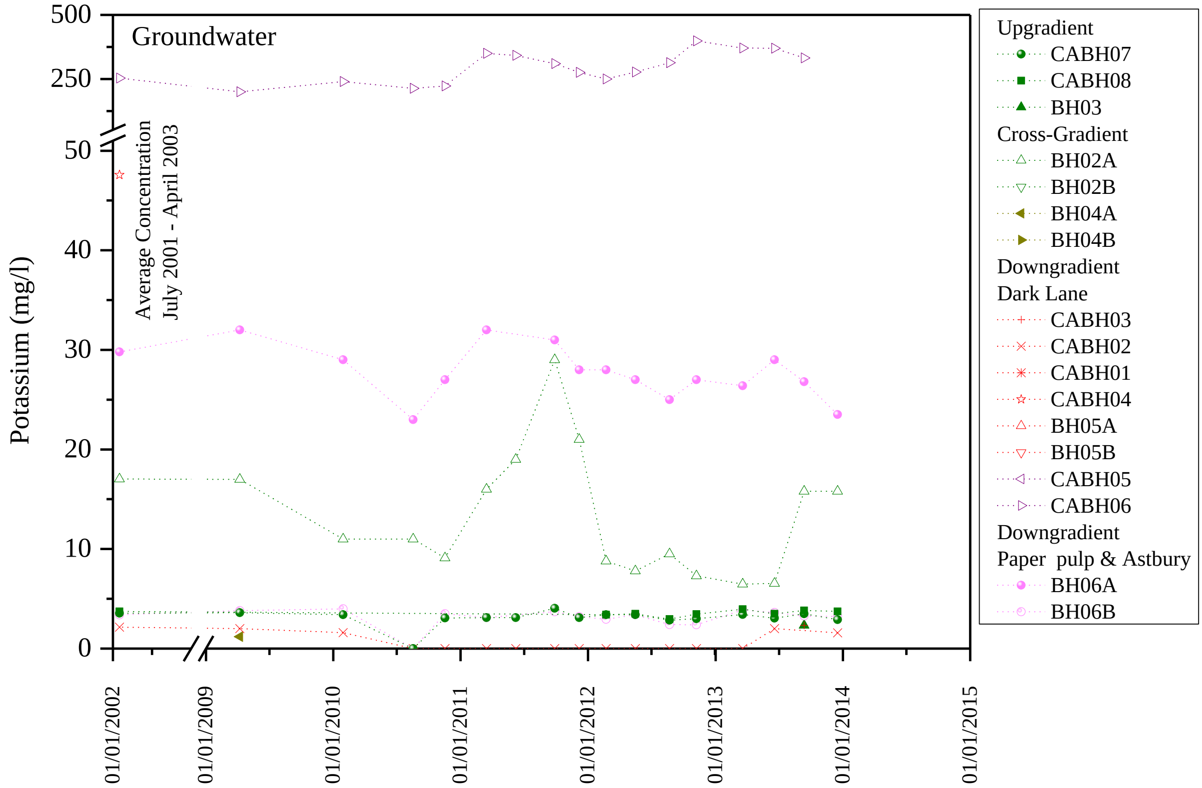


Figure B4 Groundwater Sulphate

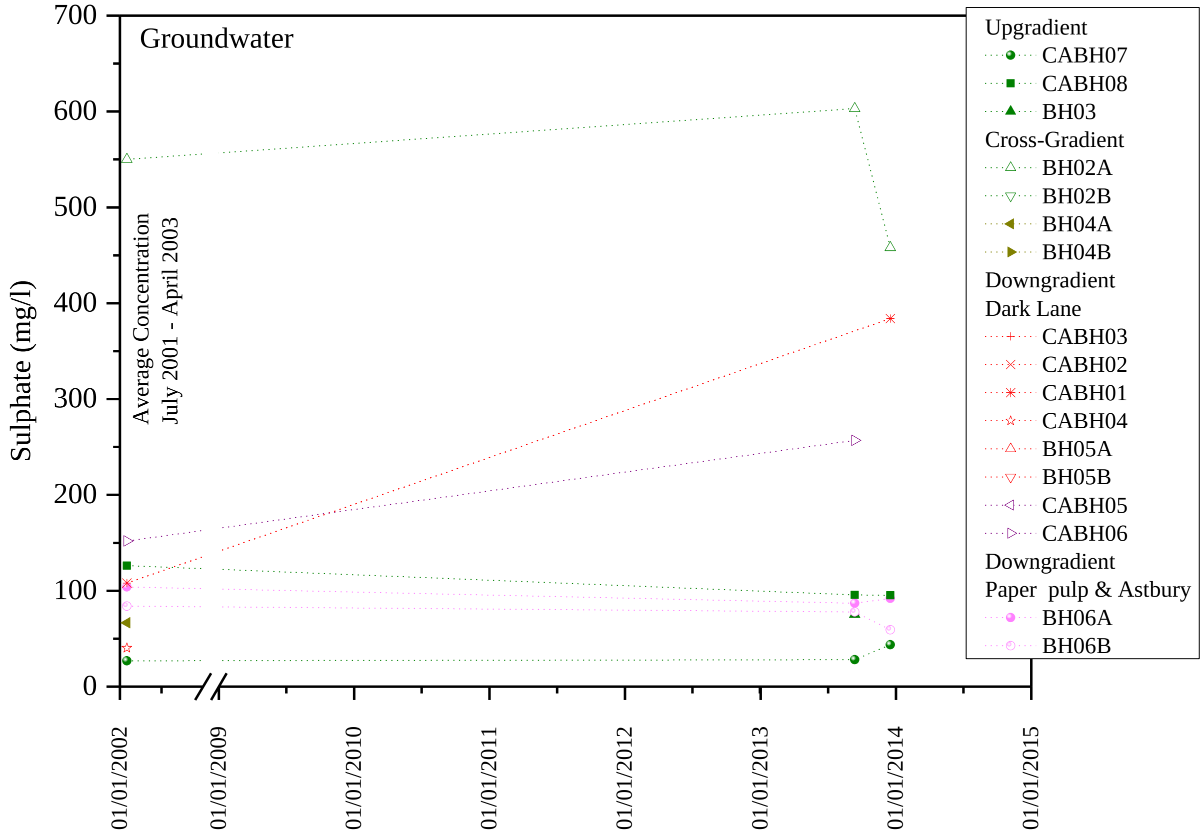


Figure B5 BH02A Groundwater Quality

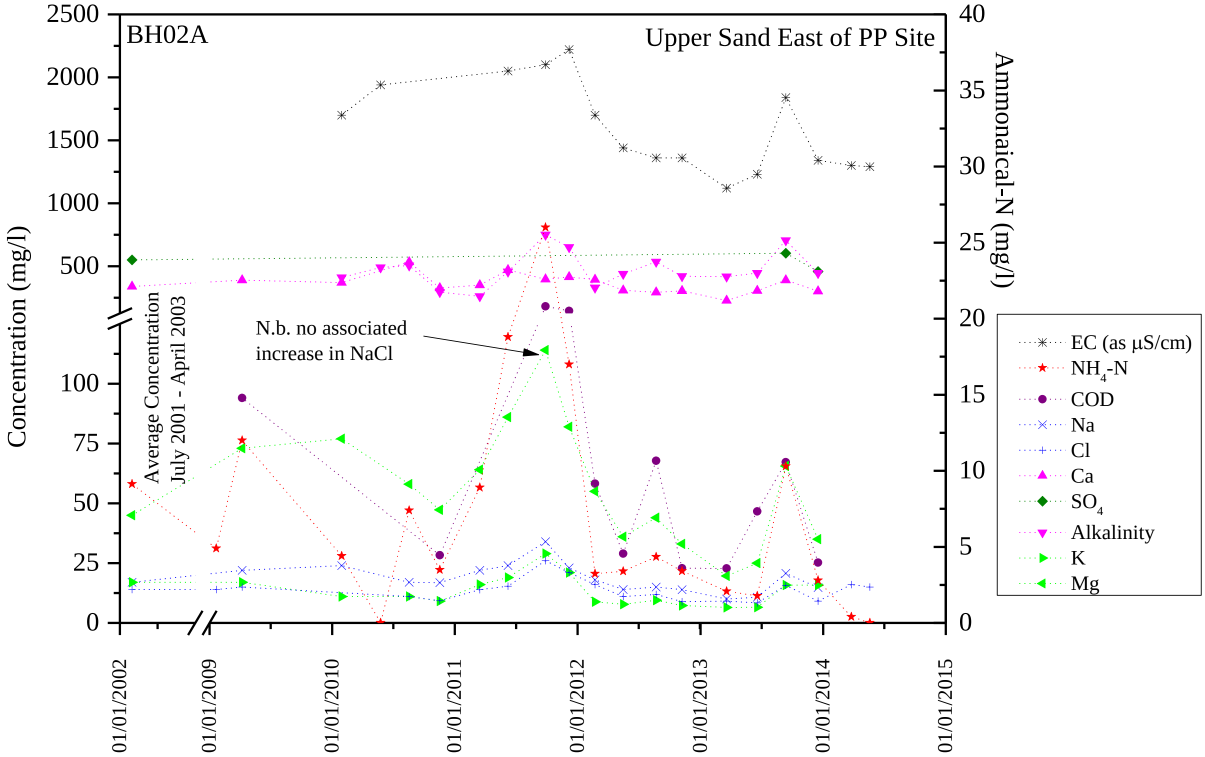


Figure B6 BH03 Groundwater Quality

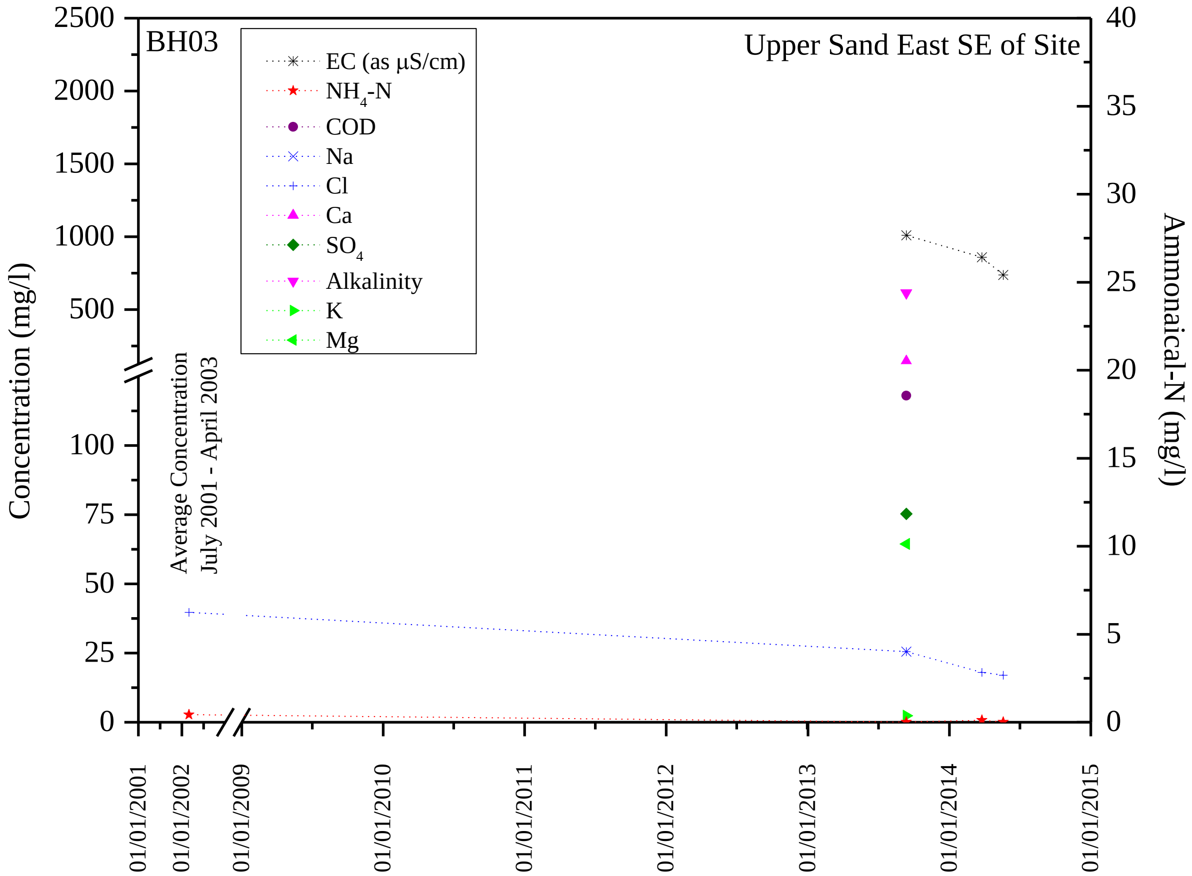


Figure B7 BH05A Groundwater Quality

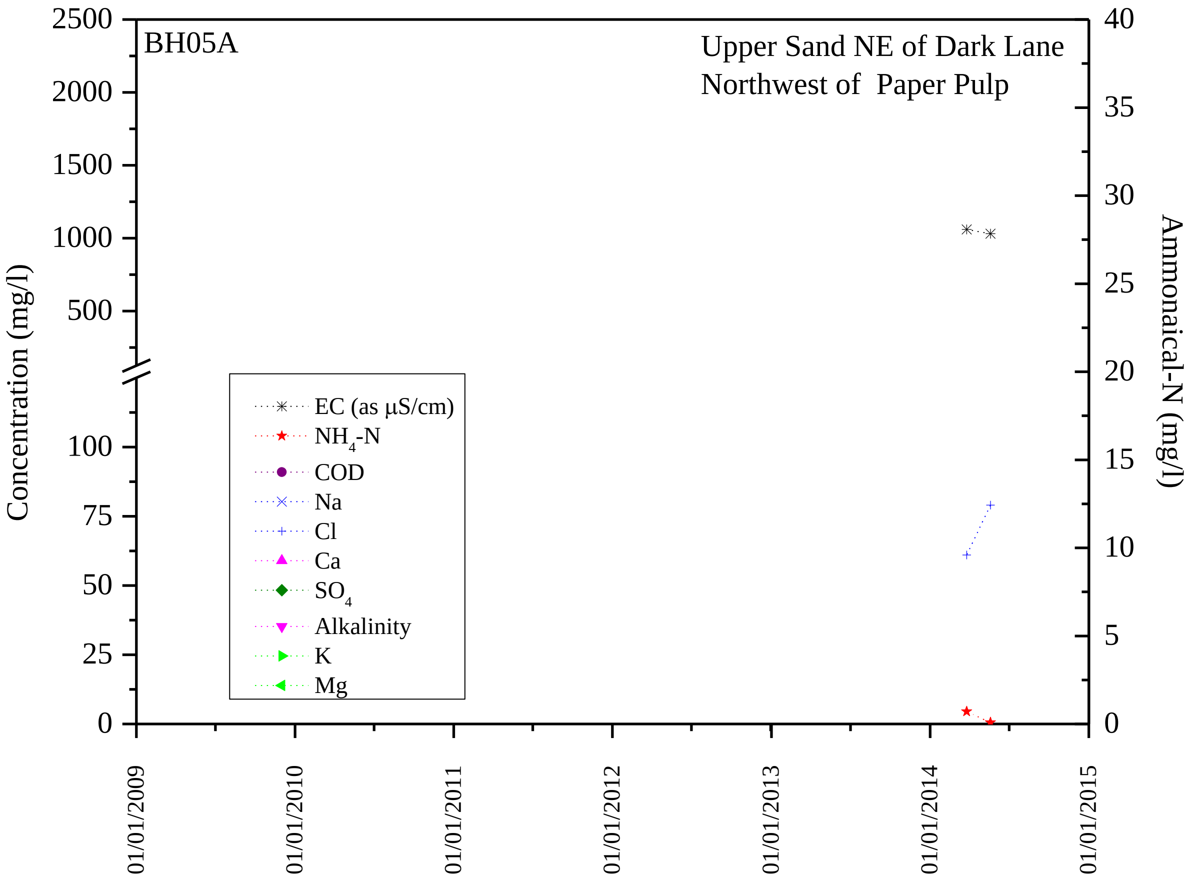


Figure B8 BH06A Groundwater Quality

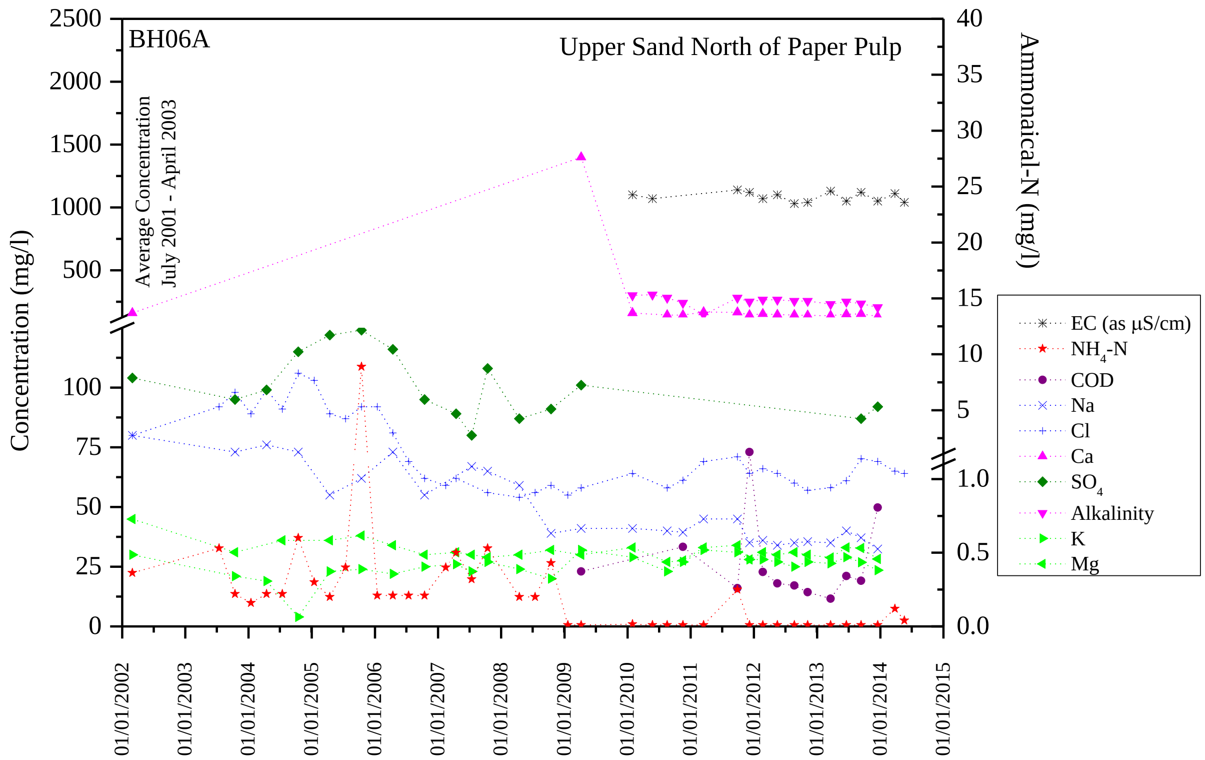


Figure B9 BH06B Groundwater Quality

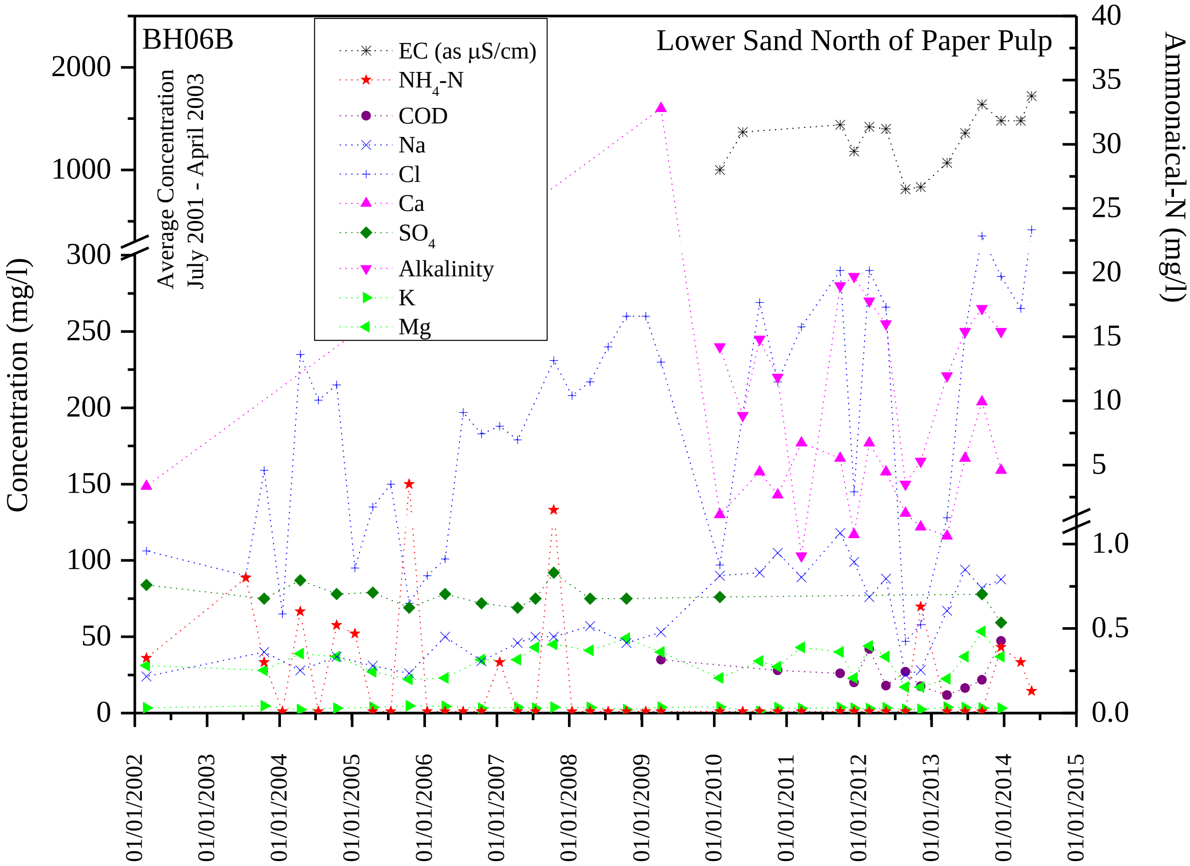


Figure B10 CABH01 Groundwater Quality

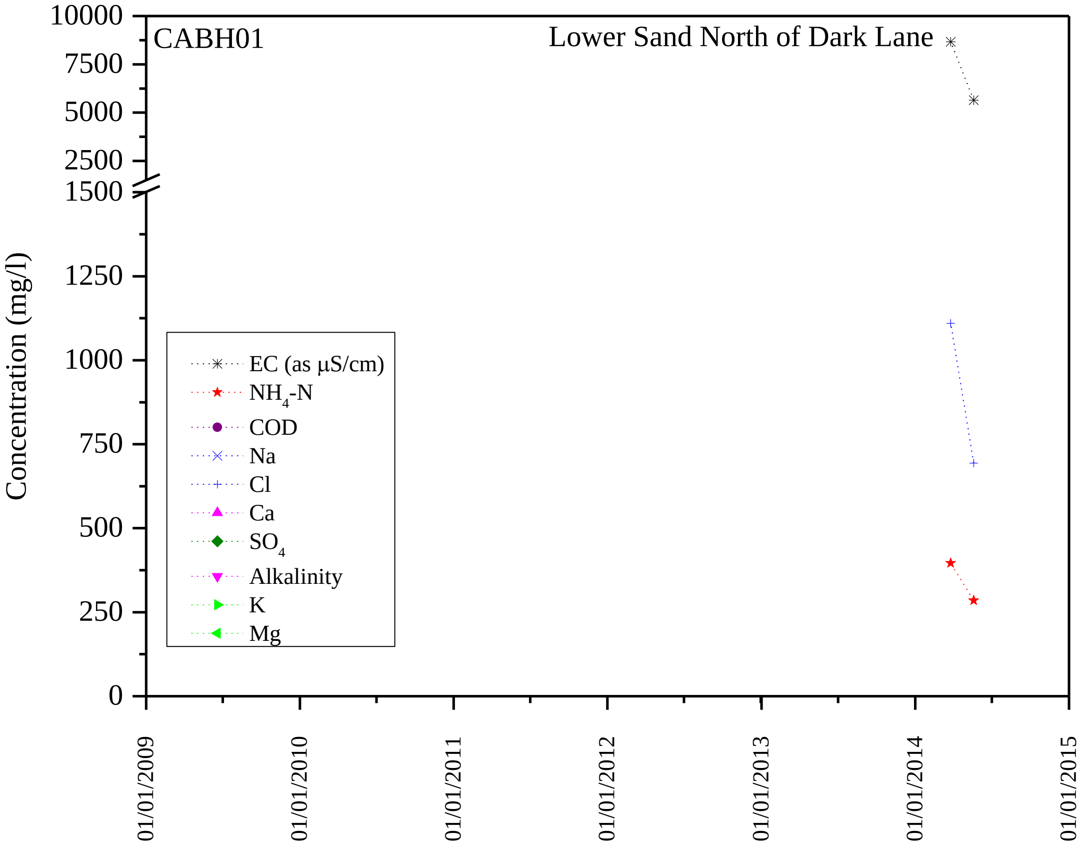


Figure B12 CABH02 Groundwater Quality

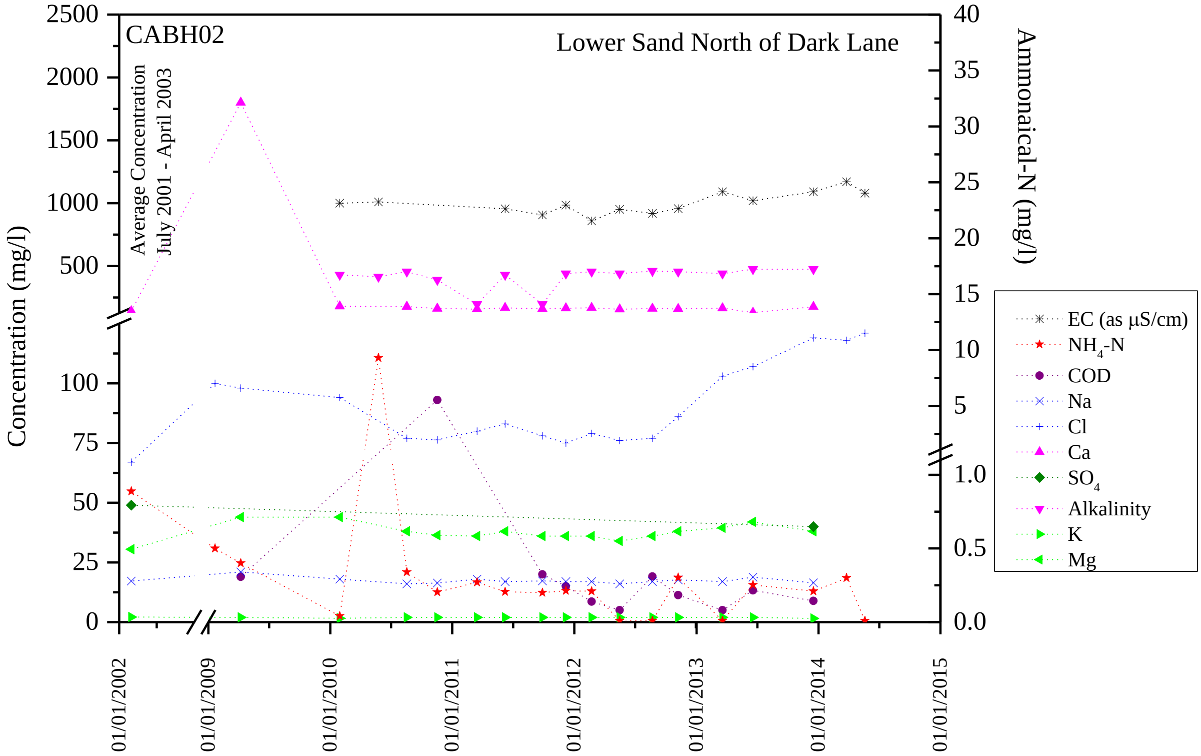


Figure B13 CABH03 Groundwater Quality

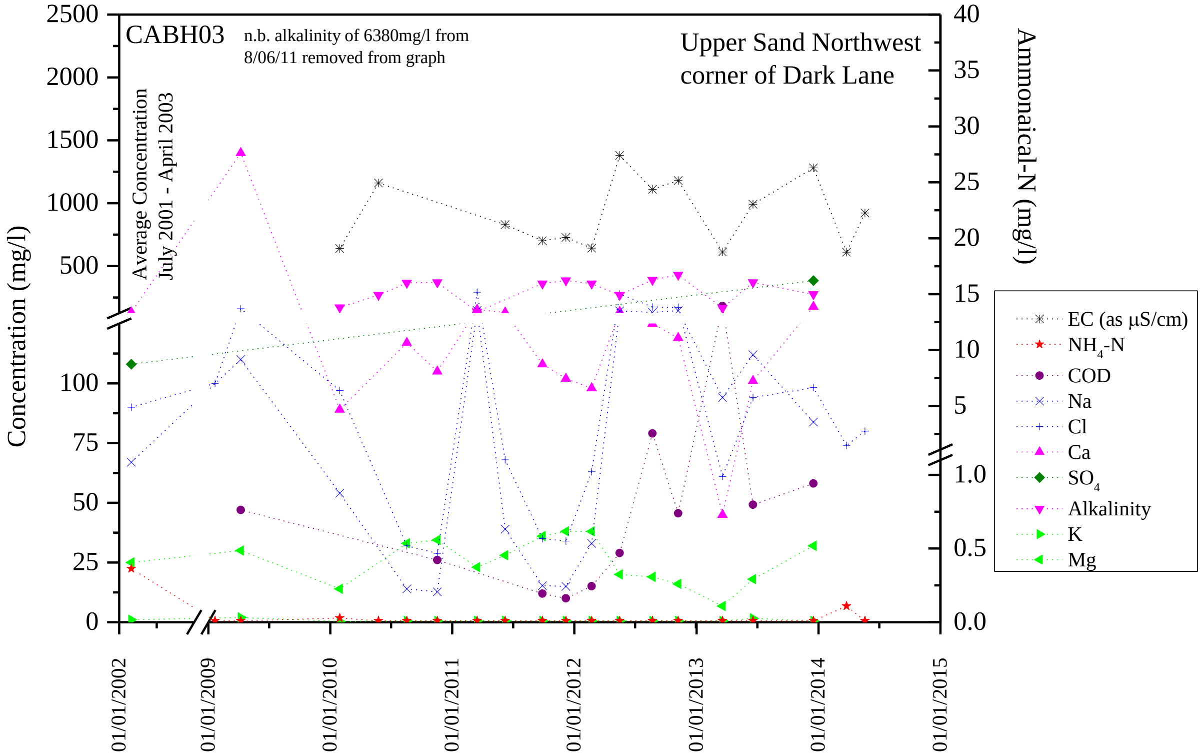


Figure B14 CABH04R Groundwater Quality

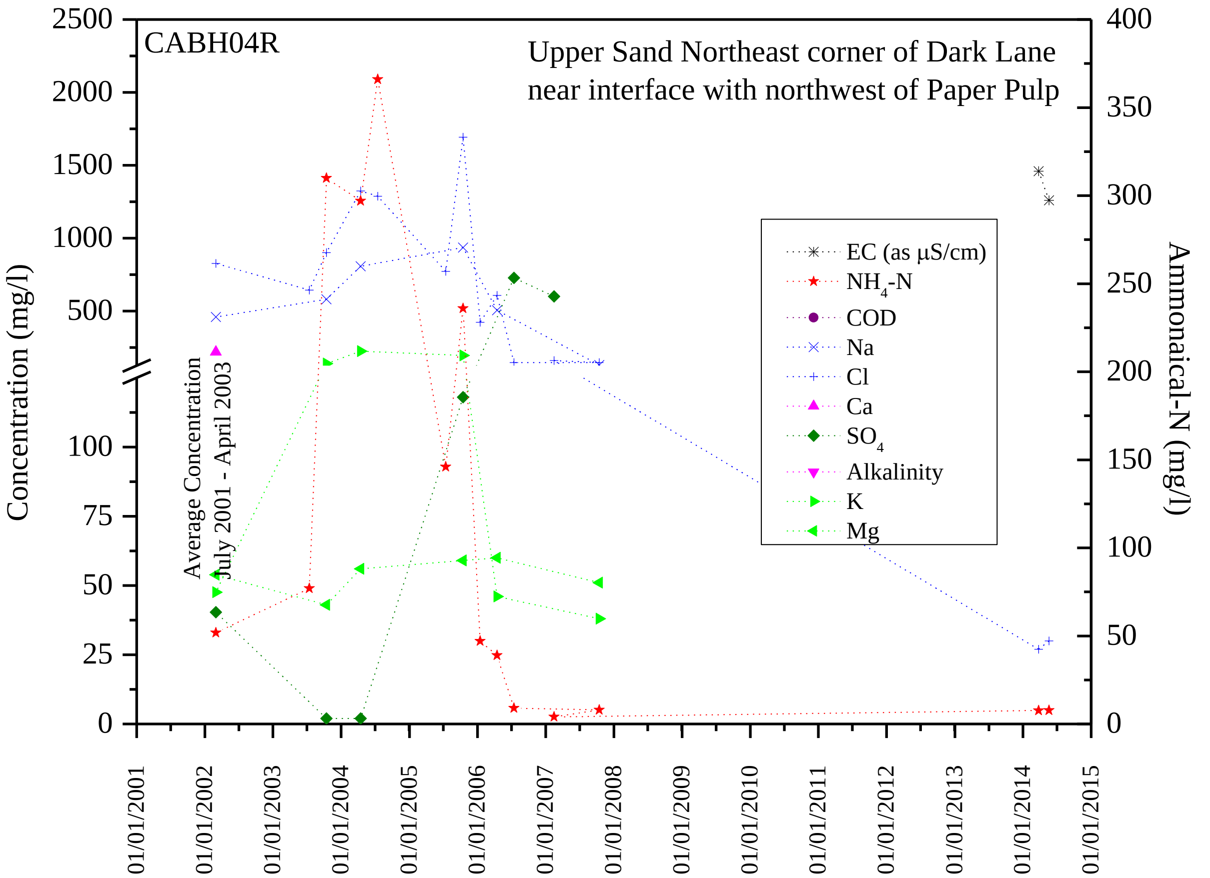


Figure B15 CABH06 Groundwater Quality

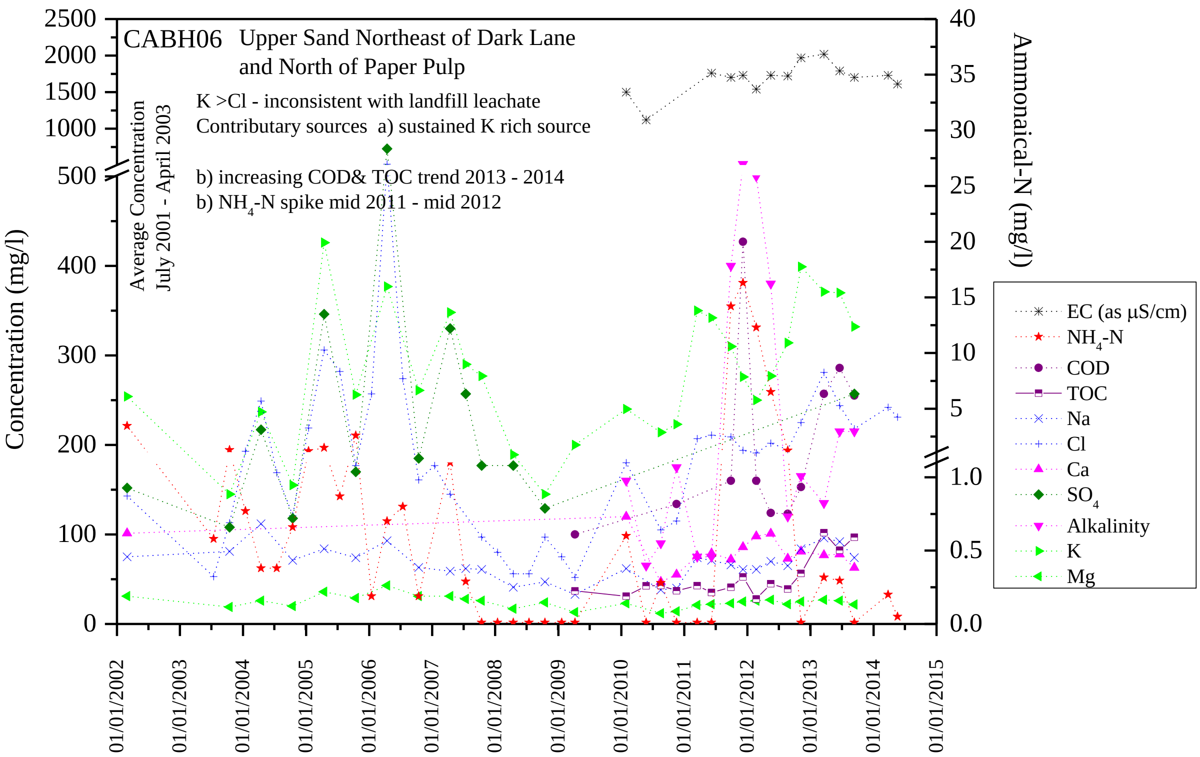


Figure B16 CABH07 Groundwater Quality

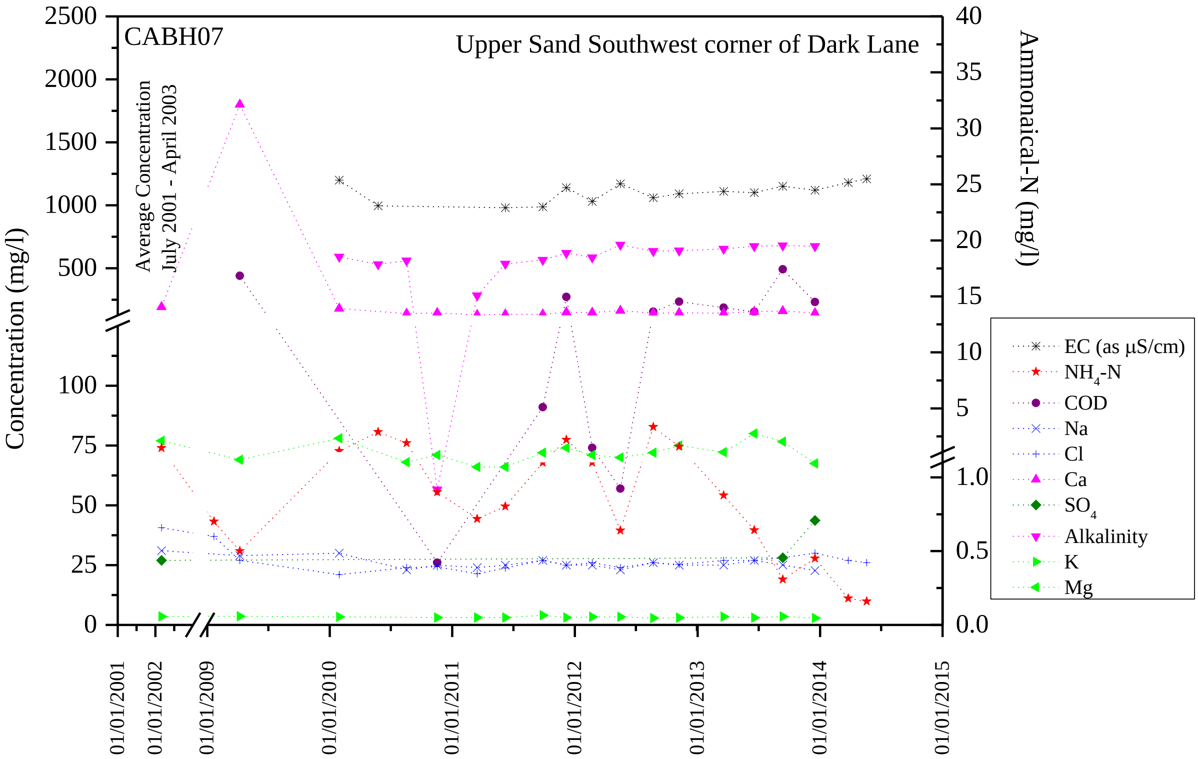


