Pen-y-Bont Landfill
Chirk, Wrexham

Hydrogeological Risk Assessment Review

February 2016
Version 3

Contents

Tables

Page

Figures

Drawings

1.0 Introduction

The landfill is located within a former mineral extraction quarry (Pen-y-bont Quarry) situated within a meander of the easterly flowing River Dee. The site is bounded to the north, east and south by the river and is bounded to the west by the B5605 road. Residential properties are located within 250m to the west and south-west of the landfill area. The installation is located within 60m of the River Dee, which is a Special Area of Conservation and a site of Special Scientific Interest (SSSI). It is also within 2km of Nant y Belan and Prynela Woods SSSI.

The site was as a partially restored quarry void that was historically excavated into reddish brown mudstone/marl strata (Ruabon Marl) of the Upper Carboniferous Coal Measures. The Ruabon Marl has historically been exploited for use in brick and tile manufacturing.

Planning permission for landfill with Controlled Wastes was granted in August 1993 and was first licensed in December 1994. An application was made for a PPC permit in October 2004 and this was supported by a Hydrogeological Risk Assessment (HRA) written by Encia Consulting (reference 1). The PPC permit, number GP3830BG, was issued on 9th November 2005. The permit contains a requirement for periodic reviews of the HRA and the first such review was written in March 2009 by Golder Associates (reference 2). The second review is due to be submitted between 9th February and 9th May 2015, and this document is submitted to fulfil this obligation.

The permit was re-issued on 28th June 2007 (variation PP3032LN) with two improvement conditions (IC). IC1 required groundwater control and trigger levels to be submitted for borehole T10. A further variation to the permit (V004) was issued on 24 February 2011 and this recorded that this IC has been completed. The second IC from the 2007 permit is reproduced below.

2	The Operator shall submit to the Agency for approval, proposed timescales for reducing the leachate head to 1m as required by Table S4.1. The proposed timescales shall be implemented by the operator from the date of approval in writing by the Agency	28th August 2008

The 2011 variation records that this had not been completed. This issue is ongoing and is included in the leachate management plan. This document will assess progress.

This document was first updated and re-issued as version 3 to reflect amendments made following comments made in a letter from NRW on 29 May 2015. This document (version 3) has included a few minor changes to address comments made in a letter from NRW on 19 October 2015.

2.0 Review of Conceptual Hydrogeological Site Model

The hydrogeological cross-section is shown in Appendix 1.

The site is entirely surrounded by the Ruabon Marl apart from an area of made ground to the north. To the west of the site the Marl is overlain by an area of superficial Alluvium, The Ruabon Marl overlies the Middle Coal Measures which are classed as a Secondary A aquifer from which local abstractions may be possible but yields are likely to vary both spatially and temporally. The site has been operated as a fully contained landfill site since its beginning, with the basal liner comprising 1m of engineered clay (permeability $1x10^{-9}msec^{-1}$ or less) and a side liner that incorporates a 2mm HDPE flexible membrane liner with the mineral liner.

The base of the landfill is below the local water level in the Marl and also below the elevation of the base of the River Dee, as shown in Appendix 1 (Drawing ESID 12 from 2004 HRA). These elevations can be summarised as follows:

- Base of the landfill: 39.5 mAOD (Cell 3) – 40.5mAOD (Cells 1 and 2)
- Water level in the Marl: 46-55mAOD
- Base of the River Dee: ~43 mAOD
- Water Level in the River Dee: ~45 mAOD

The HRA was written on a source – pathway – target basis. The source is the leachate within the waste and the pathway is the liner. The targets are shallow groundwater in the Alluvium, groundwater in the Marl and surface water in the River Dee. For hazardous (formerly List I substances), the compliance point is the outside of the liner. For non-hazardous substances (formerly List II) the nearest significant compliance point is the River Dee.

The pathways and the targets remain the same as originally modified and so the HRA will remain valid as long as the source term is also the same or less. This risk assessment will assess whether or not this is the case by comparing recent data for the indicative substances with those data sets used in the original HRA (reference 1) and the first review (reference 2).

3.0 Hydrogeological Risk Assessment

3.1 Numerical Modelling

3.1.1 Justification for Modelling Approach and Software

No new modelling has been carried out. Since the pathway and targets are the same, the modelling remains valid as long as the source term parameters used in the model are not exceeded. Primarily this will be the parameters used in the 2009 review when the source term was updated.

3.1.2 Model parameterisation

The source term parameters are reviewed in this section. In Section 3.1 (and later in Section 3.2)

- n refers to the number of samples
- data sets that contain some data that were below the LOD are represented by the use of italics
- Data taken since the last review (recent data) refers to that data collected since January 2009.

Leachate quality

Time series graphs of leachate quality are presented in Appendix 2.

Hazardous (formerly List 1) substances

The 2004 risk assessment and the first review chose to model mecoprop, naphthalene and cadmium as hazardous substances.

Mecoprop

Table 1 summarises the recent leachate mecoprop concentrations.

	LC03	LC01B	LC04A	LC04B	LC05A	LC05B	LM04B	LM05B	LM06A	LM06B	LM07B
n	11	7	5	6	7	4	9	11	5	6	11
min	*0.2*	*0.2*	10	*0.2*	*0.2*	*5*	*0.2*	*0.2*	*1*	*0.5*	*0.5*
mean	*23.24*	*26.44*	*73.38*	*24.75*	*51.10*	*41.85*	*43.81*	*36.10*	*38.34*	*28.17*	*41.19*
max	45.6	74.2	116	66.1	99.3	71.6	120	89.7	83.8	83.8	94.5

Table 1: Recent leachate mecoprop concentrations (µg/l)

Mecoprop results are compared to results from previous reviews in Table 2.

	2004 Review	2009 review	This review
min	67.5	5.29	*0.2*
mean	80.2	66.95	*67.64*
max	92.1	104	120

Table 2: Comparison of leachate mecoprop data between reviews (µg/l)

The mean concentration is similar to that from the previous review but the maximum value has risen slightly. The frequency distribution of mecoprop concentrations is shown in Figure 1.

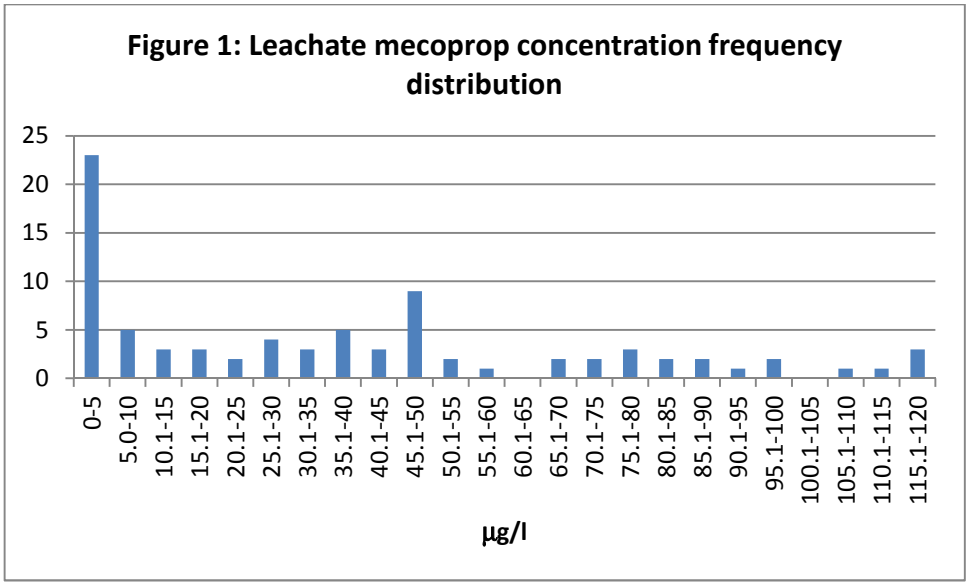


Figure 1 shows the majority of results are low with a scatter of higher results. The time series plot presented in Appendix 2 does not indicate a long term upward trend. The risk from mecoprop is not believed to have risen since the last review.

Naphthalene

Recent naphthalene results are summarised in Table 3 and compared to previous values in Table 4.

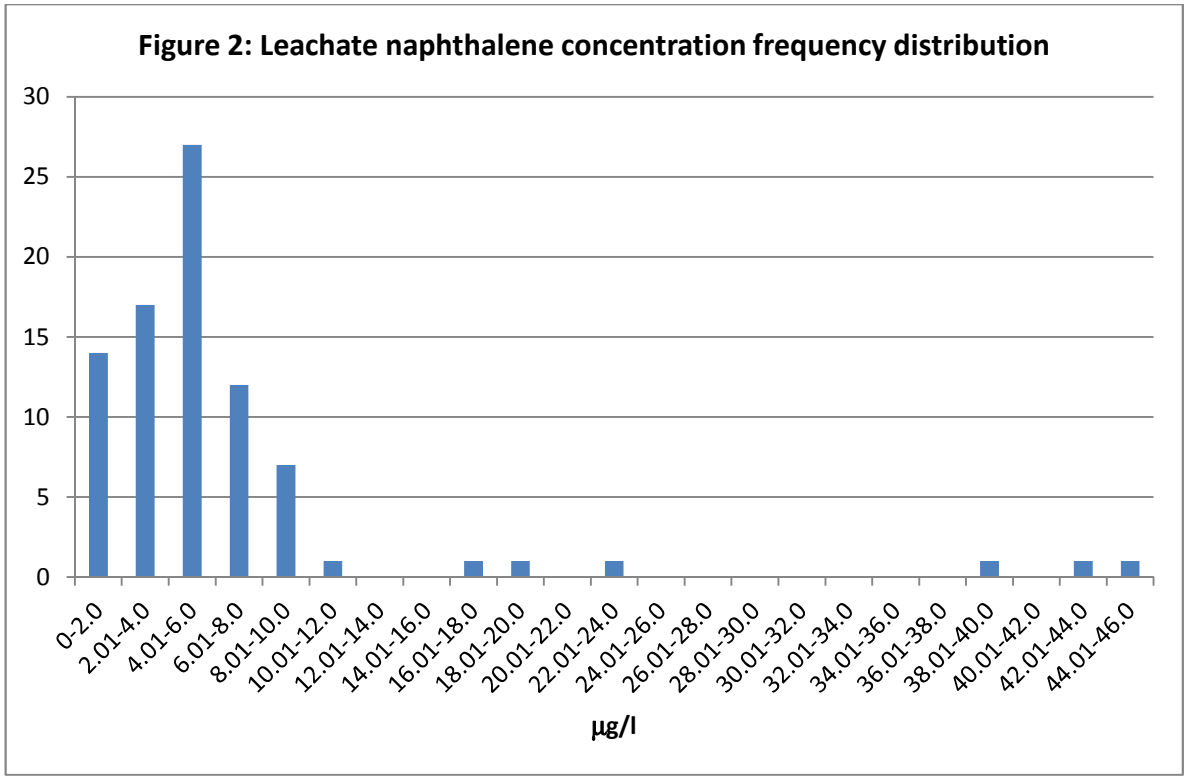
	LC03	*LC01A*	LC01B	*LC04A*	*LC05A*	*LM04B*	*LM05B*	*LM06A*	LM06B	*LM07B*	LT01
n	10	*4*	7	*9*	*10*	*8*	*10*	*3*	6	*10*	9
min	1.39	*2*	1.08	*2*	*2*	*2.03*	*2*	*2*	1.86	*1.95*	2.22
mean	20.10	*4.30*	3.25	*5.01*	*5.75*	*5.55*	*5.89*	*4.97*	5.07	*4.86*	4.07
max	45.3	*7.3*	6	*7*	*10*	*8.23*	*11.9*	*10*	8.31	*10*	5.4

Table 3: Recent leachate naphthalene concentrations (µg/l)

	2004 HRA	2009 review	This review
min	13.6	3.5	0.47
mean		22.07	*6.73*
max		30	45.3

Table 4: Comparison of naphthalene concentrations between reviews (µg/l)

N.b. only one value was quoted in the 2004 HRA . The recent naphthalene results are skewed by containing nine results with a very high LOD (<80.0µg/l) which have been excluded from the calculations. The naphthalene concentration frequency distribution is shown in Figure 2, below.



Only a handful of positive results were recorded that were greater than 10µ/gl. The time series plot presented in Appendix 2 does not indicate a long term upward trend. The risk from naphthalene has not increased.

Cadmium

Cadmium concentrations are summarised in Table 5 and compared to previous reviews in Table 6.

	LC03	LC01A	LC01B	LC04A	LC04B	LC05A	LC05B	LM04A
n	25	13	10	15	8	15	8	3
min	0.0003	0.00005	0.0018	0.0002	0.0005	0.00005	0.0005	0.0007
mean	0.0012	0.0031	0.0053	0.0034	0.0015	0.0036	0.0015	0.0025
max	0.0041	0.016	0.02	0.018	0.0028	0.019	0.003	0.0042
	LM04B	LM05B	LC06	LM06A	LM06B	LM07A	LM07B	LT01
n	20	25	1	13	12	1	22	23
min	0.00005	0.00005	0.0015	0.0002	0.0005	0.0028	0.00012	0.0002
mean	0.0027	0.0026	0.0015	0.0023	0.0014	0.0028	0.0014	0.0020
max	0.018	0.016	0.0015	0.0085	0.0034	0.0028	0.0074	0.011

Table 5: Recent leachate cadmium concentrations (mg/l)

	2004 HRA	2009 review	This review
min	0.0006	0.0005	0.00005
mean	0.0024	0.0024	*0.0024*
max	0.0006	0.007	0.02

Table 6: Comparison of cadmium concentrations between reviews (mg/l)

The maximum value has risen since the 2009 review but this is due to outlying, uncharacteristic results. The frequency distribution of the cadmium results is shown in Figure 3.

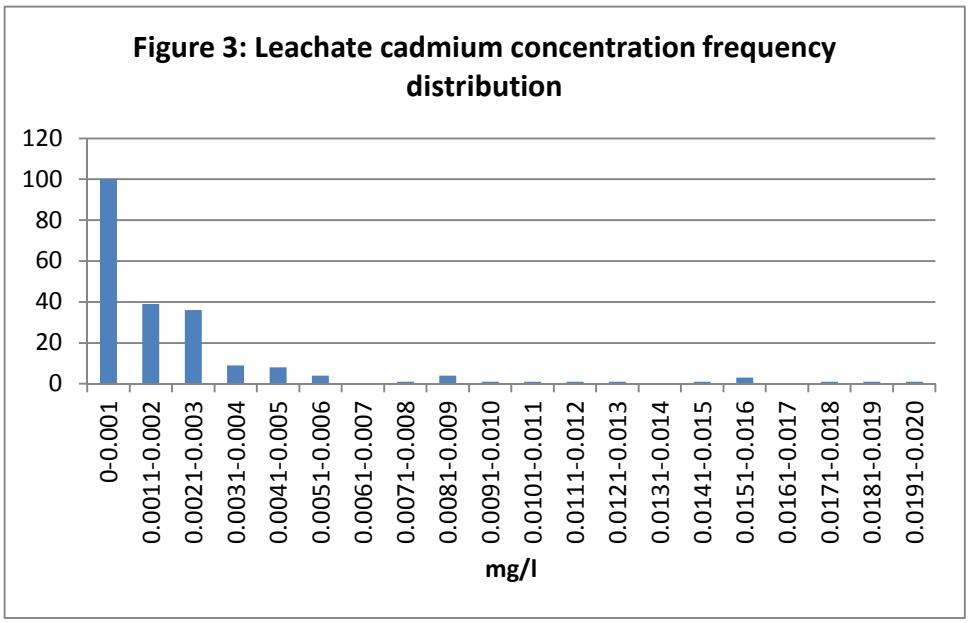


Figure 3 shows a distribution extending to approximately 0.006mg/l with a series of outlying results. The time series plot presented in Appendix 2 shows a number of high cadmium results were recorded during a short time period towards the end of 2010. FCC believes that this is more likely to have been a laboratory issue rather than a change within the site. There is no long-term upward trend. The great majority of results are as previously described.

Non-hazardous (formerly List 2) pollutants

The non-hazardous determinands modelled were ammoniacal-N, chloride, nickel and phenol.

Ammoniacal-nitrogen

Ammoniacal-N concentrations are compared to previous data sets in Table 7 and are compared to previous reviews in Table 8.

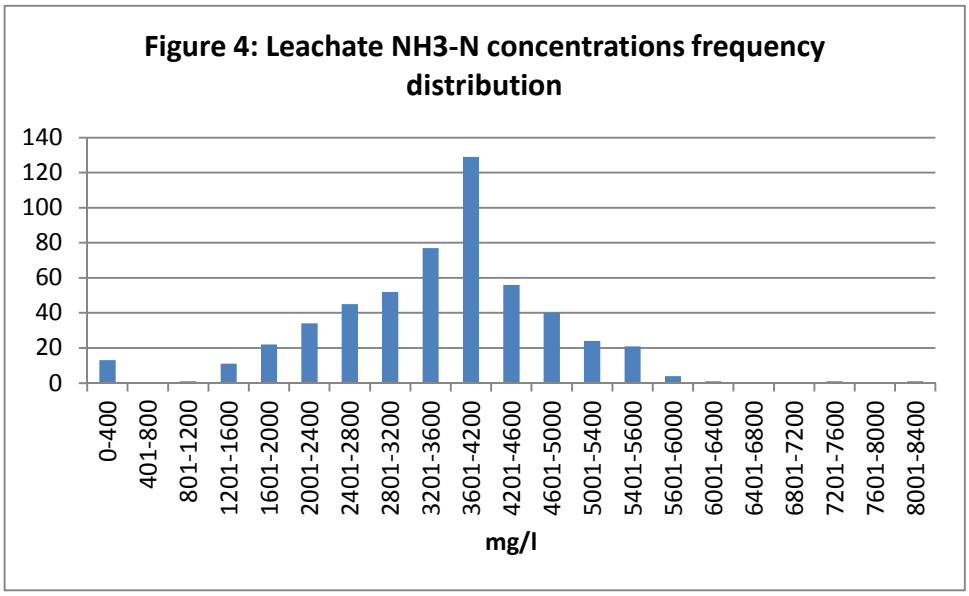
	LC03	LC01A	LC01B	LC04A	LC04B	LC05A	LC05B	LM04A	LM04B
n	59	39	29	43	24	41	24	5	44
min	43	68	1880	95	1610	42	341	2500	99
mean	2102	3048	2887	4168	3942	4120	3519	3584	4335
max	5470	5430	4690	5710	5440	7600	5440	4190	6370
	LM05A	LM05B	LC06	LM06A	LM06B	LM07A	LM07B	LT01	
n	2	53	3	34	24	2	51	56	
min	4200	53	3980	86	2380	4080	2200	190	
mean	4360	3735	4660	3900	3700	4100	3679	3524	
max	4520	5310	5300	5430	5480	4120	8200	5430	

Table 7 Recent leachate ammoniacal-N concentrations (mg/l)

	2004 HRA	2009 review	This review
min	5	1090	42
mean	1153	3185	3597
max	4430	7700	8200

Table 8: Comparison of the ammoniacal-N data between reviews (mg/l)

Mean and maximum values have risen slightly and are marginally higher than in the first review data set. This data set includes outliers. The frequency distribution of ammoniacal-N results is shown in Figure 4.



The ammoniacal-N data has been assessed for normality using the D'Agostino test and Figure 4 shows a normal distribution (y=1.55) extending between 1040 and 6370mg/l with a number of outlying values. Excluding the outlying values, the distribution sits within the maximum from the first review.

Chloride

Chloride results are summarised in Table 9 and are compared to previous data sets in Table 10.

	LC03	LC01A	LC01B	LC04A	LC4B	LC05A	LC05B	LM04A	LM04B
n	59	39	28	43	11	41	11	5	44
min	*3*	61	1600	53	1560	216	1870	2260	56
mean	1329	2784	2402	2447	2551	2397	2552	2510	2517
max	17000	4300	3260	3260	3400	3200	3430	3100	3360
	LM05A	LM05B	LC06	LM06A	LM06B	LM07A	LM07B	LT01	
n	2	53	3	34	11	8	45	55	
min	1800	1240	2390	51	1620	2010	1100	190	
mean	2250	2401	2500	2091	2216	2408	1990	3588	
max	2700	3460	2630	2770	3450	3100	3240	5430	

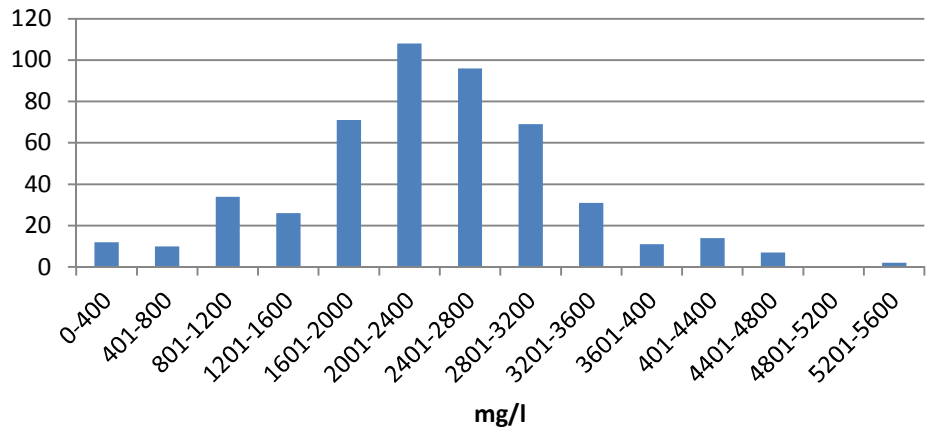
Table 9: Recent leachate chloride concentrations (mg/l)

	2004 HRA	2009 review	This review
min	14	60	*3*
mean	1153	2050	2394
max	4430	3610	17000

Table 10: Comparison of the chloride data between reviews (mg/l)

As with the ammoniacal-N data, the data set contains outlying values. The frequency distribution of chloride results is shown in Figure 5. There is a single value of 17000mg/l within the dataset which was an isolated result. The next-highest value was 5430mg/l and the value prior to the 17000mg/l result was 1720mg/l and the one after was 1300mg/l: it may be that the result was mis-transcribed and should have been 1700mg/l. The extreme outlier, 17000mg/l is not shown on the frequency distribution or the time series plots presented in Appendix 2.

Figure 5: Leachate chloride concentrations frequency distribution



The chloride data has been tested using the D'Agostino statistic and Figure 5 shows a normal distribution (*y*= -3.085) between 530-4800mg/l plus a number of outliers. The mean of the normal range is 2408, slightly higher than the previous mean.

Phenol

Recent leachate phenol results are summarised in Table 11 and are compared to earlier data sets in Table 12.

	LC03	LC01A	LC01B	LC04A	LC04B	LC05A	LC05B	LM04A
n	24	12	10	11	12	9	12	3
min	0.029	0.05	0.1	0.5	0.6654	0.5	2.7	9.9
mean	3.54	8.12	3.35	71.01	13.62	85.46	13.12	18.43
max	14.6	85	17.19	490	29.5	490	27.1	24
	LM04B	LM05B	LC06	LM06A	LM06B	LM07A	LM07B	LT01
n	18	23	1	9	12	1	20	21
min	0.5	0.5	8.6	9	0.05	5.6	0.05	0.5
mean	49.17	37.93	8.60	40.84	15.28	5.60	19.35	28.34
max	490	500	8.6	210	39.1	5.6	150	320

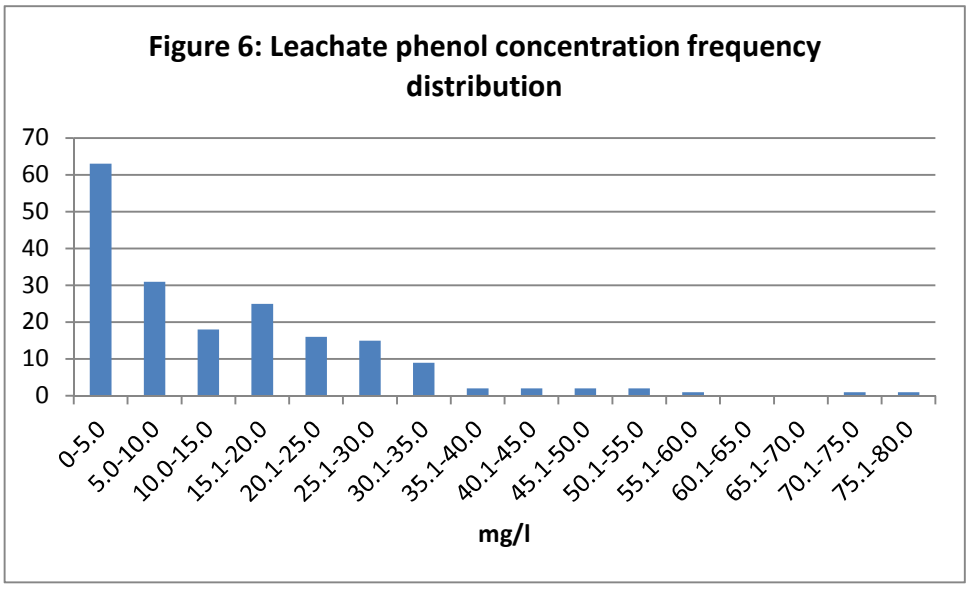
Table 11: Recent leachate phenol concentrations (mg/l)

The table above included data from November 2010. In 2010 the highest eight results of the whole data set were all recorded. These results are thought highly questionable and have not been included in the comparison table below. The abnormal nature of the results from November 2010 is clear on the time series plot presented in Appendix 2. FCC is aware of the significance of phenol as a pollutant but we are concerned with the problematic nature of its analysis as an indicator in leachate and groundwater. The two methods in use at commercial laboratories both produce positive results from a number of different compounds and they can give significantly different results. Also a positive result in leachate and one in groundwater may not be caused by the same substance and so it is difficult to definitively demonstrate cause and effect. Whilst this is an extreme example of problems with phenol analysis, similar problems have been found at other sites.

	2004 HRA	2009 review	This review
min	0.038	0.1	*0.029*
mean	4.787	13.84	14.3
max	9.52	24.7	77.0

Table 12: Comparison of phenol data between reviews (mg/l)

The phenol concentration frequency distribution is shown in Figure 6 below.



The largest group of result are in the lowest group, up to 5.0mg/l. The mean value is slightly higher than the mean from the first review but this is affected by the small number of outlying results over 40.0mg/l.

Nickel

Nickel results are summarised in Table 13 and compared to previous reviews in Table 14.

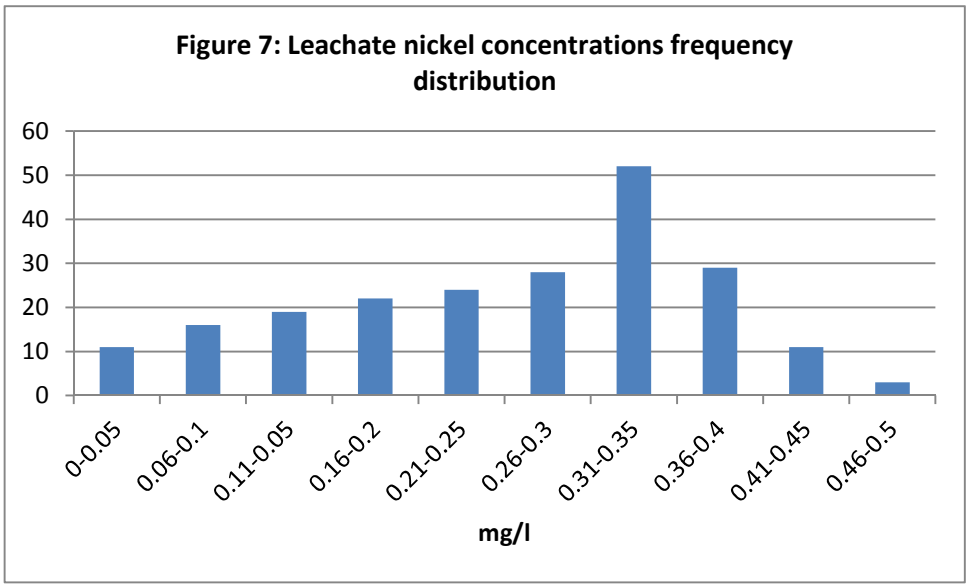
	LC03	LC01A	LC01B	LC04A	LC04B	LC05A	LC05B	LM04A
n	25	13	10	15	8	15	12	4
min	0.012	0.0202	0.277	0.043	0.201	0.024	0.089	0.28
mean	0.14	0.28	0.35	0.26	0.36	0.24	0.33	0.30
max	0.23	0.42	0.438	0.355	0.473	0.41	0.426	0.32
	LM04B	LM05B	LC006	LM06A	LM06B	LM07A	LM07B	LT001
n	19	25	1	10	12	1	22	24
min	0.0208	0.01	0.41	0.062	0.124	0.49	0.005	0.04
mean	0.27	0.28		0.22	0.31		0.23	0.24
max	0.448	0.45	0.41	0.37	0.436	0.49	0.369	0.46

Table 13: Recent leachate nickel concentrations (mg/l)

	2004 HRA	2009 review	This review
min	0.026	0.013	*0.01*
mean	0.154	0.21	0.26
max	0.276	0.37	0.49

Table 14: Comparison of nickel data between reviews (mg/l)

The mean concentration and the maximum have both risen since the last review. The frequency distribution of nickel concentrations is shown in Figure 7.



Using the D'Agostino statistic, the data shown in Figure 7 is normally distributed (n=215, sd=0.112, *y*=0.686).

In summary, concentrations of most leachate quality parameters show similar ranges as in the 2009 review but often with higher outlying results. In some cases the distributions have shifted upwards but this may simply be the effect of a greater number of readings producing a wider range of results or it could be caused by capping areas of the site.

Leachate levels

Recent leachate levels are summarised in Table 15.

	LC03	LC01A	**LC01B**	LC04A	**LC04B**	LC05A	**LC05B**	LM04A
n	**241**	66	**177**	151	**86**	156	**86**	42
min	**64.29**	37.82	**40.86**	40.91	**41.57**	40.7	**41.9**	40.96
mean	**64.70**	41.61	**41.34**	41.56	**41.70**	41.33	**42.08**	42.60
max	**65.01**	53.17	**42.61**	52.66	**41.79**	46.46	**42.58**	47.88
base +1m	**65.01**	42.30	**41.64**	41.47	**41.82**	41.52	**42.23**	41.48
	LM04B	LM05A	**LM05B**	LM06A	**LM06B**	LM07A	**LM07B**	
n	**201**	7	**236**	128	**86**	11	**235**	
min	**40.7**	42.43	**40.48**	39.62	**41.15**	40.45	**39.29**	
mean	**41.54**	43.16	**41.36**	39.95	**41.33**	40.65	**40.21**	
max	**51.5**	44.57	**44.17**	42.15	**41.44**	41.88	**55.96**	
base +1m	**41.63**	41.58	**41.58**	40.05	**41.47**	40.6	**40.6**	

Table 15: Leachate level (mAOD)
Current leachate wells are shown in **bold**

Base +1m levels represent the compliance limit for the leachate well. The mean leachate levels in the current wells show 100% compliance with the 1m above base limit and show that the requirements of IC1 are now met. A hydrograph of leachate levels is included in Appendix 3 and shows that the periods of non-compliance are brief. In addition hydrographs are presented for individual leachate wells which include the base of the well and the compliance limit of 1m above base. All leachate wells are installed to the leachate drainage stone at the base of the respective cells with the exception of LC03 which was installed on a bench at a much higher elevation and as such is not monitoring leachate levels acting on the base of the site which is the reason why it shows a leachate level in the region of 65mAOD whereas all other wells are around 40-43mAOD.