Figure B17 CABH08 Groundwater Quality

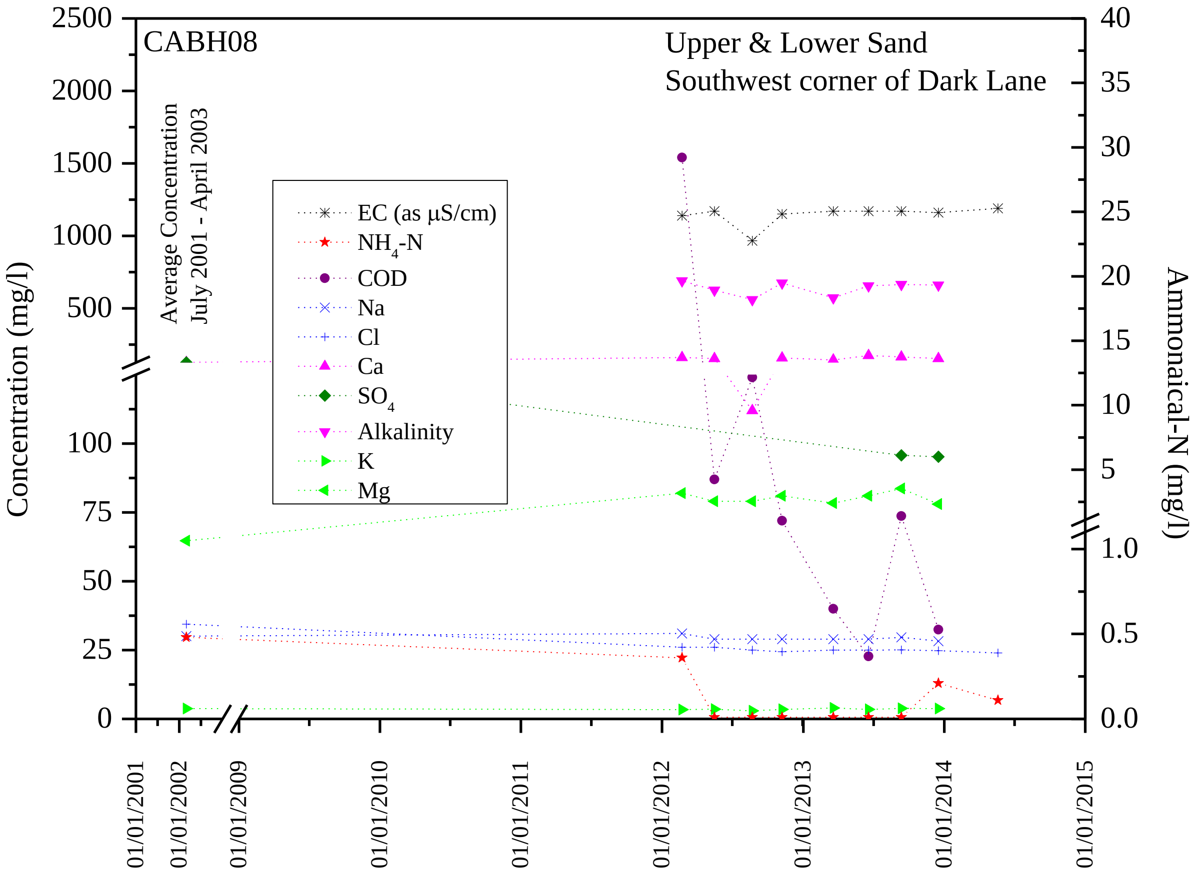


Table B1 Groundwater Salinity and Organic Indicator Components (2009 - 2014)

Location	pH Field		pH lab		EC Field		EC lab		NH_4-N (mg/l)		COD (mg/l)		TOC (mg/l)	
	Ave	Max	Ave	Max	Ave	Max	Ave	Max	Ave	Max	Ave	Max	Ave	Max
CABH06	7.3	8.0	7.4	8.3	1,234	1,720	1,687	2,020	4.8	16.3	198	427	51	102
CABH03	7.5	7.9	7.7	8.4	830	1,440	913	1,380	0.1	0.1	50	181	10	19
CABH02	7.5	7.8	7.7	8.4	981	1,200	999	1,170	0.9	9.3	23	93	4	6
CABH01	7.1	7.2	7.2	7.2	5,205	6,020	7,160	8,670	340.5	396.0				
CABH04	6.7	6.9	6.8	6.8	1,076	1,111	1,360	1,460	7.7	7.7				
BH005A	6.9	6.9	6.6	6.6	790	850	1,045	1,060	0.4	0.7				
BH006A	7.7	8.6	7.4	8.4	895	1,236	1,084	1,140	0.1	0.3	27	73	5	7
BH006B	7.6	8.3	7.7	8.5	1,238	1,370	1,300	1,720	0.4	0.6	26	47	4	6
BH002A	7.1	7.5	7.2	8.1	1,547	1,900	1,599	2,220	7.1	26.0	66	181	9	19
BH002B							696	696	9.2	9.2			<6	0
BH004A			7.7	7.7	800	800			<0.2	<0.2	9	9	4	4
BH004B			8.0	8.0	830	830			0.2	0.2				
CABH07	7.2	7.7	7.4	8.7	1,029	1,200	1,101	1,210	1.1	3.4	201	492	15	49