Summary

The current leachate quality remains largely as modelled and the site is now essentially complaint with the permit limit of 1m above base and is hydraulically contained.

3.2 Emissions to groundwater

Recent groundwater levels are summarised in Table 16. A hydrograph of groundwater levels is included in Appendix 3.

	BH01	BH02	BH03	BH04	BH05	BH07	BH08	BH09	BH10
n	72	72	72	72	69	72	72	72	72
min	58.69	72.38	45.64	50.65	46	53.97	44.02	50.05	49.66
mean	59.84	74.50	47.33	53.38	46.74	54.72	65.93	54.15	51.14
max	62.44	76.25	78.04	54.31	48.2	64.64	72.34	55.74	53.54
	BH11	BH12	BH13	BH14	BH03A	T01	T02	T03	T04
n	72	72	72	72	72	72	72	71	72
min	48.41	43.3	32.45	55.35	45.9	54.35	50.58	52.45	52.74
mean	52.15	53.93	50.98	57.07	47.93	55.05	53.01	53.24	53.43
max	53.62	54.09	52.58	61.19	49	56.01	53.96	54.63	54.12
	T05	T06	T07	T08	T09	T10	T11	T12	T13
n	72	71	69	69	66	75	74	75	75
min	52	52.39	52.57	52.33	51	52.18	52.14	50.97	52.13
mean	53.48	52.93	53.14	53.32	52.66	52.03	52.71	51.20	51.97
max	53.92	54.39	54.8	54.17	53.9	53.07	53.57	52.54	52.95

Table 16: Recent groundwater levels (mAOD)

Water levels generally vary within similar ranges. The exception is BH08 which showed periods of extreme instability.

3.2.1 Emissions to groundwater – Hazardous substances

Hazardous indicators from the previous reviews are mecoprop, naphthalene and cadmium.

Mecoprop

Mecoprop concentrations in boreholes are summarised in Table 17.

	BH01	BH02	BH03	BH04	BH05	BH07	BH08	BH09	BH10
n	12	10	12	12	12	12	12	12	12
min	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
mean	*0.015*	*0.014*	*0.017*	*0.015*	*5.755*	*0.015*	*0.145*	*2.705*	*0.015*
max	*0.02*	*0.02*	0.03	*0.02*	68.9	*0.02*	1.52	35.2	*0.02*
	BH11	BH12	BH13	BH14	BH03A	T01	T02	T03	T04
n	12	12	12	12	12	12	12	12	12
min	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
mean	*0.016*	*0.020*	*0.030*	*0.018*	*0.016*	*0.023*	*0.015*	*0.015*	*0.016*
max	0.02	0.41	0.13	0.057	*0.02*	0.11	*0.02*	0.02	0.02
	T05	T06	T07	T08	T09	T10	T11	T12	T13
n	10	12	11	12	12	12	12	12	12
min	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
mean	*0.014*	*0.015*	*0.026*	*0.025*	*0.038*	*0.022*	*0.015*	*0.052*	*0.015*
max	*0.02*	*0.02*	0.1	0.13	0.18	0.08	*0.02*	0.26	*0.02*

Table 17: Recent groundwater mecoprop concentrations (µg/l)

The compliance limit in boreholes BH1, BH2, BH3, BH3A, BH4, BH5 T01, T02, T03, T04, t05, T06, T07, T08, T09, T11, T12 and T13 is 0.04µg/l. At boreholes BH07, BH08, BH09, BH10, BH11, BH12, BH13 and T10 the compliance limit is 0.1µg/l. There were compliance limit breaches at several boreholes although typically these were isolated incidents. The previous review also

contained positive mecoprop concentrations up to 2.0µg/l. Compliance limits are discussed in Section 4.1.2.

All results in this data set were below this concentration except the maxima from boreholes BH05 and BH07. These results are extreme outliers. All other results at borehole BH05 were below the LOD. There were two other results above the LOD at BH07 but these were well below the 2.0µg/l level. These isolated positive values have been attributed to non-landfill sources.

Naphthalene

Naphthalene results are summarised in Table 18.

	BH01	BH02	BH03	BH04	BH05	BH07	BH08	BH09	BH10
n	12	10	12	12	12	12	11	12	12
min	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
mean	*0.64*	*0.62*	*0.64*	*0.64*	*0.64*	*0.64*	*0.69*	*0.64*	*0.64*
max	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*
	BH11	BH12	BH13	BH14	BH03A	T01	T02	T03	T04
n	12	12	12	12	12	12	12	12	12
min	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
mean	*0.64*	*0.64*	*0.64*	*0.64*	*0.64*	*0.66*	*0.64*	*0.64*	*0.72*
max	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*
	T05	T06	T07	T08	T09	T10	T11	T12	T13
n	12	12	11	12	12	12	12	12	12
min	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
mean	*0.64*	*0.64*	*0.65*	*0.64*	*0.64*	*0.64*	*0.64*	*0.64*	*0.64*
max	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*

Table 18: Recent groundwater naphthalene results (µg/l)

The great majority of results were below the LOD with occasional positive results at ten of the boreholes. This range of results is similar to those previously reported. The permit limit is 1.0µg/l at all boreholes. On two sampling occasions the LOD was above this concentration at 5µg/l. No positive result was recorded that was above the permit limit.

Cadmium

Cadmium results are summarised in Table 19.

	BH01	BH02	BH03	BH04	BH05	BH07	BH08	BH09	BH10
n	11	9	11	11	11	11	11	11	11
min	*0.00005*	*0.00005*	*0.00005*	*0.00005*	*0.00005*	*0.00005*	*0.00005*	*0.00005*	*0.00005*
mean	*0.00009*	*0.00006*	*0.00008*	*0.00008*	*0.00011*	*0.00008*	*0.00008*	*0.00008*	*0.00012*
max	0.0003	*0.00015*	*0.00015*	*0.00015*	0.0005	*0.00015*	*0.00015*	*0.00015*	0.0006
	BH11	BH12	BH13	BH14	BH03A	T01	T02	T03	T04
n	11	11	11	11	11	11	11	11	11
min	*0.00005*	*0.00005*	*0.00005*	*0.00005*	*0.00005*	*0.00005*	*0.00005*	*0.00005*	*0.00005*
mean	*0.00015*	*0.00012*	*0.00015*	*0.00044*	*0.00010*	*0.00014*	*0.00012*	*0.00020*	*0.00014*
max	0.0005	0.0004	0.0008	0.001	0.0004	0.0008	0.0006	0.013	0.0008
	T05	T06	T07	T08	T09	T10	T11	T12	T13
n	9	11	10	11	11	11	11	11	11
min	*0.00005*	*0.00005*	*0.00005*	*0.00005*	*0.00005*	*0.00005*	*0.00005*	*0.00005*	*0.00005*
mean	*0.00006*	*0.00015*	*0.00016*	*0.00017*	*0.00008*	*0.00016*	*0.00011*	*0.00027*	*0.00016*
max	*0.00015*	0.0009	0.001	0.0011	*0.00015*	0.0007	0.0005	0.0011	0.0011

Table 19: Recent groundwater cadmium concentrations (mg/l)

The original HRA reported cadmium concentrations up to 0.05mg/l. All results are well within this range. The compliance limit at boreholes BH1, BH2, BH3, BH3A, BH4, BH5 T01, T02, T03, T04, t05, T06, T07, T08, T09, T11 and T13 is 0.0005mg/l. At boreholes BH07, BH08, BH09, BH10, BH11, BH12, BH13 and T10 the compliance limit is 0.001mg/l and the level for borehole T12 is 0.006mg/l. Compliance limits are discussed in Section 4.1.2.

The only breaches of the compliance limit (at boreholes T01, T02, T03, T04, T07, T08 and T13) were all recorded on the first sampling occasion in August 2009. Since all these breaches were recorded on the same occasion it is likely that laboratory error may have been involved.

3.2.2 Emissions to groundwater – Non-hazardous (formerly List II) pollutants

Non-hazardous indicators are ammoniacal nitrogen, chloride and nickel.

Ammoniacal-nitrogen

Ammoniacal-nitrogen results are shown in Table 20. Time series plots of ammoniacal nitrogen are included in Appendix 4

	BH01	BH02	BH03	BH04	BH05	BH07	BH08	BH09	BH10
n	71	50	70	71	68	71	71	71	70
min	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*
mean	*0.11*	*0.86*	*0.18*	*0.91*	*0.11*	*0.19*	*0.28*	*0.08*	*0.23*
max	2.1	19	2.2	3.1	0.85	1.5	4.4	1.35	1.7
limit	2.2	1.3	1.5	3.0	1.4	1.3	1.2	0.5	1.1
	BH11	BH12	BH13	BH14	BH03A	T01	T02	T03	T04
n	70	71	71	71	71	71	72	71	70
min	*0.005*	0.01	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*
mean	*0.18*	2.57	*0.28*	*0.15*	*0.09*	*0.07*	*0.07*	*0.27*	*0.08*
max	6.77	3.5	1.1	1.86	0.75	0.9	0.65	2.2	1.1
limit	0.39	3.5	0.7	1.9	0.5	3.9			

	T05	T06	T07	T08	T09	T10	T11	T12	T13
n	51	69	66	68	63	67	71	71	71
min	*0.005*	*0.005*	*0.005*	*0.01*	*0.005*	*0.01*	0.3	*0.005*	*0.005*
mean	*0.06*	*0.05*	*0.07*	1.64	*0.56*	1.51	0.69	*0.17*	*0.52*
max	0.8	0.4	0.81	4.8	3.7	2.97	2.8	3.54	3.6
limit						1.9			

Table 20: Recent groundwater ammoniacal-nitrogen results (mg/l)

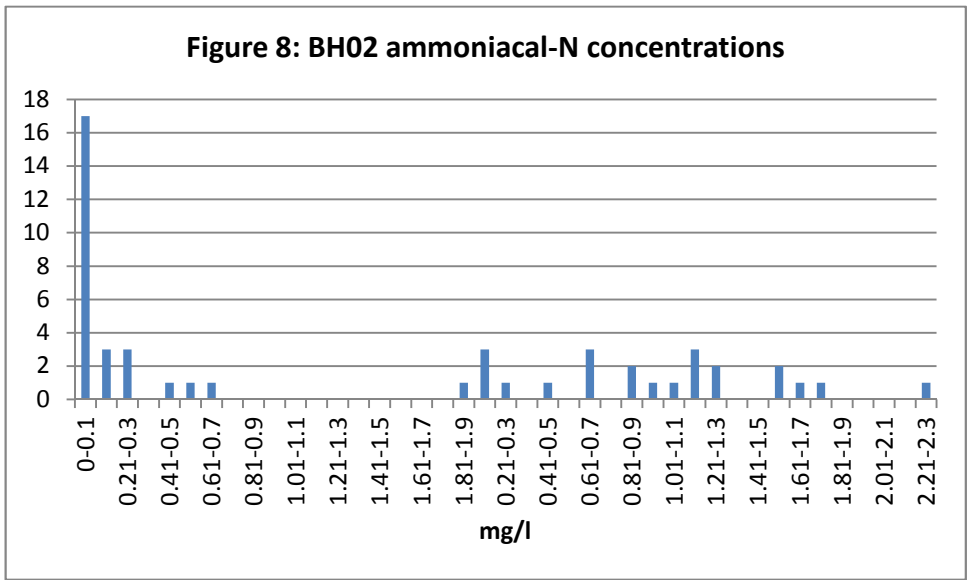
The permit limits for ammoniacal-N are shown in the table.

Breaches of compliance limits were recorded over the review period in 11 boreholes. In most cases, there were only one or two breaches and the results were close to the limit. Exceptions were BH02 where there were six breaches up to 2.3mg/l and an outlier at 19.0mg/l; BH10 where there were five breaches up to 1.7mg/l; BH11 where there were two breaches up to 0.9mg/l and an outlier at 6.77mg/l; BH13 where there were eight breaches up to 1.1mg/l; and borehole T10 where there were seventeen breaches up to 3.97mg/l.

Results at the four boreholes with more than two results that breached the compliance limit (excluding outliers) are characterised by a large number of very low results and a population of results at a much higher level. The results have been statistically analysed as follows.

Borehole BH02

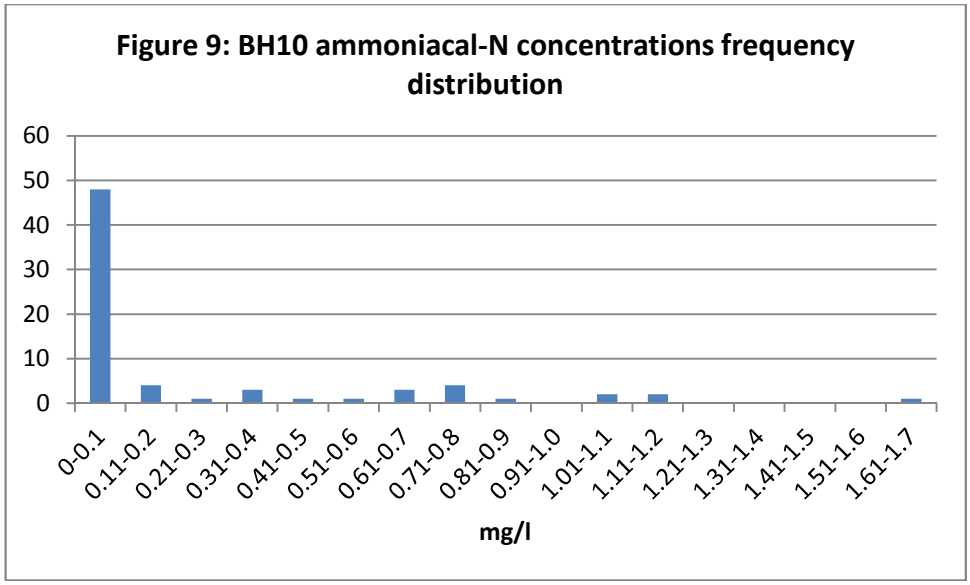
The frequency distribution of borehole BH02 results is shown in Figure 8.



One extreme outlying value of 16mg/l is not shown. The results have been analysed and the range 0.19mg/l-1.8mg/l has been proved to be normally distributed using the D'Agostino test statistic (n=23, mean=0.93, sd=0.51, *y*=0.279). This strongly suggests that there are two types of results, a population of very low values and the normal range (with one or two higher outliers).