CABH08	7.0	7.0	7.5	8.3	900	900	1,143	1,190	0.2	0.4	249	1540	7	10
BH003	7.5	7.6	7.5	7.5	575	580	869	1,010	0.1	0.1	118	118	<6	0

Table B2 Leachate Matrix Ions (2009 - 2014)

Location	Ca (mg/l)		Mg (mg/l)		Na (mg/l)		K (mg/l)		Cl		Alkalinity	
	Ave	Max	Ave	Max	Ave	Max	Ave	Max	Ave	Max	Ave	Max
CABH06	467	5,900	22	27	66	96	298	399	188	281	219	515
CABH03	200	1,400	26	38	77	147	1	2	108	292	713	6380
CABH02	272	1,800	38	44	17	21	2	2	92	121	410	475
CABH01									902	1110		
CABH04									29	30		
BH005A									70	79		
BH006A	232	1,400	30	34	38	45	28	32	63	71	251	305
BH006B	248	1,600	33	54	80	118	3	4	229	417	226	286
BH002A	361	533	57	114	19	34	13	29	14	26	472	750
BH002B											130	130
BH004A	1,500	1,500	24	24	12	12	1	1	17	17		
BH004B									17	17		
CABH07	251	1,800	72	80	25	30	3	4	26	37	560	685
CABH08	152	174	80	84	29	31	4	4	25	26	638	690
BH003	143	143	64	64	26	26	2	2	20	26	615	615

Table B3 Leachate Minor Ions (2009 - 2014)

Location	SO_4 (mg/l)		TON (ng/l)		B (mg/l)		Fe (mg/l)		Mn (mg/l)		Zn (μg/l)	