Borehole BH10

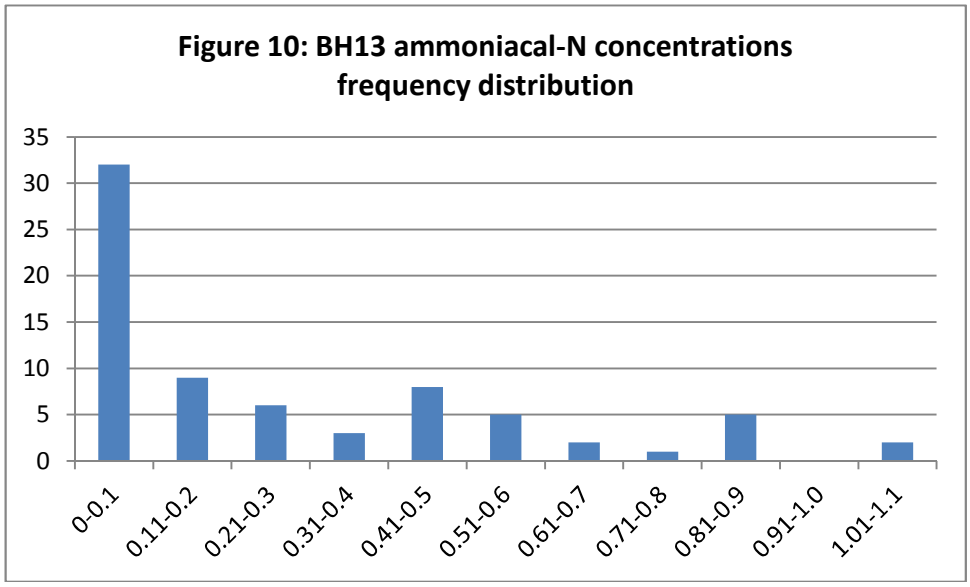
The frequency distribution of results from borehole BH10 is shown in Figure 9.



Carrying out the D'Agostino test proves the range 0.13mg/l-0.844mg/l to be normal (n=18, mean=0.49, sd=0.245, *y*=-0.89). Similarly to BH02, there is a large number of dilute results and a scatter of results above the normal range.

Borehole BH13

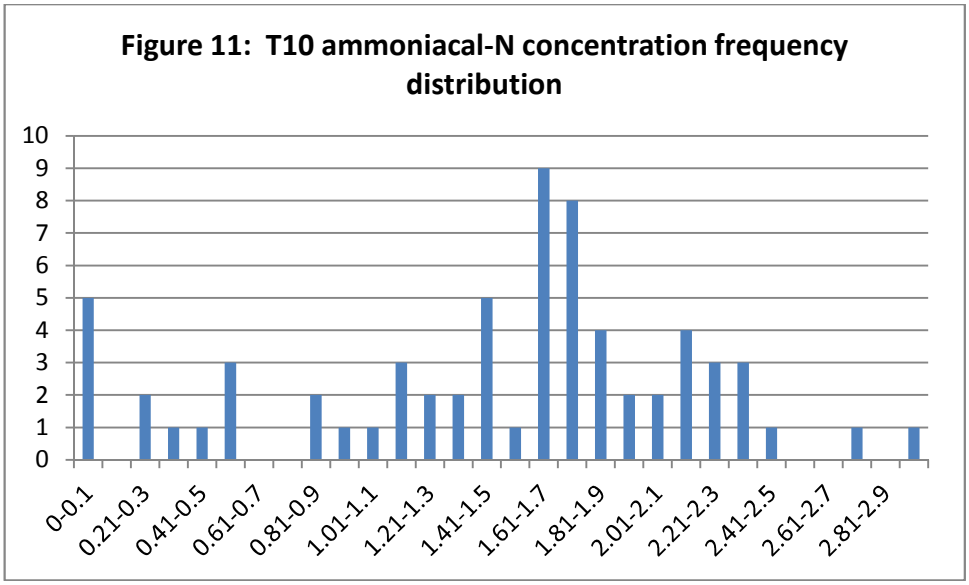
The frequency distribution of ammoniacal-N results ay borehole BH13 is shown in Figure 10.



The concentration range 0.14mg/l-0.88mg/l is preved to be normal (n=35, mean=0.466, sd=0.227, *y*=0.34). Again there is a large number of dilute results above the normal range with a few outliers above.

Borehole T10

The frequency distribution of ammoniacal-N results at borehole T10 is shown in Figure 11.



The range 0.9mg/l-2.5mg/l is proven to be normal (n=53, mean=1.69, sd=0.34, *y*=-1.183). Again there is a population of results below the normal range and a number of outliers above it.

The pattern of results shown by all four boreholes is characteristic of boreholes where the natural groundwater concentrations are affected infiltration by surface water, which typically has a low ammoniacal-N concentration. When no such infiltration has occurred results are higher, but concentrations within the normal range above should still be regarded as background level.

Overall there would not appear to be rising trends observed for ammoniacal nitrogen from the time series graphs presented in appendix 4. The key trends have been mentioned in the discussion above.

Chloride

Chloride results are summarised in Table 21.

	BH01	BH02	BH03	BH04	BH05	BH07	BH08	BH09	BH10
n	71	51	70	71	69	70	71	71	71
min	*2.5*	14	20	23.6	24	59	*2.5*	*2.5*	*2.5*
mean	*32.59*	20.85	46.6	77.27	34.37	80.51	*26.72*	*34.27*	*15.05*
max	109	45	70	121	116	166	103	79	22
	BH11	BH12	BH13	BH14	BH03A	T01	T02	T03	T04
n	71	71	71	71	71	71	71	71	71
min	*2.5*	32	65	103	27	*2.5*	*2.5*	10	*2.5*
mean	*29.5*	376	200	203	61.2	*17.41*	*15.15*	48.62	*32.21*
max	50	460	384	340	183	58	38	96	118
	T05	T06	T07	T08	T09	T10	T11	T12	T13
n		70	67	68	63	67	71	71	71
min	12.4	23	11	*2.5*	*2.5*	46	54	72	57
mean	34.79	77.33	26.84	*39.46*	*32.03*	128	78.19	165.6	70.06
max	59	170	86	68	62	273	200	363	91

Table 21: Recent groundwater chloride results (mg/l)

Time series plot of Chloride are included in Appendix 4

A compliance limit of 250mg/l is set for all boreholes except BH12, BH13 and BH14. The compliance limit was exceeded at T10 and BH13 on a single occasion with both concentrations outside the long term trend at the boreholes. There have been two periods of elevated chloride concentrations at T12 in early 2012 and late 2013 with an exceedance of the compliance limit observed both times. Since these concentrations have typically been below 150mg/l with no evidence of an increasing trend.

Phenol

Phenol results are summarised in Table 22.

	BH01	BH02	BH03	BH04	BH05	BH07	BH08	BH09	BH10
n	7	7	7	7	7	7	7	7	7
min	*0.00025*	*0.00025*	*0.00025*	*0.00025*	*0.00025*	*0.00025*	*0.00025*	*0.00025*	*0.00025*
mean	*0.0758*	*0.0806*	*0.0758*	*0.0758*	*0.0758*	*0.0758*	*0.0758*	*0.0758*	*0.0758*
max	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*
	BH11	BH12	BH13	BH14	BH03A	T01	T02	T03	T04
n	7	7	7	7	7	7	7	7	7
min	*0.00025*	*0.00025*	*0.00025*	*0.00025*	*0.00025*	*0.00025*	*0.00025*	*0.00025*	*0.00025*
mean	*0.0758*	*0.0758*	*0.0758*	*0.0758*	*0.0760*	*0.0758*	*0.0758*	*0.0758*	*0.0758*
max	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*
	T05	T06	T07	T08	T09	T10	T11	T12	T13
n	7	7	7	7	7	7	7	7	7
min	*0.00025*	*0.00025*	*0.00025*	*0.00025*	*0.00025*	*0.00025*	*0.00025*	*0.00025*	*0.00025*
mean	*0.0758*	*0.0758*	*0.0759*	*0.0758*	*0.0758*	*0.0759*	*0.0758*	*0.0758*	*0.0758*
max	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*

Table 22: Recent groundwater phenol results (mg/l)

All results were below the LOD except five. There are no trigger levels set for phenol.

Nickel

Nickel results are summarised in Table 23.

	BH01	BH02	BH03	BH04	BH05	BH07	BH08	BH09	BH10
sum	0.00795	0.0065	0.007	0.00795	0.00645	0.00645	0.00795	0.00945	0.00645
n	4	3	4	4	4	4	4	4	4
min	*0.00045*	*0.0005*	*0.0005*	*0.00045*	*0.00045*	*0.00045*	*0.00045*	*0.00045*	*0.00045*
mean	*0.0020*	*0.0022*	*0.0018*	*0.0020*	*0.0016*	*0.0016*	*0.0020*	*0.0024*	*0.0016*
max	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*
	BH11	BH12	BH13	BH14	BH03A	T01	T02	T03	T04
sum	0.01245	0.0612	0.00984	0.0234	0.0142	0.00867	0.01239	0.01264	0.03286
n	4	4	4	4	4	4	4	4	4
min	*0.00045*	*0.005*	*0.00045*	0.0024	*0.0005*	*0.00045*	*0.00045*	0.0015	*0.00045*
mean	*0.0031*	*0.0153*	*0.0025*	0.0059	*0.0036*	*0.0022*	*0.0031*	0.0032	*0.0082*
max	*0.005*	0.0252	0.00339	0.012	0.0082	*0.005*	*0.005*	0.00514	0.019

	T05	T06	T07	T08	T09	T10	T11	T12	T13
sum	0.0141	0.01045	0.00695	0.01245	0.0119	0.1397	0.00845	0.0237	0.00945
n	4	4	4	4	4	4	4	4	4
min	0.002	*0.00045*	*0.00045*	*0.00045*	0.0019	0.009	*0.00045*	0.003	*0.00045*
mean	*0.0035*	*0.0026*	*0.0017*	*0.0031*	*0.0030*	0.0349	*0.0021*	0.0059	*0.0024*
max	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	0.079	*0.005*	0.0107	*0.005*

Table 23: Recent groundwater nickel results (mg/l)

There is a compliance limit of 0.02mg/l in all boreholes except BH12 which is 0.04mg/l and T12 where the trigger level is 1.4mg/l. There were no breaches of the compliance limit.

3.2.3 Emissions to Surface Waters

There was no discharge of surface water during the Review Period.

Results for ammoniacal-nitrogen, Cl and EC at the 3 surface water monitoring points on the River Dee are shown in Table 23. WP01 is farthest upstream of the site at Newbridge whilst WP03 is opposite the site and WP02 is farthest downstream. Table 24: Surface water monitoring results

	Ammoniacal-N mg/l			Chloride mg/l			EC µS/cm			COD mg/l		
	WP01	WP02	WP03	WP01	WP02	WP03	WP01	WP02	WP03	WP1	WP2	WP3
n	69	70	69	70	71	71	70	71	70	72	72	71
min	*0.005*	*0.005*	*0.005*	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*	*2.5*	50	50	50
mean	*0.33*	*0.11*	*0.12*	*11.03*	*11.18*	*11.48*	*13.87*	*14.20*	*12.73*	142	125	123
max	6.9	2.2	3.2	24	20	19	37	89	28	390	330	193

The mean chloride concentration at the three monitoring points is effectively the same. Chloride is a good indicator of leachate in receptors that naturally have a low concentration, although there are other environmental sources. In this case mean chloride concentrations at all three points are between 11.03 and 11.48mg/l. These results do not indicate any effect from the site.

3.3 Sensitivity analysis

The sensitivity analysis carried out in the first review modelled two head differences between leachate head and groundwater head, 0.5m and 1.0m. Excluding the shallow leachate well LC03, the highest figure for mean leachate level in Table 15 is 43.16mAOD, whereas the lowest minimum groundwater level in Table 16 is 46.03mAOD at BH05, i.e. the head difference is now at least 2.87m.

With the current degree of hydraulic containment the risk to the environment is lower than at when the previous sensitivity analysis was carried out and at that time the risk was described as negligible. Even a modest increase in leachate head, e.g. 1.0m, would still represent a safer situation than modelled at the last review, see Section 4.1.2.

It is suggested that the permit is varied to allow such a head increase, i.e. to 2m depth of leachate, when the site is closed and fully capped.

3.4 Review of Technical Precautions

Leachate removal is the primary technical precaution at Pen-y-Bont. During the review period leachate removals from Pen-y-Bont were as shown on Table 25.

	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Pen-Y-Bont	2009	2568	2962	2514	2416	1814	1758	1362	1614	1285	911	837	2007	22047
Pen-Y-Bont	2010	1335	1852	1672	1598	1712	1882	1917	1581	1484	1291	1750	1158	19232
Pen-Y-Bont	2011	1266	1383	1722	1598	1674	2465	3294	2512	1614	1323	1674	1277	21803
Pen-Y-Bont	2012	1371	1636	1408	1383	1393	995	1551	1034	812	1539	1604	1538	16264
Pen-Y-Bont	2013	1130	1631	983	1181	2237	2018	1680	2140	2283	1785	1823	1846	20736
Pen-Y-Bont	2014	1606	1803	1827	1485	1989	1599	1624	1763	1883	1729	1868	1986	21162

Leachate removals are maintaining the site in a hydraulically contained state.

4.0 Requisite Surveillance

4.1 Leachate, Groundwater and Surface Water Monitoring Schedule

4.1.1 Monitoring frequency and determinands

The monitoring schedule is shown in Table 26.

	Monitoring Type	Sample Points	Monitoring
Monthly	Leachate Collection Chambers	LC01B, LC03, LM05B, LC05B, LC04B, LM04B, LM06B, LM07B.	DTL DTB
	Groundwaters	BH1, BH2, BH3, BH3A, BH4, BH5, BH7, BH8, BH9, BH10, BH11, BH12, BH13, BH14, T1, T2, T3, T4, T5, T6, T7, T8, T9, T10, T11, T12, T13	DTL DTB pH Temp EC Cl NH3-N DO SS COD BOD
	Surface Waters	WP1, WP2, WP3.	pH Temp EC oil and grease Cl NH3-N DO SS COD
Quarterly	Groundwaters	BH1, BH2, BH3, BH3A, BH4, BH5, BH7, BH8, BH9, BH10, BH11, BH12, BH13, BH14, T1, T2, T3, T4, T5, T6, T7, T8, T9, T10, T11, T12, T13	DTL DTB pH Temp EC Cl NH3-N DO SS COD BOD SO4 Alk Ca Cr Pb Mg K TOC TON
	Surface Waters	WP1, WP2, WP3.	pH Temp EC oil and grease Cl NH3-N DO SS COD SO4 Alk Ca Cd Cr Cu Fe K Mg Mn Na Ni Zn PO4 TOC TON
	Leachate Tank	LT1	Temp pH EC Cl NH3-N SO4 Alk COD BOD Ca Cd Cr Cu Fe Hg K Mg Mn Na Ni Pb Zn phenol TOC TON oil
	Leachate Collection Chambers	LC01B, LC03, LM05B, LC05B, LC04B, LM04B, LM06B, LM07B.	Temp pH EC Cl NH3-N SO4 Alk COD BOD Ca Cd Cr Cu Fe Hg K Mg Mn Na Ni Pb Zn phenol TOC TON
Bi-Annual	Groundwaters	BH1, BH2, BH3, BH3A, BH4, BH5, BH7, BH8, BH9, BH10, BH11, BH12, BH13, BH14, T1, T2, T3, T4, T5, T6, T7, T8, T9, T10, T11, T12, T13	As quarterly + mecoprop Hg naphthalene phenol, TPH Haz subs found in leachate
	Leachate Tank	LT1	As quarterly + mecoprop naphthalene
	Leachate Collection Chambers	LC01B, LC03, LM05B, LC05B, LC04B, LM04B, LM06B, LM07B.	As quarterly + mecoprop naphthalene
Annual	Groundwaters	BH1, BH2, BH3, BH3A, BH4, BH5, BH7, BH8, BH9, BH10, BH11, BH12, BH13, BH14, T1, T2, T3, T4, T5, T6, T7, T8, T9, T10, T11, T12, T13	As quarterly + Cu Fe Mn Ni PO4 toluene Zn mecoprop naphthalene phenol TPH Cd
	Leachate Tank	LT1	As quarterly + mecoprop naphthalene CN Has subs
	Leachate Collection Chambers	LC01B, LC03, LM05B, LC05B, LC04B, LM04B, LM06B, LM07B.	As quarterly + mecoprop naphthalene CN Has subs

Table 26: Current monitoring schedule

4.1.2 Compliance Limits

Groundwater Quality

In view of the analysis of ammoniacal-N results at boreholes BH02, BH10, BH13 and T10 it is suggested that the compliance limits at these boreholes are amended as shown in Table 27 based on a mean+2sd basis.

Borehole	Existing limit	Proposed limit
BH02	1.3	1.44
BH10	1.1	1.00
BH13	0.7	0.92
T10	1.9	2.49

Table 27: Proposed ammoniacal-N compliance limit amendments

The groundwater mecoprop concentration limit under the permit is set at 0.04µg/l in boreholes BH1, BH2, BH3, BH3A, BH4, BH5 T01, T02, T03, T04, T05, T06, T07, T08, T09, T11 and T13. In view of the complex matrix in the groundwater at Pen-y-Bont it is suggested that this is amended to 0.1µg/l in line with the Agency fact sheet on minimum reporting values (reference 3).

Reference 3 also suggests a cadmium limit of 0.001mg/l for groundwaters with a complex matrix. The permit limit is set at this level for some of the boreholes but is set at 0.00005mg/l at BH1, BH2, BH3, BH3A, BH4, BH5 T01, T02, T03, T04, T05, T06, T07, T08, T09, T11 and T13. It suggested that the 0.001mg/l is applied at all boreholes.

Leachate Levels

The current leachate compliance limits are set at 1m above the base of the cells. The site has been modelled through hydrogeological risk assessments in 2004 and 2009 on the principal of hydraulic containment such that leachate levels are maintained below surrounding groundwater elevations.

The 2009 HRA utilised a normal operating conditions scenario (Section 3.2.1) where a minimum of 1m head difference is maintained between leachate and groundwater. The modelling utilised a minimum observed groundwater level of 46mAOD and as such a corresponding leachate level of 45mAOD. This assessment concluded that concentrations of Hazardous substances (formerly list I) and Non-Hazardous pollutants (formerly list II) were acceptable and that the risk to the water environment is deemed negligible.

It is considered that the minimum groundwater level of 46mAOD remains appropriate and as such the modelling previously undertaken would support an increased leachate compliance limit up to 45mAOD. In order to provide a degree of conservatism it is however proposed that a compliance limit of 43mAOD be adopted which represents a 3m head difference between leachate and groundwater. It is proposed that this level be adopted once the site is closed and capped as this provides a further precaution that should leachate control be lost for a short period of time the likelihood of leachate levels increasing and resulting in a loss of hydraulic containment would be much reduced. It is also proposed that the compliance limit for LC03 is removed as this well is located on a bench close to the sidewall and as such does not monitor leachate levels acting on the base of the site.

5.0 Conclusions

Leachate quality remains largely as modelled but in some instances e.g. chloride, the mean of the distribution has shifted slightly. The site is now fully hydraulically contained with a large factor of safety and as such it is proposed that the leachate compliance limit be marginally increased to 43mAOD once the site has ceased operations and is capped.

Groundwater data does not show any effect from the site. Some suggestions have been made for amendments to compliance limits.

Sampling of the River Dee shows no significant difference in quality as it passes the site.

The site continues to comply with Regulations.

6.0 References

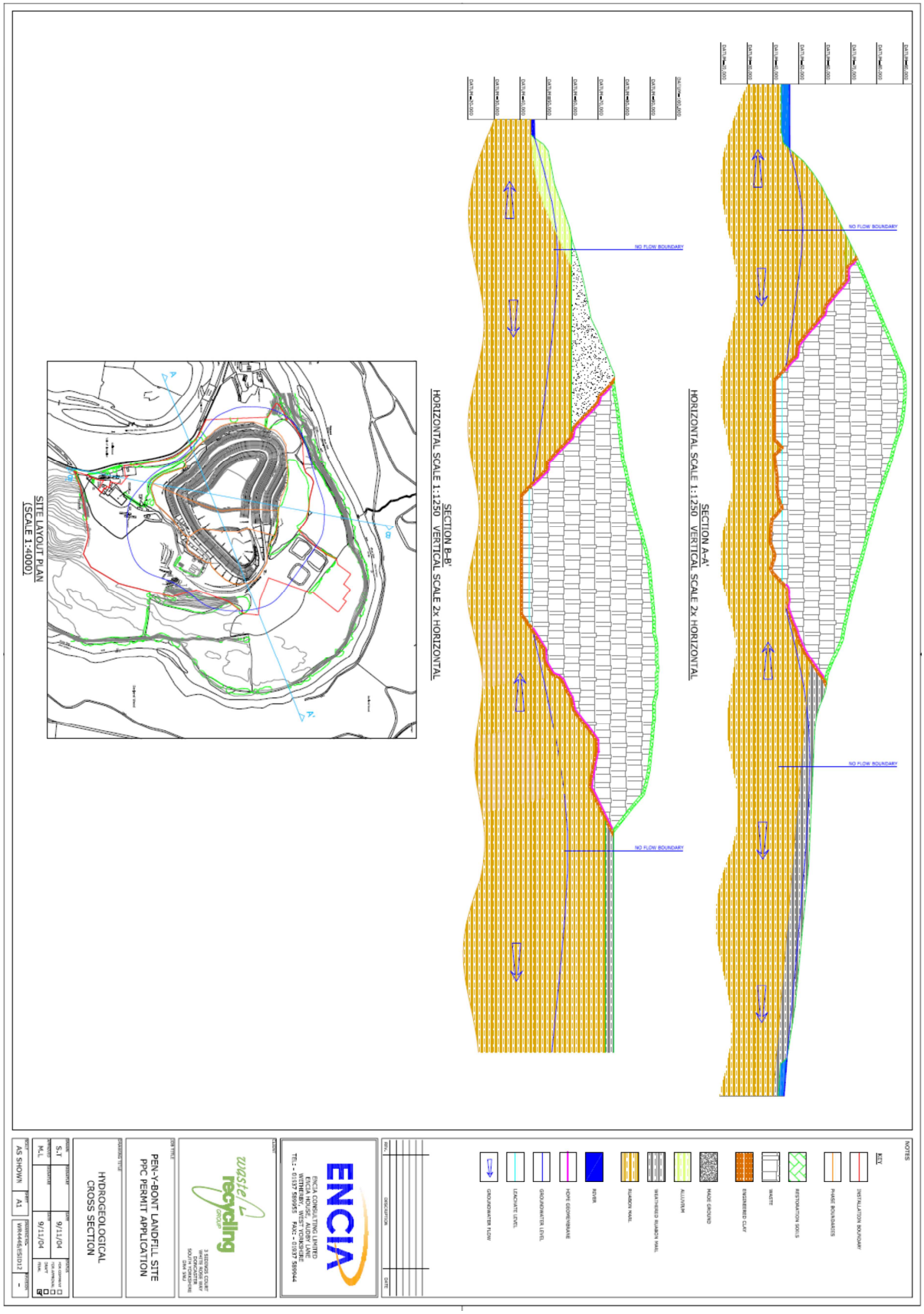
Reference 1 – Hydrogeological Risk Assessment, Pen-y-Bont Landfill Site, Encia Consulting Ltd, October 2004

Reference 2 – Pen-y-Bont Landfill Site Hydrogeological Risk Assessment Review, Golder Associates, March 2009

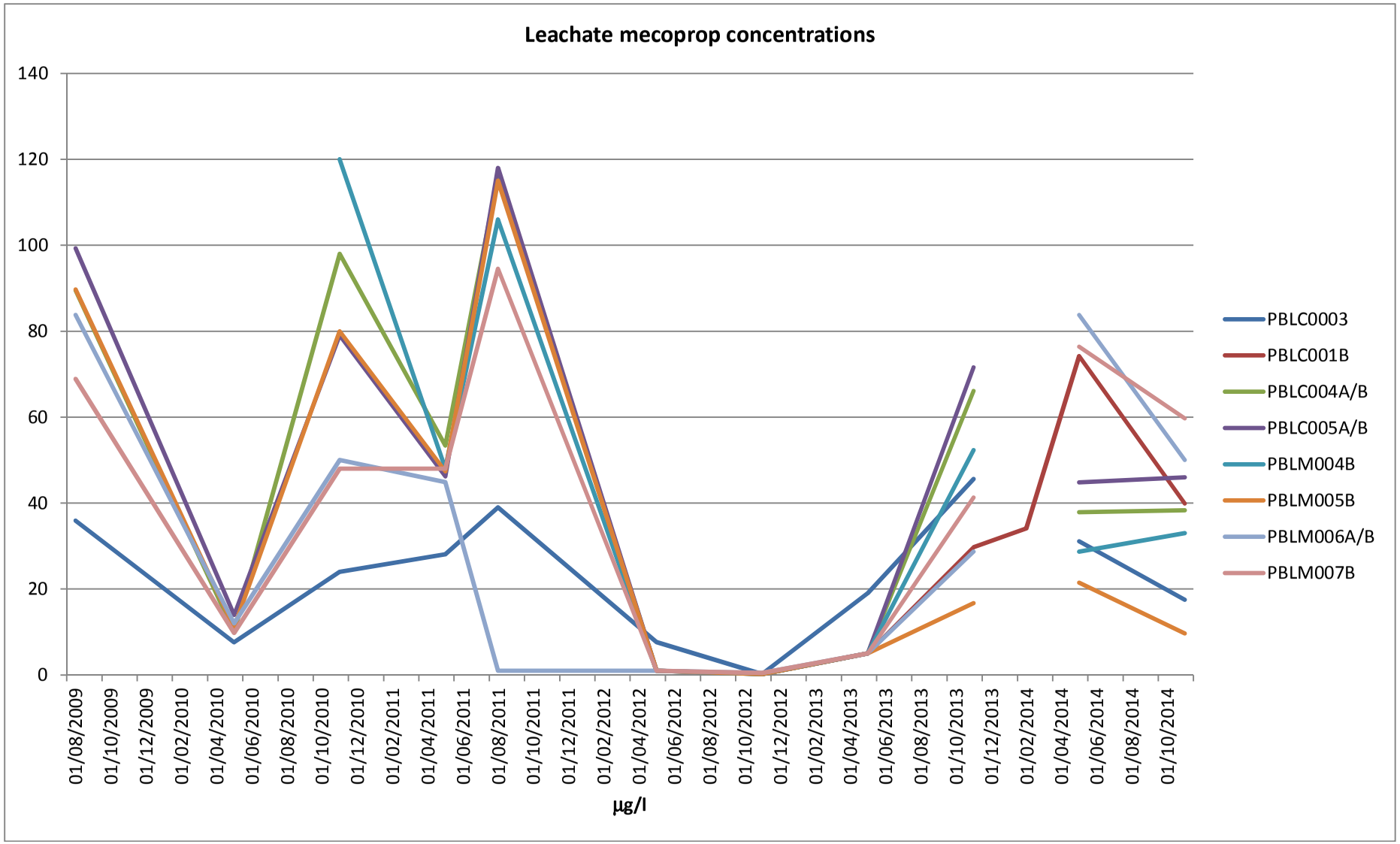
Reference 3 – Groundwater trigger levels, minimum reporting values and limits of detection, Environment Agency, April 2008

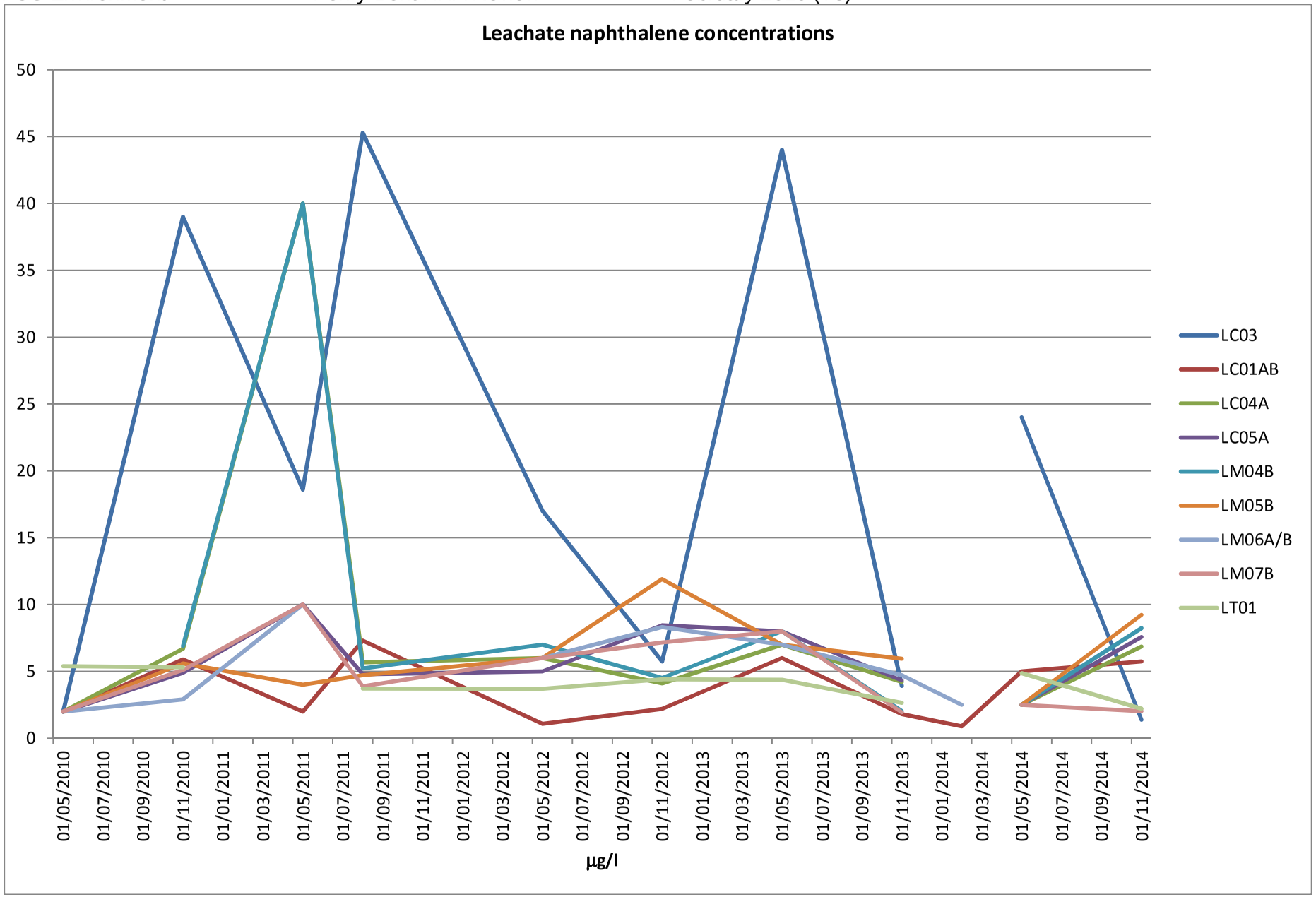
Appendix 1 HRA Drawings from the original HRA