	Ave	Max	Ave	Max	Ave	Max	Ave	Max	Ave	Max	Ave	Max
CABH06	257	257	37.9	77.0			<0.02	14.7	0.4	0.8	47	112
CABH03	384	384	0.2	0.3	0.06	0.08	<0.02	1.0	0.6	2.4	2	5
CABH02	40	40	0.1	0.1			<0.02	3.1	0.4	0.8	2	4
CABH04					0.22	0.25						
BH006A	90	92	51.7	59.6			<0.02	<0.02	0.01	0.03	7	15
BH006B	69	78	23.6	54.0			<0.02	<0.02	0.1	0.4	3	12
BH002A	531	603	<0.2	0.2			<0.02	29	1.3	3.1	15	60
BH004A							<0.02	<0.02	<0.1	<0.1		
CABH07	36	44	0.4	0.7			<0.02	15	0.2	0.7	2	5
CABH08	95	96		<0.1			<0.02	0.5	0.8	0.8	3	4
BH003	75	75	1.9	1.9			<0.02	<0.02	2.0	2.0	2	2

Table B4 Leachate Hazardous and Non-hazardous Metals (2009 - 2014)

Location	Cd (μg/l)		Hg (μg/l)		Pb (μg/l)		Cr (μg/l)		Cu (μg/l)		Ni (μg/l)		Mecoprop (μg/l)	
	Ave	Max	Ave	Max	Ave	Max	Ave	Max	Ave	Max	Ave	Max	Ave	Max
CABH06	<0.1	0.7	0.02	0.03	0.2	0.4	6	10	23	48	13	21		
CABH03	<0.1	0.1	<0.1	<0.1	0.1	0.2	13	26	1	2	2	3	0.06	0.08
CABH02	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	17	31	1	1	2	4		
CABH04													0.03	0.03
BH006A	<0.1	0.4	<0.1	<0.1	<0.1	<0.1	7	19	1	2	3	5		