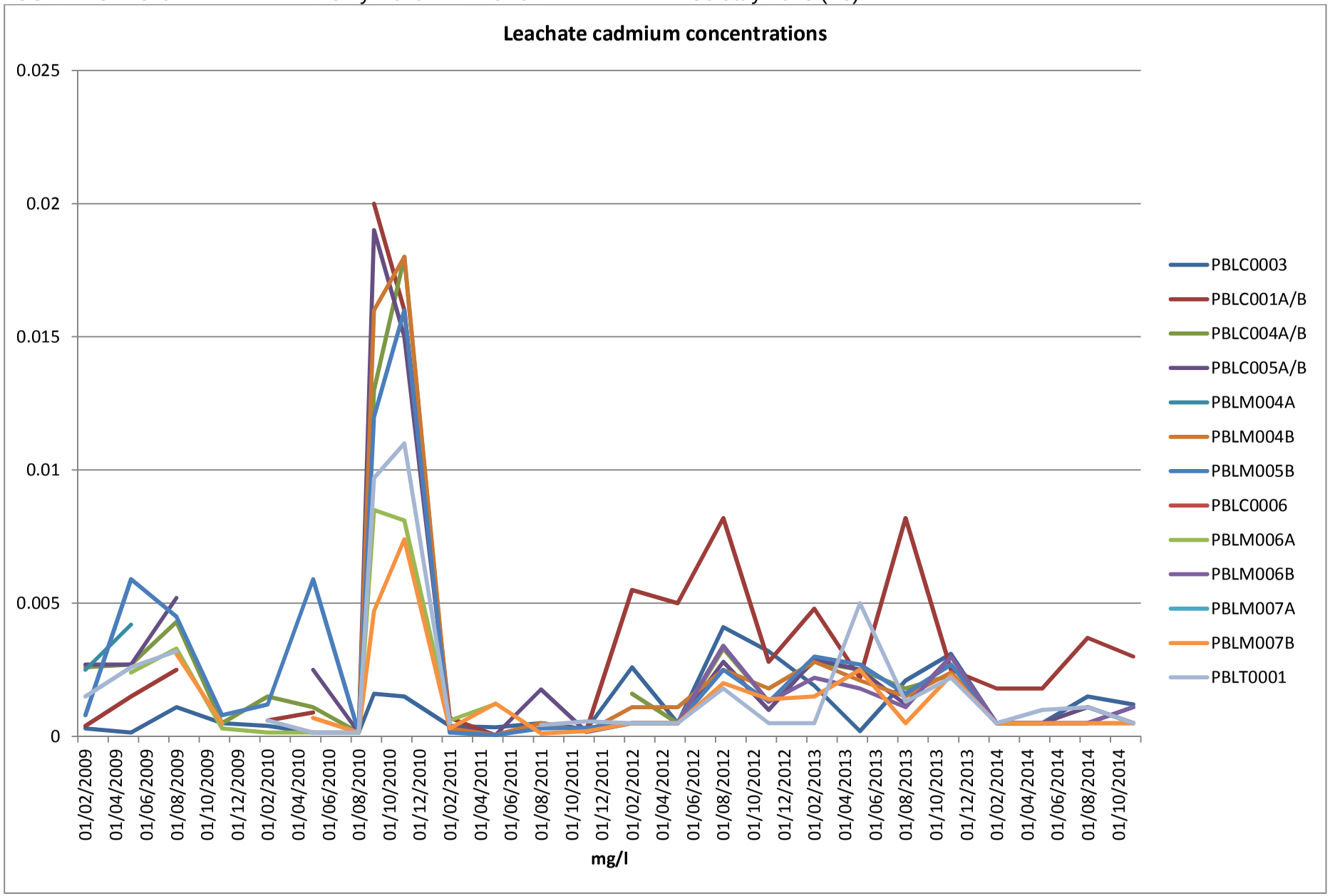
Drawing 1; Cross-section 1 (taken from Reference 1), normal operating conditions

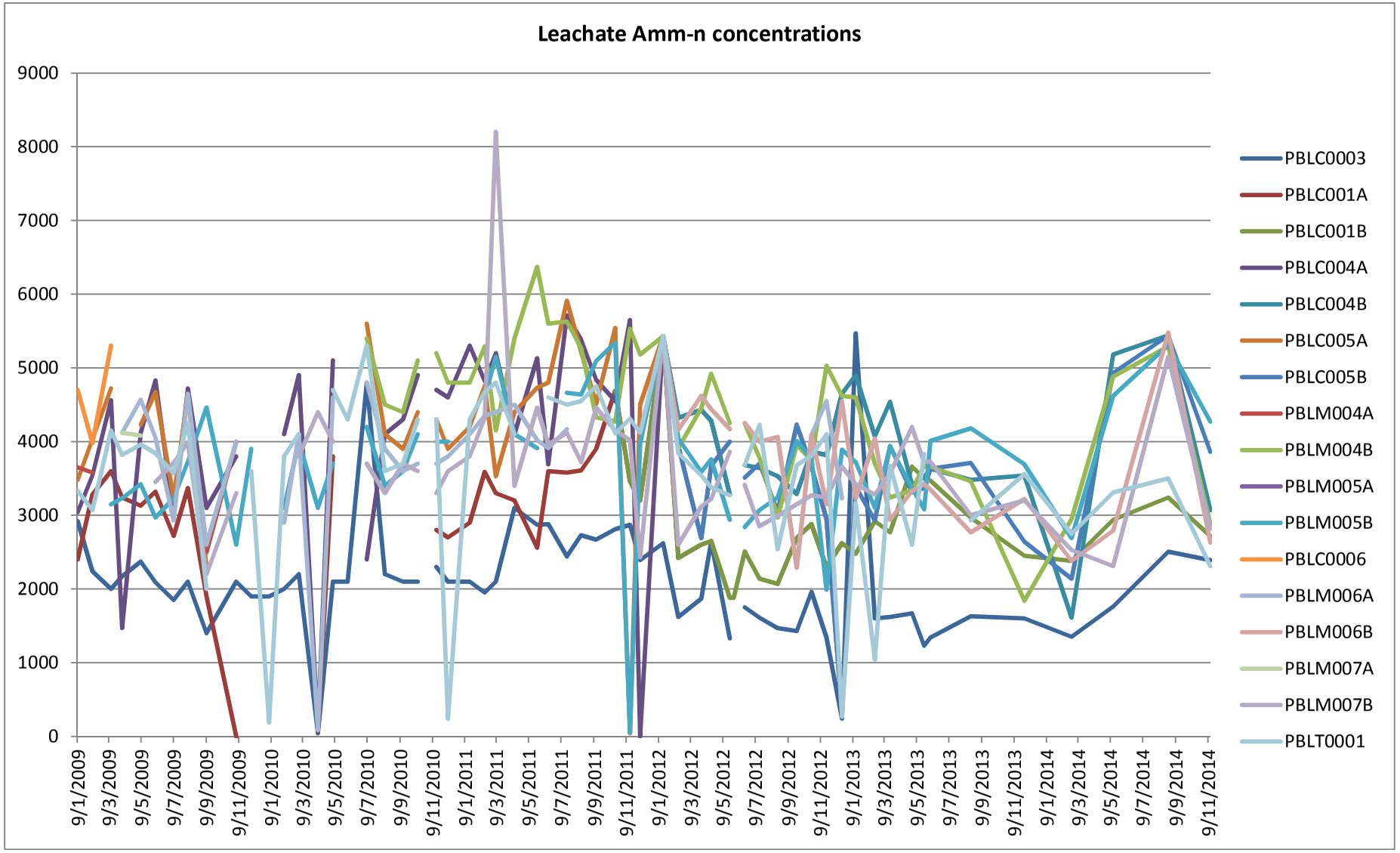


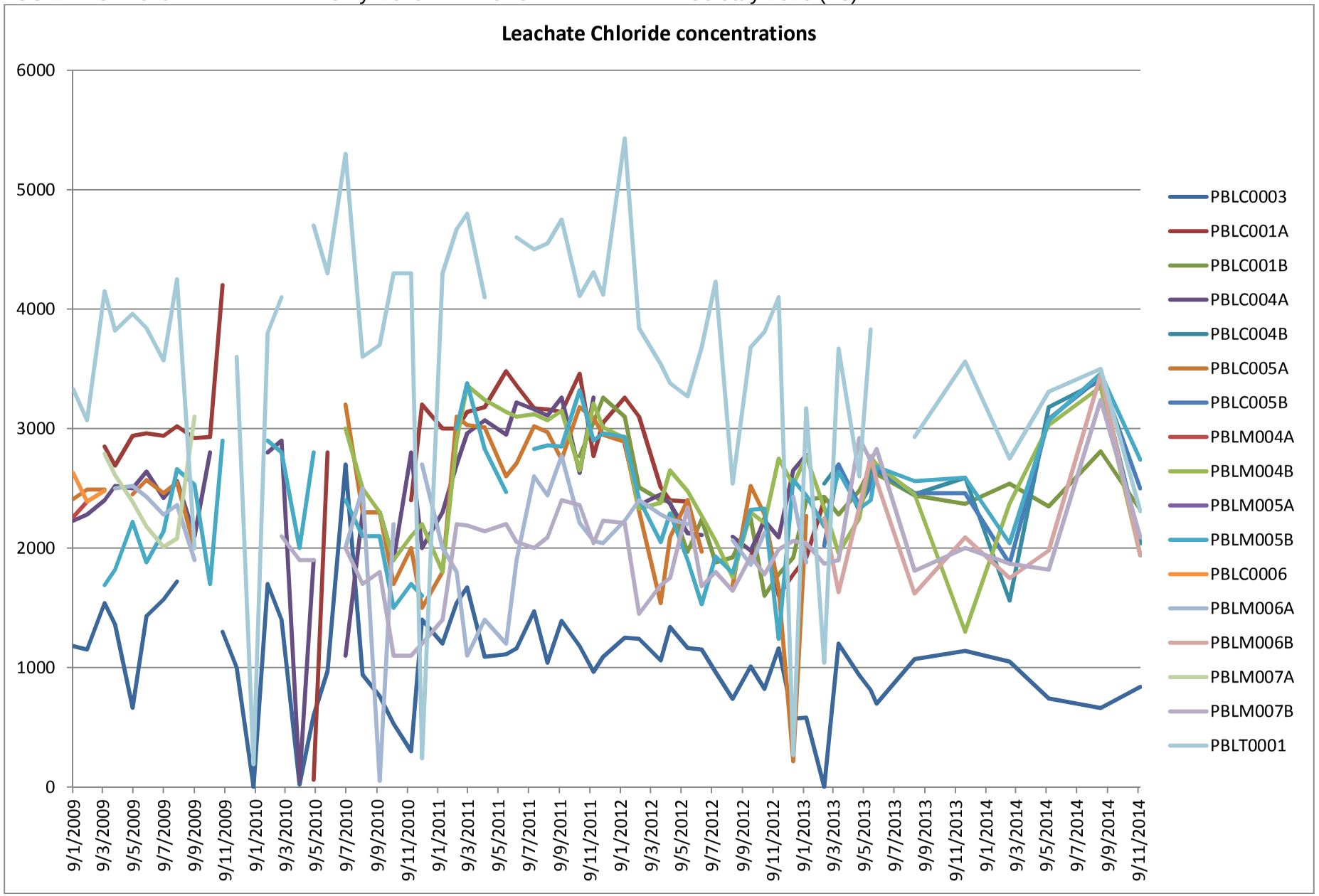
Appendix 2 Time Series graphs of leachate quality

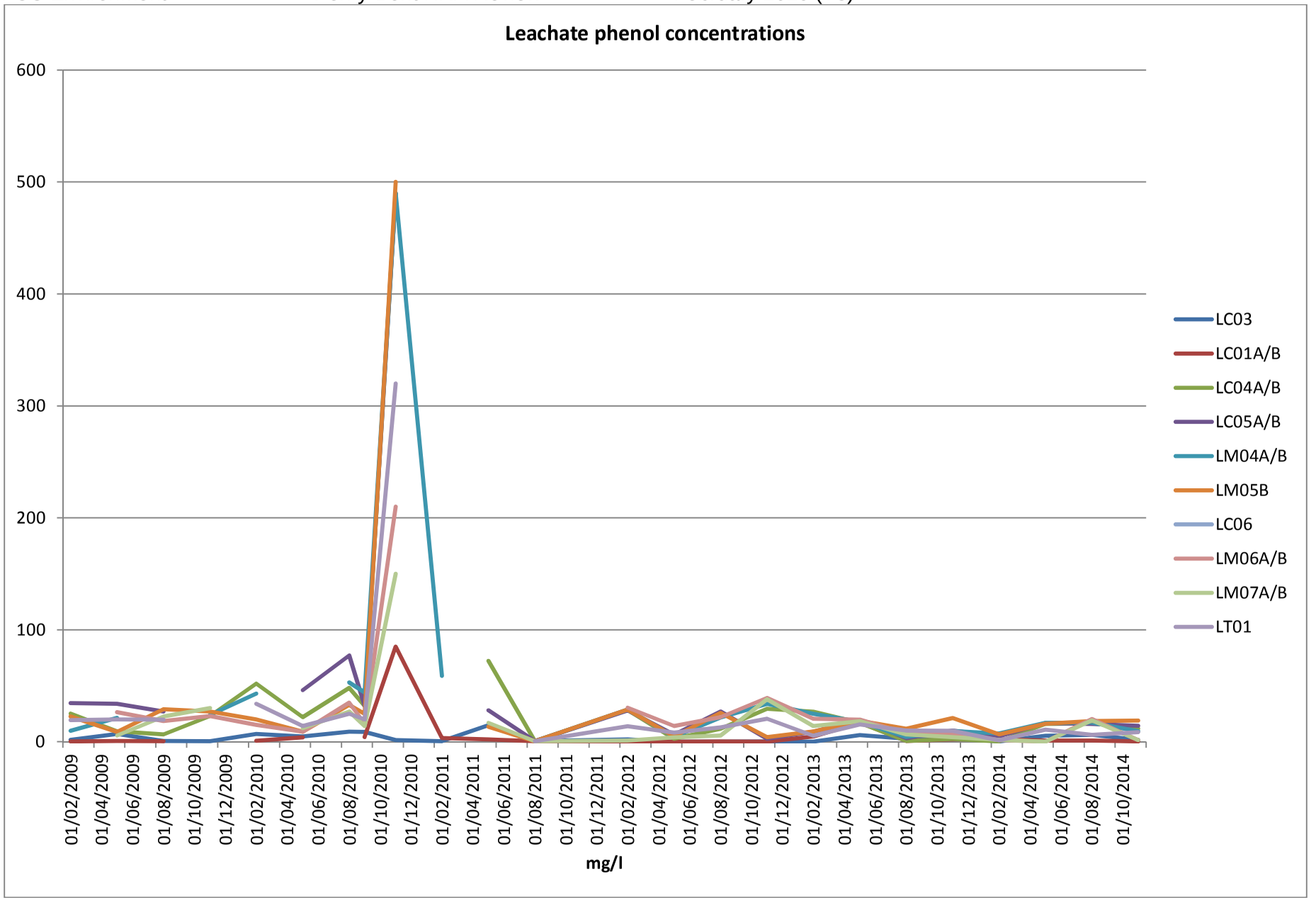



Leachate naphthalene concentrations
50
45
40
35
30
25
20
15
10
5
0
01/05/2010
01/07/2010
01/09/2010
01/11/2010
01/01/2011
01/03/2011
01/05/2011
01/07/2011
01/09/2011
01/11/2011
01/01/2012
01/03/2012
01/05/2012
01/07/2012
01/09/2012
01/11/2012
01/01/2013
01/03/2013
01/05/2013
01/07/2013
01/09/2013
01/11/2013
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
µg/l
LC03
LC01AB
LC04A
LC05A
LM04B
LM05B
LM06A/B
LM07B
LT01

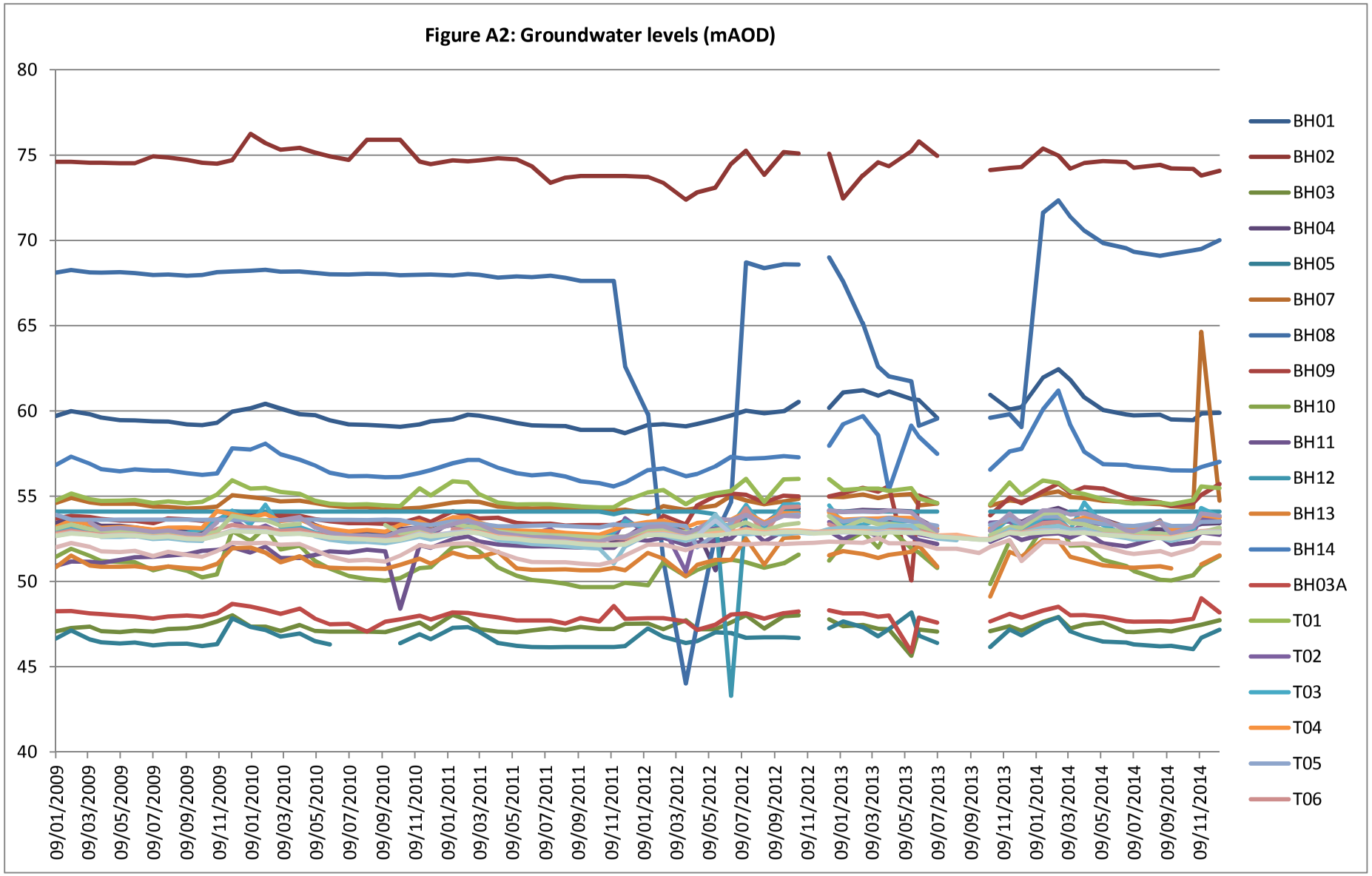

Leachate cadmium concentrations
0.025
0.02
0.015
0.01
0.005
0
01/02/2009
01/04/2009
01/06/2009
01/08/2009
01/10/2009
01/12/2009
01/02/2010
01/04/2010
01/06/2010
01/08/2010
01/10/2010
01/12/2010
01/02/2011
01/04/2011
01/06/2011
01/08/2011
01/10/2011
01/12/2011
01/02/2012
01/04/2012
01/06/2012
01/08/2012
01/10/2012
01/12/2012
01/02/2013
01/04/2013
01/06/2013
01/08/2013
01/10/2013
01/12/2013
01/02/2014
01/04/2014
01/06/2014
01/08/2014
01/10/2014
mg/l
PBLC0003
PBLC001A/B
PBLC004A/B
PBLC005A/B
PBLM004A
PBLM004B
PBLM005B
PBLC0006
PBLM006A
PBLM006B
PBLM007A
PBLM007B
PBLT0001

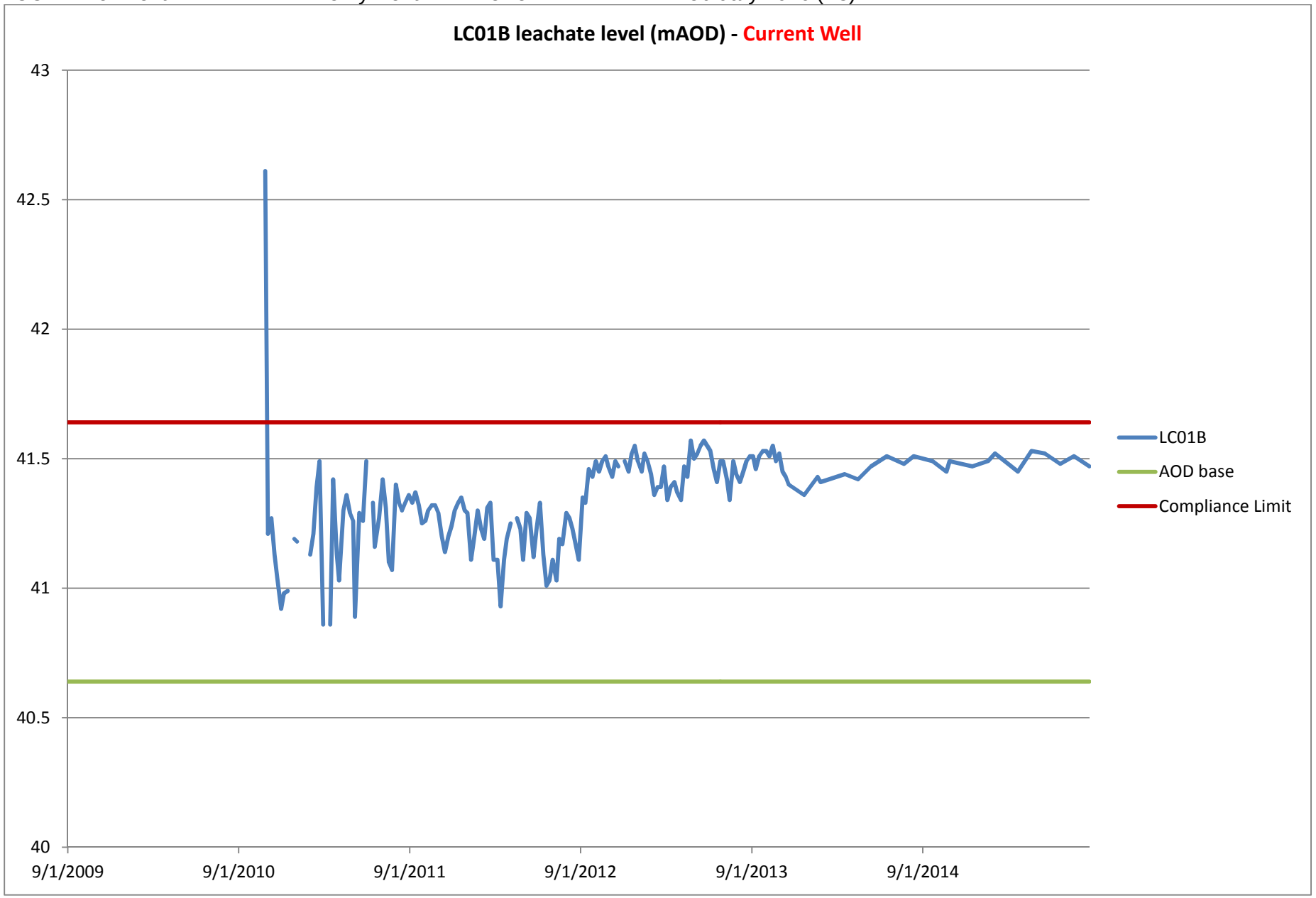

Leachate Amm-n concentrations
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
9/1/2009
9/3/2009
9/5/2009
9/7/2009
9/9/2009
9/11/2009
9/1/2010
9/3/2010
9/5/2010
9/7/2010
9/9/2010
9/11/2010
9/1/2011
9/3/2011
9/5/2011
9/7/2011
9/9/2011
9/11/2011
9/1/2012
9/3/2012
9/5/2012
9/7/2012
9/9/2012
9/11/2012
9/1/2013
9/3/2013
9/5/2013
9/7/2013
9/9/2013
9/11/2013
9/1/2014
9/3/2014
9/5/2014
9/7/2014
9/9/2014
9/11/2014
PBLC0003
PBLC001A
PBLC001B
PBLC004A
PBLC004B
PBLC005A
PBLC005B
PBLM004A
PBLM004B
PBLM005A
PBLM005B
PBLC0006
PBLM006A
PBLM006B
PBLM007A
PBLM007B
PBLT0001

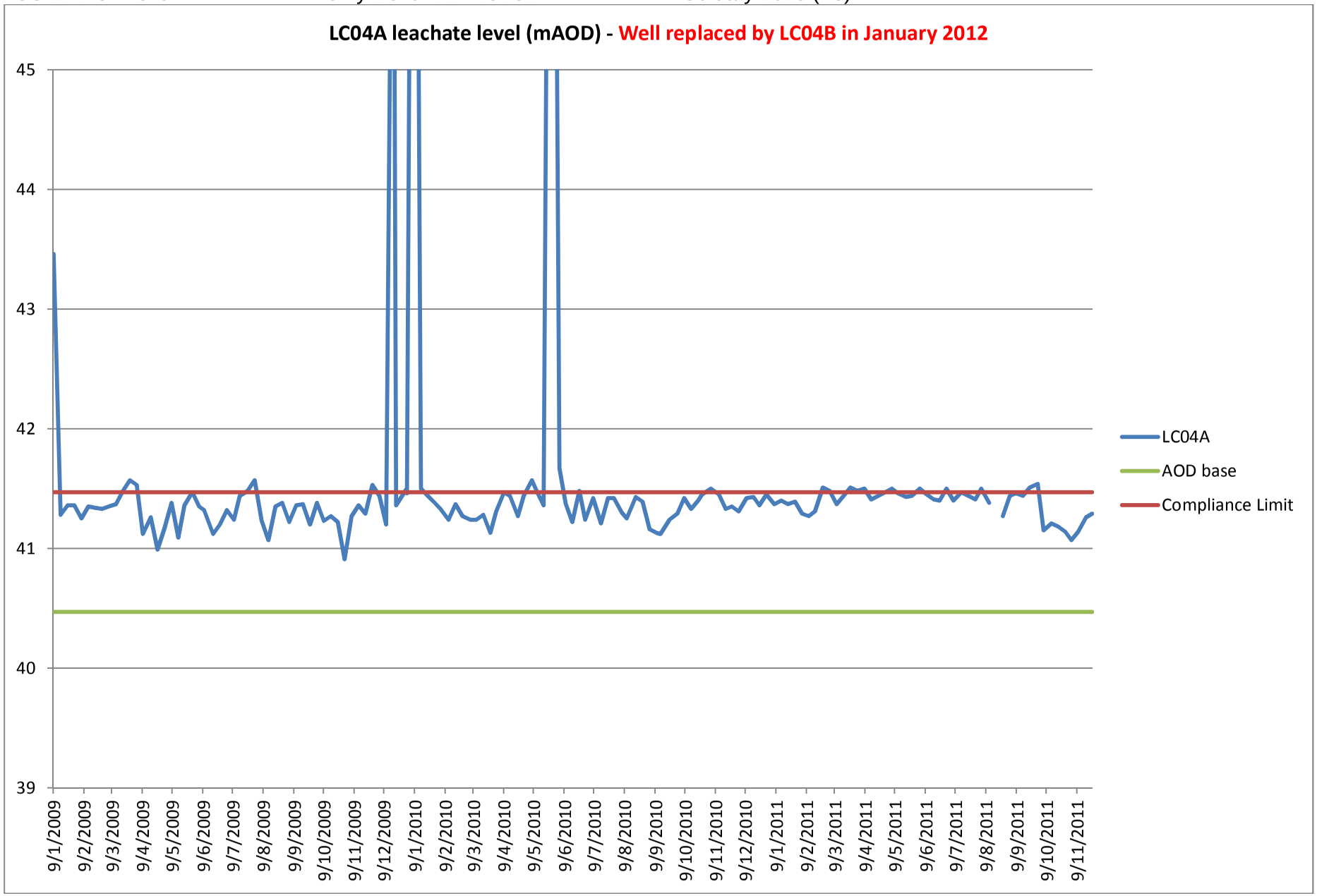

Leachate Chloride concentrations
6000
5000
4000
3000
2000
1000
0
9/1/2009
9/3/2009
9/5/2009
9/7/2009
9/9/2009
9/11/2009
9/1/2010
9/3/2010
9/5/2010
9/7/2010
9/9/2010
9/11/2010
9/1/2011
9/3/2011
9/5/2011
9/7/2011
9/9/2011
9/11/2011
9/1/2012
9/3/2012
9/5/2012
9/7/2012
9/9/2012
9/11/2012
9/1/2013
9/3/2013
9/5/2013
9/7/2013
9/9/2013
9/11/2013
9/1/2014
9/3/2014
9/5/2014
9/7/2014
9/9/2014
9/11/2014
PBLC0003
PBLC001A
PBLC001B
PBLC004A
PBLC004B
PBLC005A
PBLC005B
PBLM004A
PBLM004B
PBLM005A
PBLM005B
PBLC0006
PBLM006A
PBLM006B
PBLM007A
PBLM007B
PBLT0001