BH006B	<0.1	0.2	<0.1	<0.1	<0.1	0.1	7	15	1	1	5	15		
BH002A	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	23	65	3	5	3	7		
BH002B	<0.1	0.2												
BH004A					<0.4	<0.4	<1	<1						
CABH07	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	18	49	<1	1	3	9		
CABH08	<0.1	<0.1	<0.1	<0.1	0.4	0.4	<1	<1	<1	<1	2	3		
BH003	<0.1	<0.1	<0.1	<0.1	0.1	0.1	<1	<1	1	1	2	2		

Appendix C

Surface Water Monitoring Data

Table C1 Surface Water Matrix Components

Location	pH		Conductivity		NH_4-N		COD		BOD		Cl		SO_4		Suspended solids	
	pH units		µS/cm		mg/l		mg/l		mg/l		mg/l		mg/l		mg/l	
	Ave	Max	Ave	Max	Ave	Max	Ave	Max	Ave	Max	Ave	Max	Ave	Max	Ave	Max
ASSWOS6	7.7	8.2	326	488	0.22	0.44			8.6	14.3	12	15			16	28
ASSW0S1	8.3	8.5	556	732	0.70	0.70	39	39	2.2	2.5	20	24				
ASSWOS5	7.4	7.9	414	545	0.04	0.09			2.1	2.1	13	18			13	16
ASSW0S2	8.1	8.5	778	1,060	0.53	1.80	50	67	4.6	7.8	65	84			26	50
ASSW0S4	7.8	8.0	867	1,260	0.04	0.07			2.1	2.1	56	84			17	33
ASSW0S3			1,840	1,840	10.30	10.30	67	67	<1.5	<1.5	16	16	603	603		

Table C2 Surface Water Hazardous and Non-hazardousSubstances

Location	B		Dieldrin		Chloroform		Toluene		Mecoprop	
	µg/l		ng/l		µg/l		µg/l		µg/l	
	Ave	Max	Ave	Max	Ave	Max	Ave	Max	Ave	Max
ASSW0S2	260	280	<10	<10	<1	<1	<1	<1	0.11	0.16
ASSW0S4	92	190	<10	<10	<1	<1	<1	<1	0.05	0.05

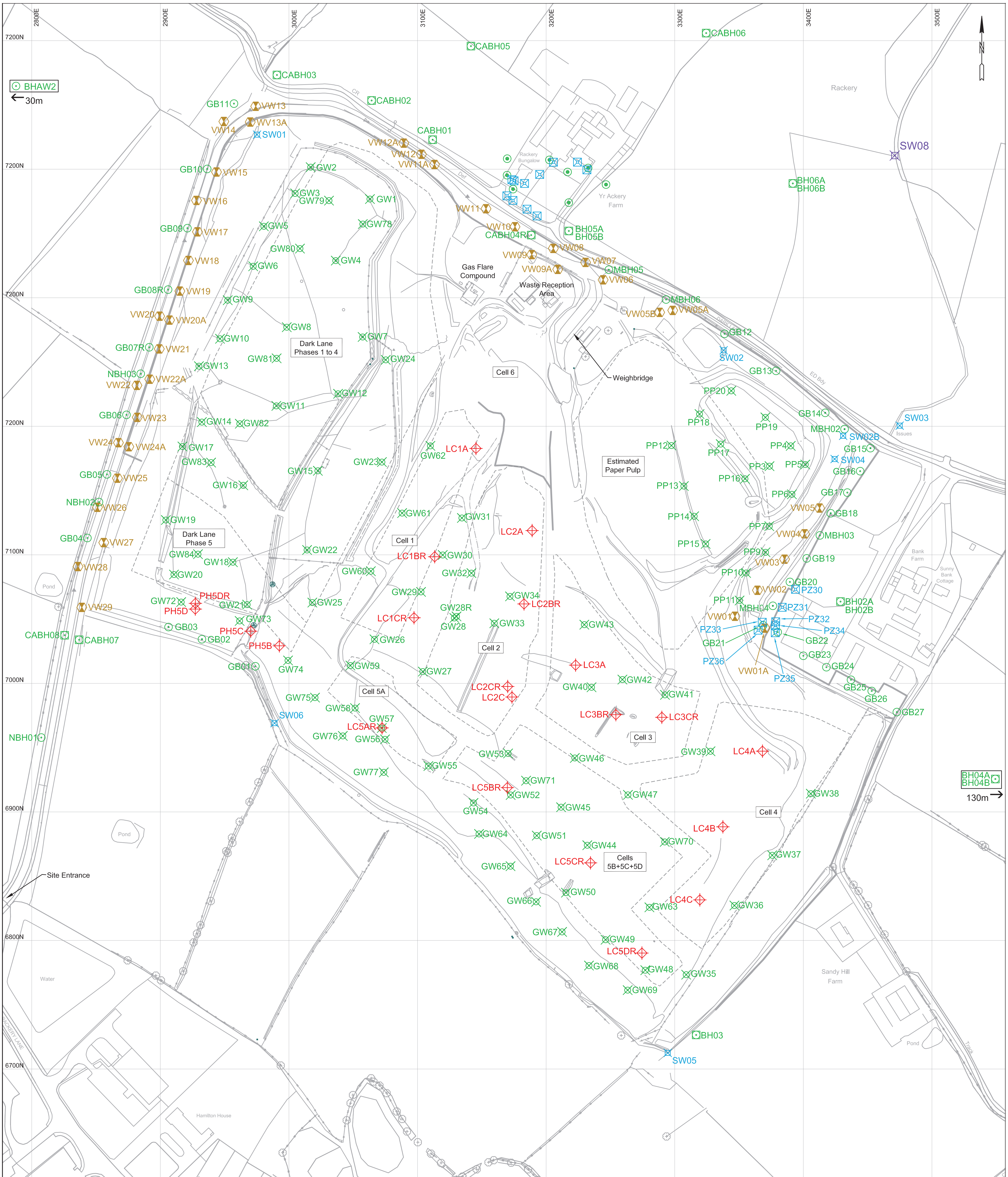
Appendix D

Groundwater Monitoring Infrastructure Review

Sample Point	Gradient	Datum level (mAOD)	Dip to Water (m)	Dip to Base (m)	Water Level (mAOD)	Base Elevation (mAOD)	Strata	Response Zone (mbgl)[3]	Fit for Purpose (y/n)[2]	Comments	Actions
ASBH002A	Cross	71.84	3.22	4.89	68.62	66.95	Upper glacial sand	1.30 to 10.00	Y	Sufficient response zone and recharge	n/a
ASBH002B	Cross	71.77	14.83	14.87	56.94	56.9	Lower glacial sand	15.50 to 27.00	N	Silted above response zone	Remove from schedule
ASBH003	Up	85.66	17.22	18.65	68.44	67.01	Upper glacial sand	4.90 to 22.30	Y	Sufficient response zone and recharge	n/a
ASBH004A	Cross	78.43					Upper glacial sand			Lost	Remove from schedule
ASBH004B	Cross	78.43					Lower glacial sand			Lost	Remove from schedule
ASBH005A	Down	78.52	7.62	8.6	70.9	69.92	Upper glacial sand	1.30 to 10.00	Y	Sufficient response zone and recharge	n/a
ASBH005B	Down	78.52	12.1	12.42	66.42	66.1	Lower glacial sand	12.30 to 21.00	N	Consistently dry and silted response zone	Remove from schedule
ASBH006A	Down	65.94	0.53	4.58	65.41	61.36	Upper glacial sand	5.80 to 8.70	Y	Response zone appears to covered but recharge allows samples to be obtained.	Attempt to de-silt
ASBH006B	Down	65.94	7.1	12.6	58.84	53.34	Lower glacial sand	11.20 to 14.10	Y		n/a
ASCABH01	Down	80.08	9.5	10.15	70.58	69.93	Upper glacial sand	0[1] to 9.50	Y		n/a
ASCABH02	Down	80.13	13.47	15.43	66.66	64.7	Lower glacial sand	10.50 to 17.50	Y		n/a
ASCABH03	Down	76.14	7.27	10.3	68.87	65.84	Upper glacial sand	0[1] to 10.40	Y		n/a
ASCABH04	Down	75.13	6.21	7.1	68.92	68.03	Upper glacial sand	Not known	Y	Similar depth to BH05A	n/a
ASCABH05	Down	77.39	6.81	6.82	70.58	70.57	Upper glacial sand	0[1] to 8.00	N	Consistently dry	Remove from schedule
ASCABH06	Down	70.54	2.55	5.27	67.99	65.27	Upper glacial sand	0[1] to 6.90	Y		n/a
ASCABH07	Up	93.24	22.81	24.48	70.43	68.76	Upper glacial sand	Not known	Y	Assume similar construct to CABBH08	n/a
ASCABH08	Up	93.08	22.91	28.55	70.17	64.53	Upper glacial sand	20.20 to 29.20	Y		n/a

1. Start of response zone not known
2. Based on visible response zone and suffient recharge to obtain representative sample
3. Response zones taken from the 2003 ESID report (ref: SH/DL/GD/2413/02, MJCA)

DRAWINGS



LEGEND

- Perimeter Gas Monitoring Borehole
- Landfill Gas Surface Monitoring Point
- Combined Gas/ Groundwater Monitoring Point
- Gas Flare Stack
- Landfill Gas Extraction Point
- Landfill Gas Extraction/ Leachate Monitoring Point
- Condensate Unit (Knock-out Pot)
- Gas Manifold
- Groundwater Monitoring Borehole
- Groundwater Pumping Point
- Surface Water Monitoring Point
- Leachate Collection Point
- Leachate Monitoring Point
- Leachate Recirculation Point
- Leachate Collection Sump
- Leachate Discharge Sampling Point
- Leachate Detection Point
- Underdrainage Monitoring Point
- Settlement Monitoring Point
- Drain/ Dewatering Tank
- Piezometer Point
- Gas Probe
- Vent Wells
- Valve
- As-built Cell Footprint
- Proposed Wells

Files Used:
Site Survey: 461A075
Cell Footprints: ro2004001

REVISIONS

No	Description	By	Chk'd	Date

Project:

ROSSETT
LANDFILL SITE

Title:

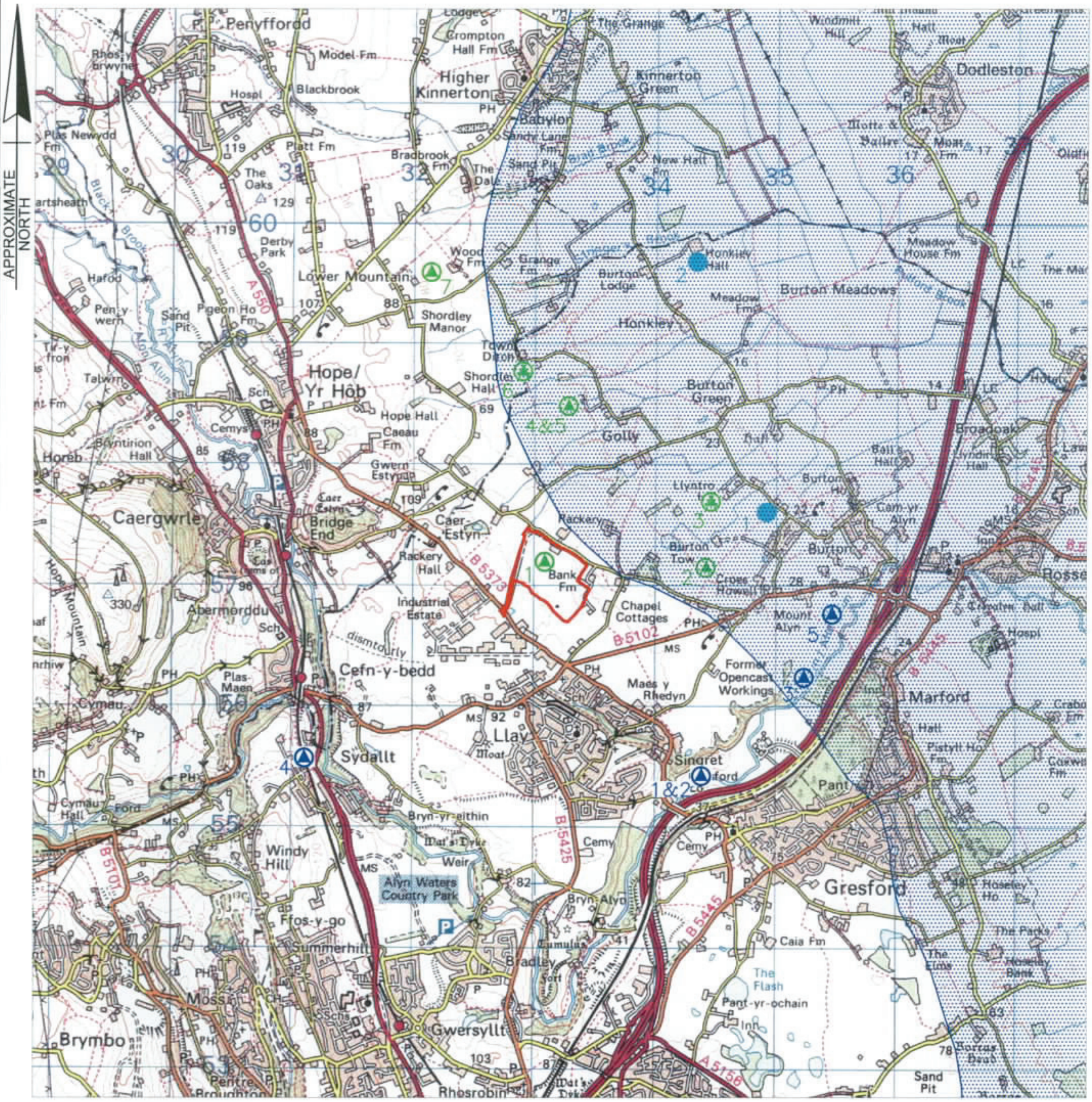
Environmental Monitoring Plan
Inc Proposed Borehole

Drawn By	LH	Date	21.08.14
Chk'd By	RB	Date	21.08.14
Scale 1:	2000	Sheet Size	A2

FCC Environment
FCC Environment (UK Limited)
3 Sidings Court, White Rose Way, Doncaster. DN4 5NU

FCC Environment UK Limited
3 Sidings Court
White Rose Way
Doncaster
DN4 5NU

Drawing No 461M082 | Plan 4A



Key / Notes

(red outline)	Application area
(green triangle)	Approximate location of licensed groundwater abstraction
(blue triangle)	Approximate location of licensed surface water abstractions
(blue dot)	Approximate location of a private water supply
(stippled blue)	Catchment area (Source Protection Zone III) for a public water supply

Site	ROSSETT LANDFILL COMPLEX
Client	Shanks
Title	Plan showing the approximate locations of licensed surface water and groundwater abstractions, private water supplies and source protection zones
Figure	Figure 8
Scale	1:50,000
Drawing Ref	SH/DL/10-03/11113
Drawn by	LR
Approved by	
Checked by	
Revisions	

DRAFT

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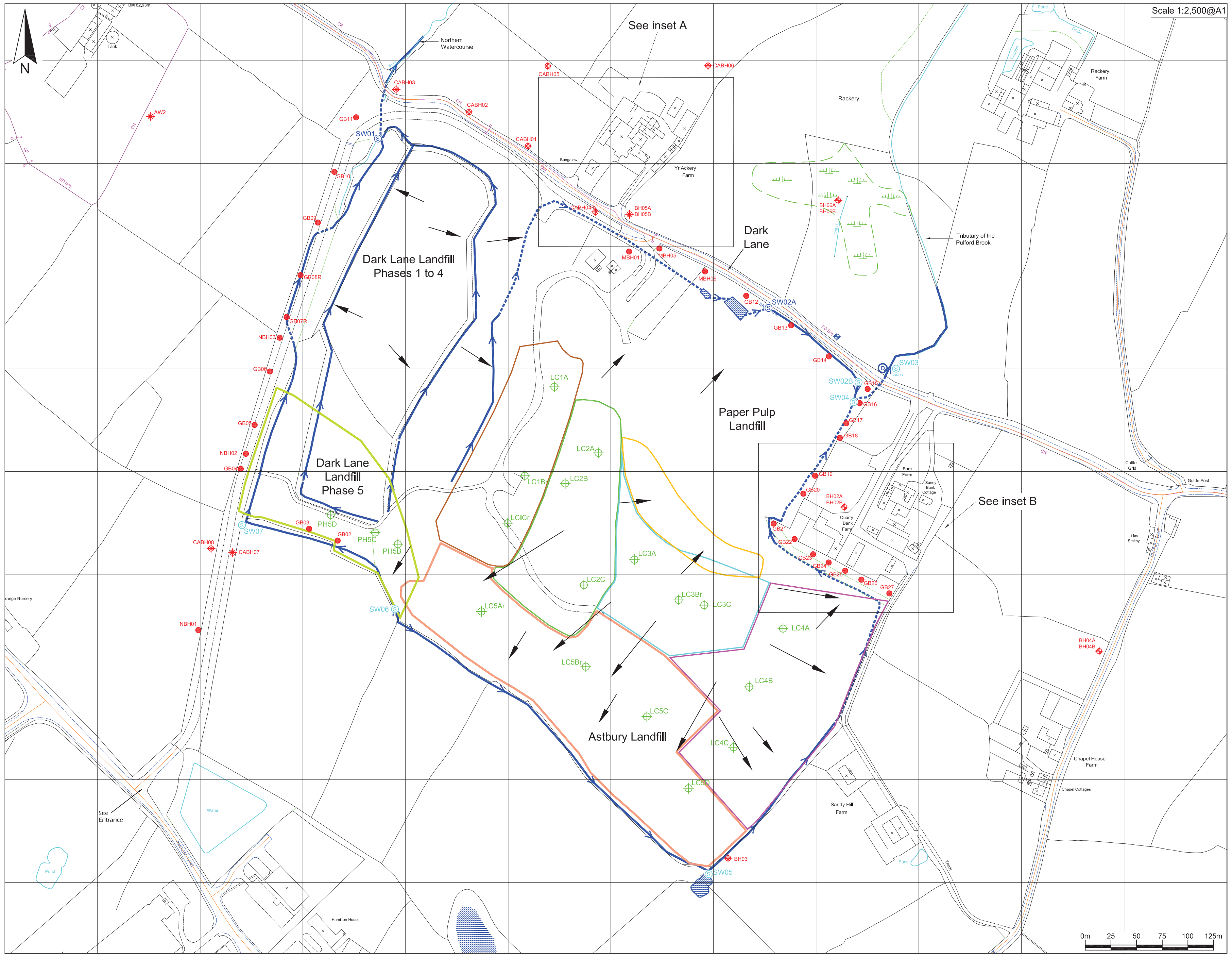

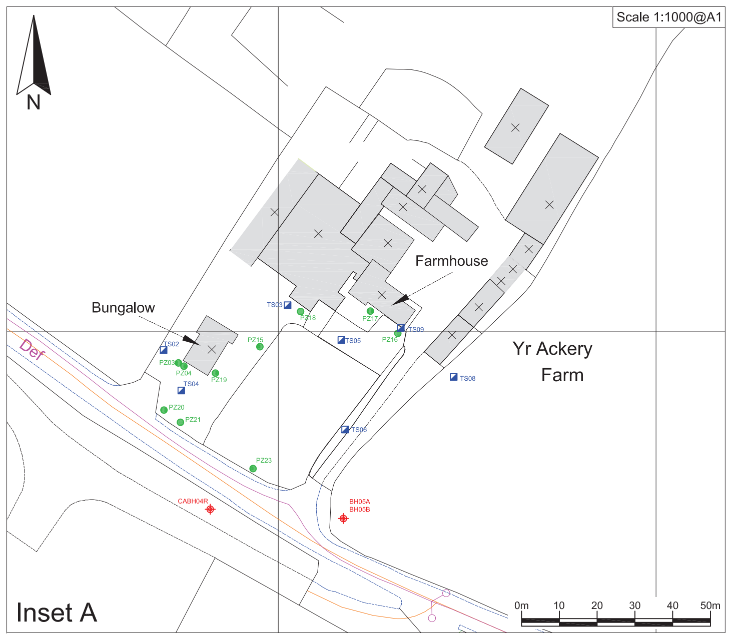

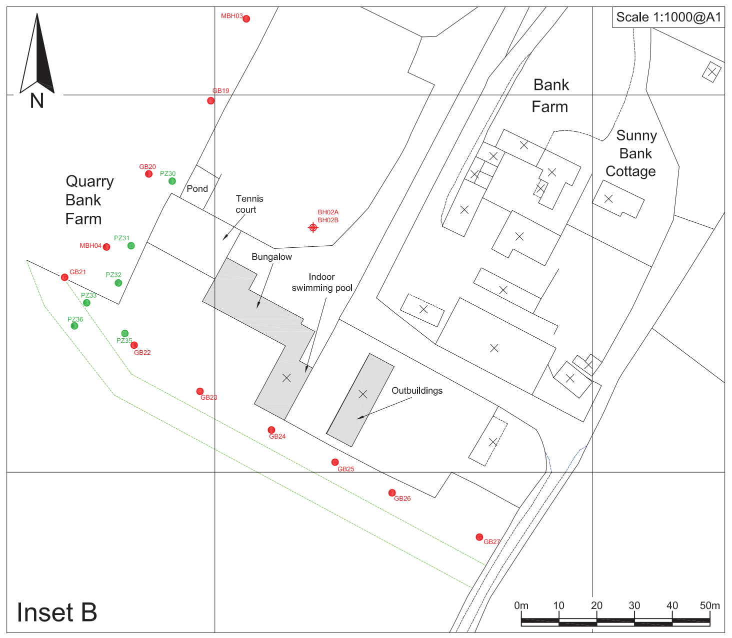

Key/Notes

- Approximate boundary of Cell 1
- Approximate boundary of Cell 2
- Approximate boundary of Cell 3
- Approximate boundary of Cell 4
- Approximate boundary of Cell 5
- Approximate boundary of the Cell 3 wedge
- Approximate boundary of Phase 5
- Approximate location of a gas monitoring borehole
- Approximate location of a shallow ground subsurface gas monitoring piezometer
- TS02 Approximate location of a gas monitoring borehole installed in 2002 and rehabilitated by Shanks in 2003
- Approximate location of a combined gas and groundwater monitoring borehole
- Approximate location of a groundwater monitoring borehole
- Approximate location of a proposed groundwater monitoring borehole drilled in the upper sand unit
- LC2B Approximate location of a leachate monitoring and abstraction well
- SW02 Approximate location of a surface water monitoring point
- SW03 Approximate location of a proposed surface water monitoring point
- Consented discharge location (Consent Reference CM00960/01)
- Indicative direction of surface water run off
- Marshy area
- Approximate route of an existing carrier drain
- Approximate route of an existing open ditch
- Approximate location of an exisiting lagoon

Note:
The monitoring points are based generally on drawing reference 461MO17E dated 13 July 2006.
The surface water drainage is based generally on ENCIA drawing reference A57052/1/006 dated 7 July 2006.

Rev	Amendments	Date
B	Amendments to borehole numbering	15/05/09

Site: ROSSETT LANDFILL COMPLEX

Client: WRG Waste Services Limited

Title: Plan showing the locations of the environmental monitoring points and the existing surface water drainage at the site

DRAFT

Figure 9 — Scale: As shown

Drawing Ref: WRG/DL/11-04/11952revB — Issue Date: 08/09/2009

Drawn by: KR — Approved by: JHP — Checked by:

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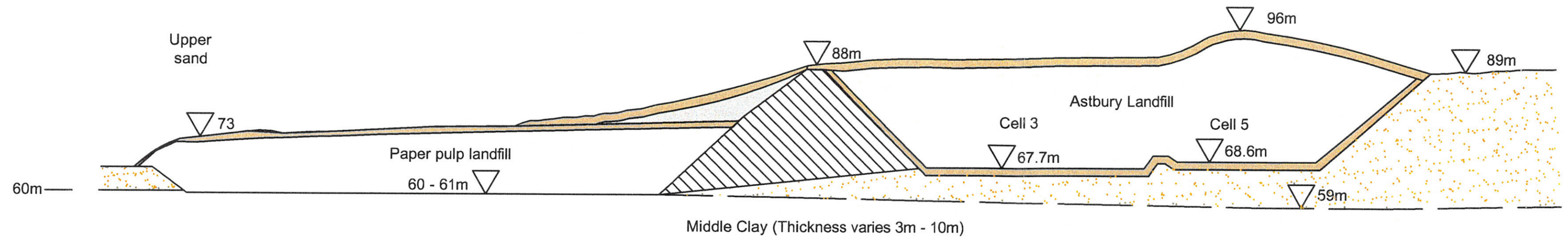
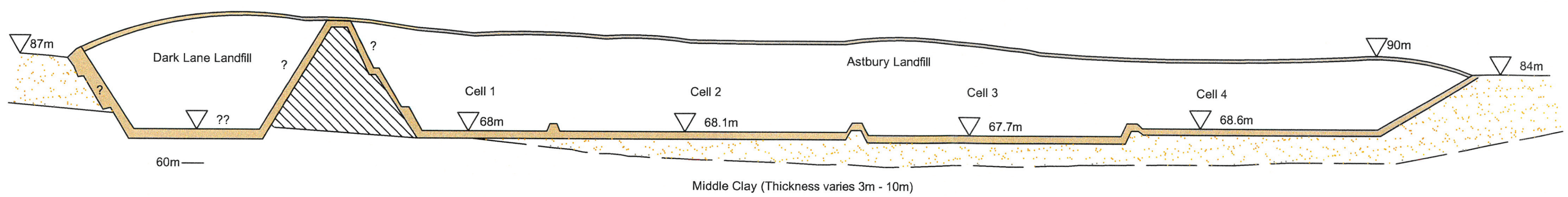
ROSSETT LANDFILL COMPLEX
SCHEMATIC NE - SW SECTION



ROSSETT LANDFILL COMPLEX
SCHEMATIC NW - SE SECTION



Key / Notes

- Upper sand
- Made ground comprising quarry spoil and overburden material
- Landfill liner and capping system
- Inert waste
- ▽ Approximate level (mAOD)
- ? Uncertain profile or level

Note: The detailed specification of the liner and capping systems used at the site is shown on Figure 2 of the Conceptual Model Report

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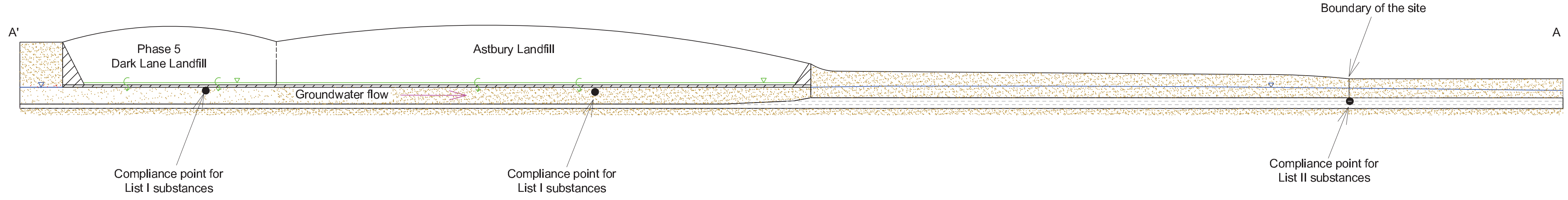
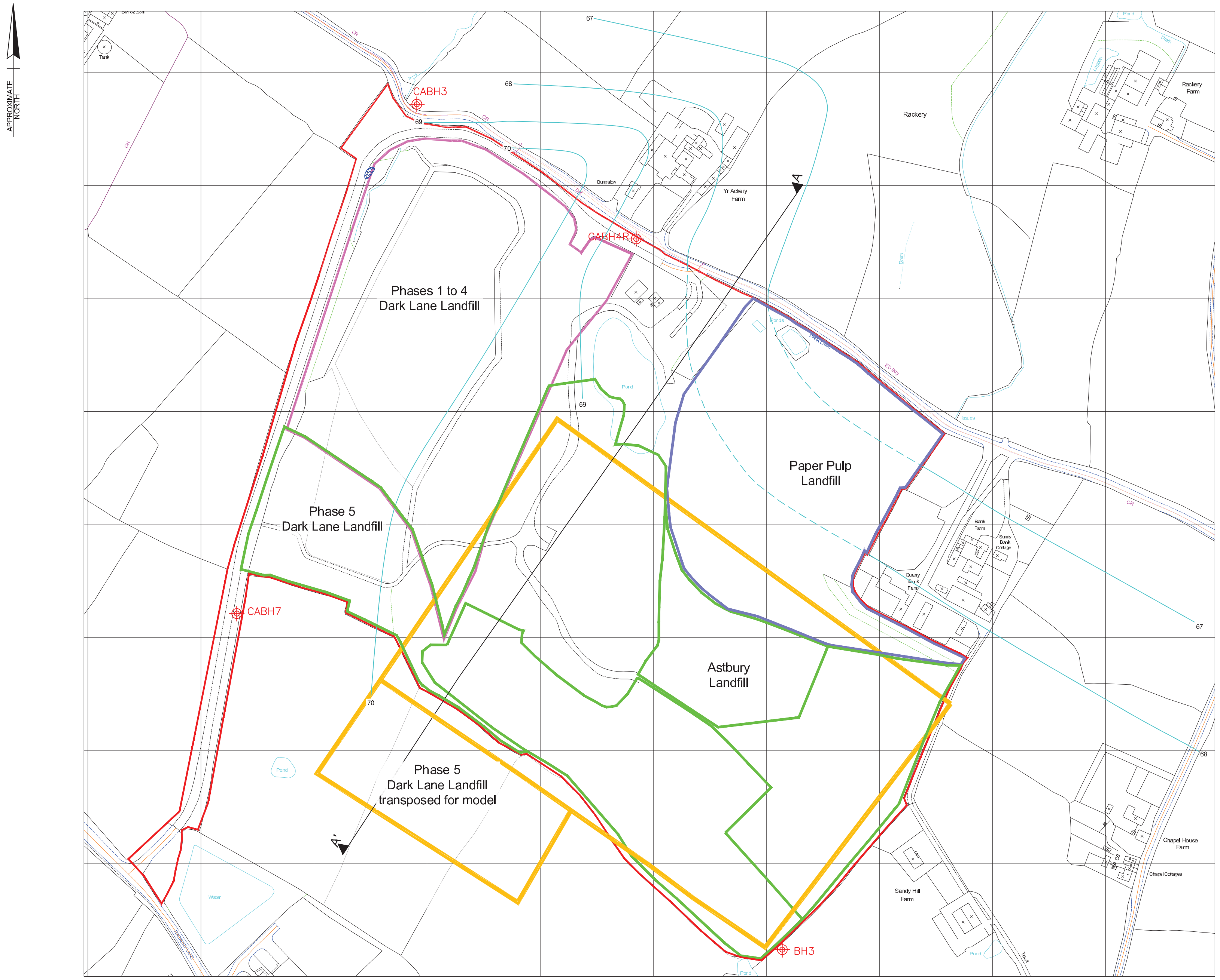
Site	ROSSETT LANDFILL COMPLEX
Client	Shanks
Title	Schematic sections of Rossett Landfill Complex
Figure	Figure 10
Scale	Not to scale
Drawing Ref	SH/DL/10-03/11161
Drawn by	RC
Approved by	
Checked by	
Revisions	

DRAFT



Vertical Scale 1:1250



Key / Notes

- The site that is the subject of Waste Management Licence reference NOW-510-L
- Astbury Landfill and Phase 5 of the Dark Lane Landfill
- Phases 1 to 4 of the Dark Lane Landfill
- Paper pulp landfill
- Sand
- Clay
- Basal liner and perimeter barriers
- Compliance point
- Leachate level
- Leakage of leachate
- Groundwater level in the upper sand
- Line of section A - A' along modelled groundwater flow direction
- Modelled geometry of landfill
- 67 Contours of groundwater levels in the upper sand in September 2003 (mAOD)

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Site and project: ROSSETT LANDFILL COMPLEX PPC APPLICATION

Title: Plan showing the conceptual hydrogeological model of the Rossett Landfill Complex

Drawing Reference		Scale:
SH/DL/11-03/11215	Figure 1	1:2,500

Date:	Drawn By:	Checked By:	Approved By:
1/10/2003	LR	JT	HN

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