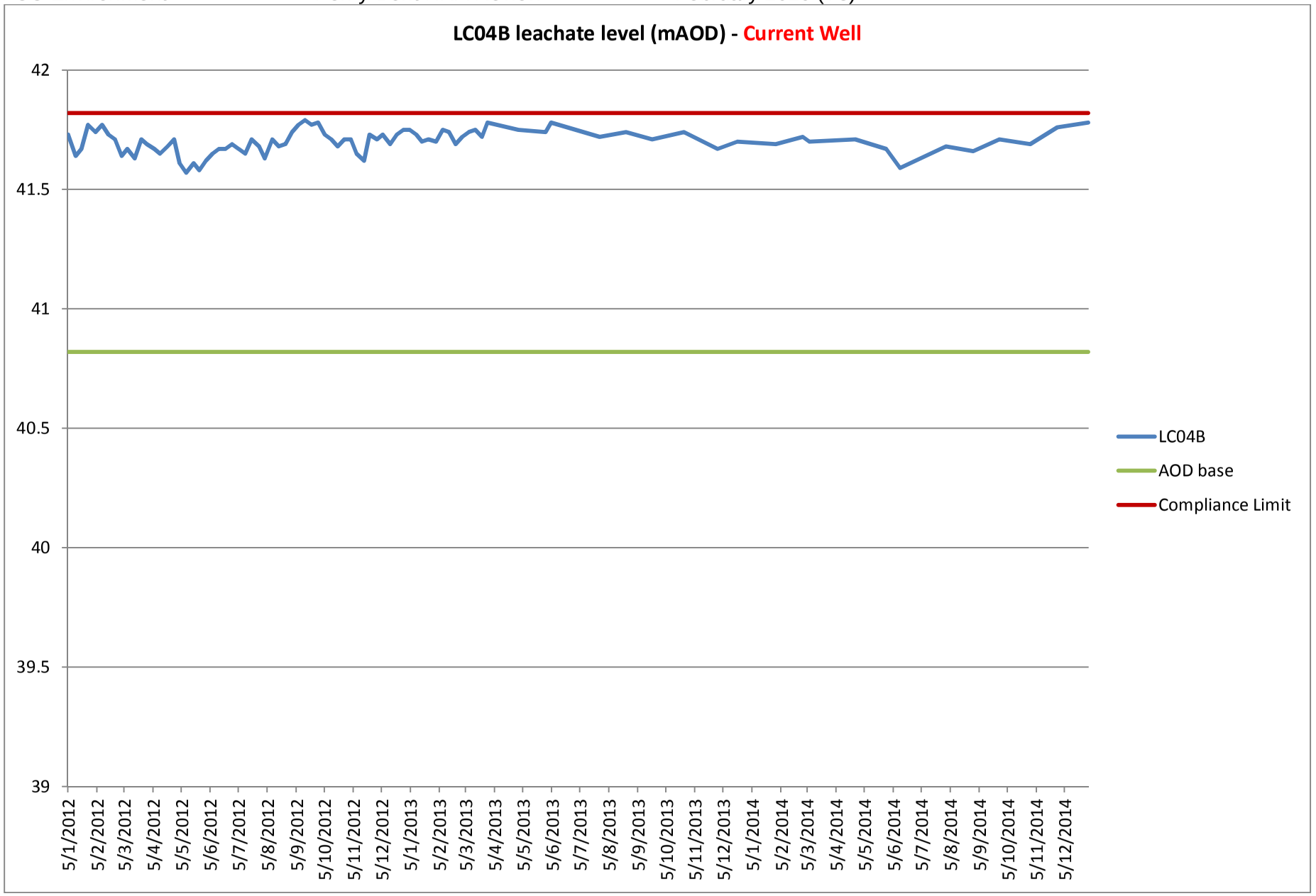

Leachate phenol concentrations
600
500
400
300
200
100
0
01/02/2009
01/04/2009
01/06/2009
01/08/2009
01/10/2009
01/12/2009
01/02/2010
01/04/2010
01/06/2010
01/08/2010
01/10/2010
01/12/2010
01/02/2011
01/04/2011
01/06/2011
01/08/2011
01/10/2011
01/12/2011
01/02/2012
01/04/2012
01/06/2012
01/08/2012
01/10/2012
01/12/2012
01/02/2013
01/04/2013
01/06/2013
01/08/2013
01/10/2013
01/12/2013
01/02/2014
01/04/2014
01/06/2014
01/08/2014
01/10/2014
mg/l
LC03
LC01A/B
LC04A/B
LC05A/B
LM04A/B
LM05B
LC06
LM06A/B
LM07A/B
LT01

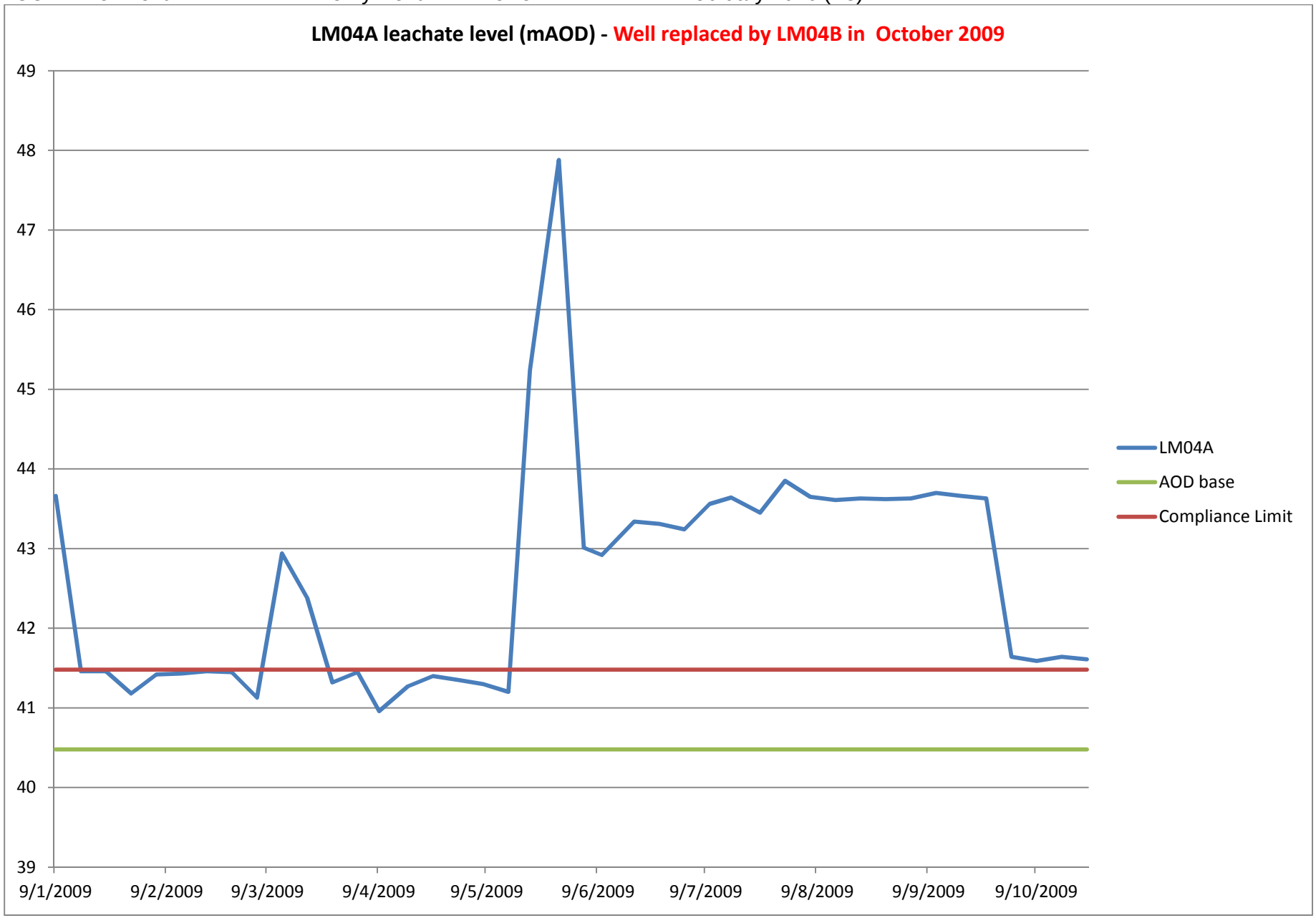
Appendix 3 Leachate and groundwater hydrographs

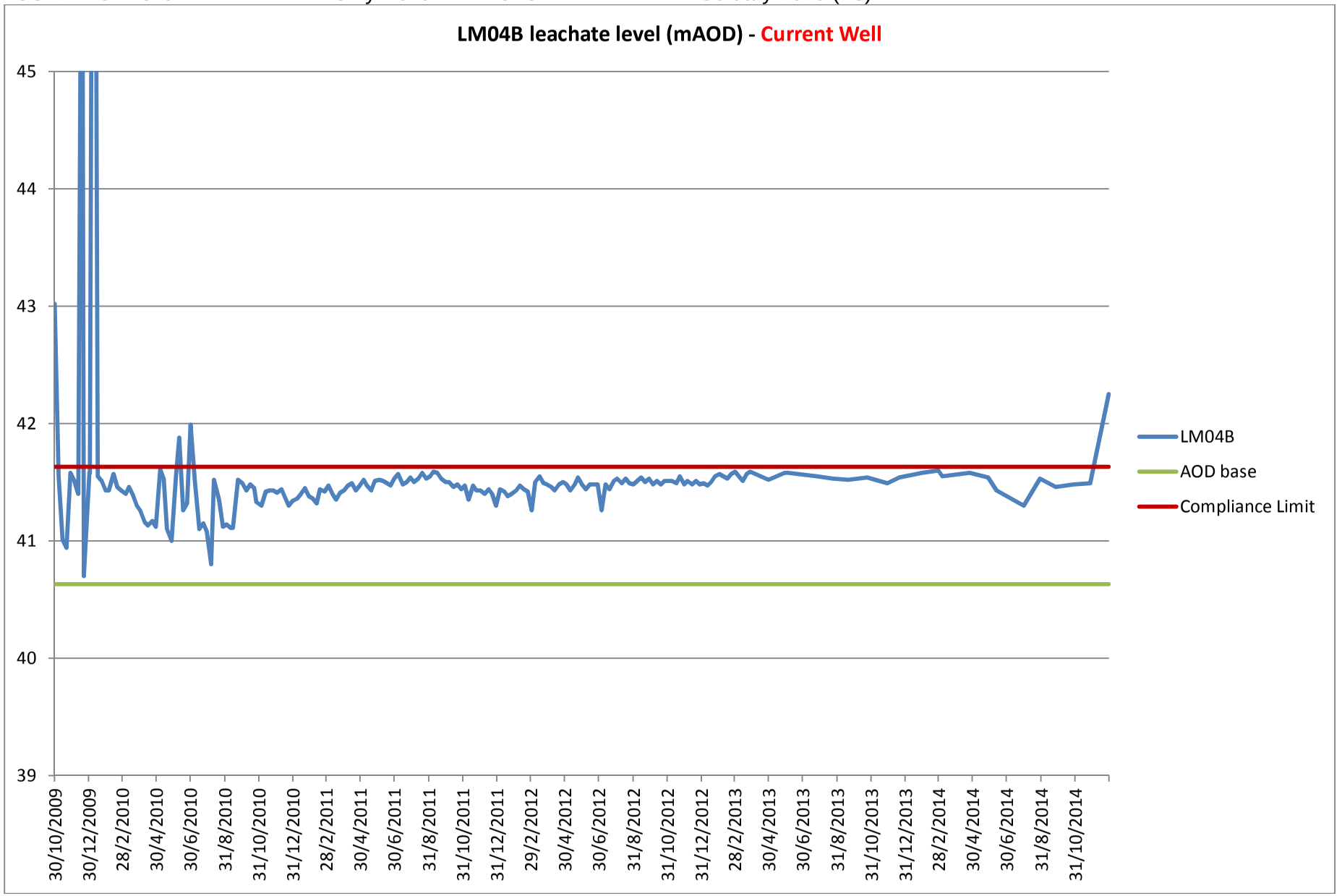


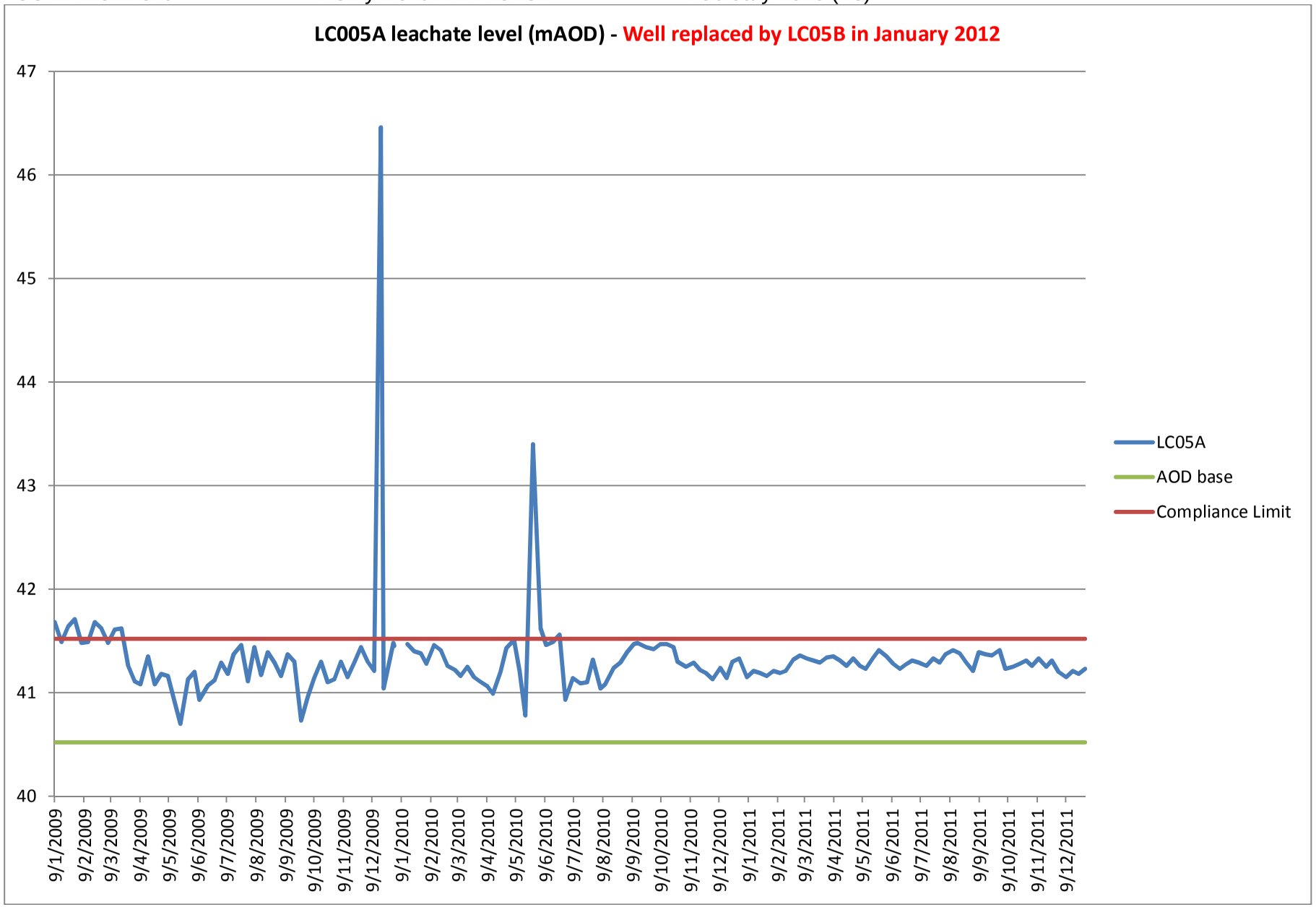

LC01B leachate level (mAOD) - Current Well
43
42.5
42
41.5
41
40.5
40
9/1/2009
9/1/2010
9/1/2011
9/1/2012
9/1/2013
9/1/2014
LC01B
AOD base
Compliance Limit

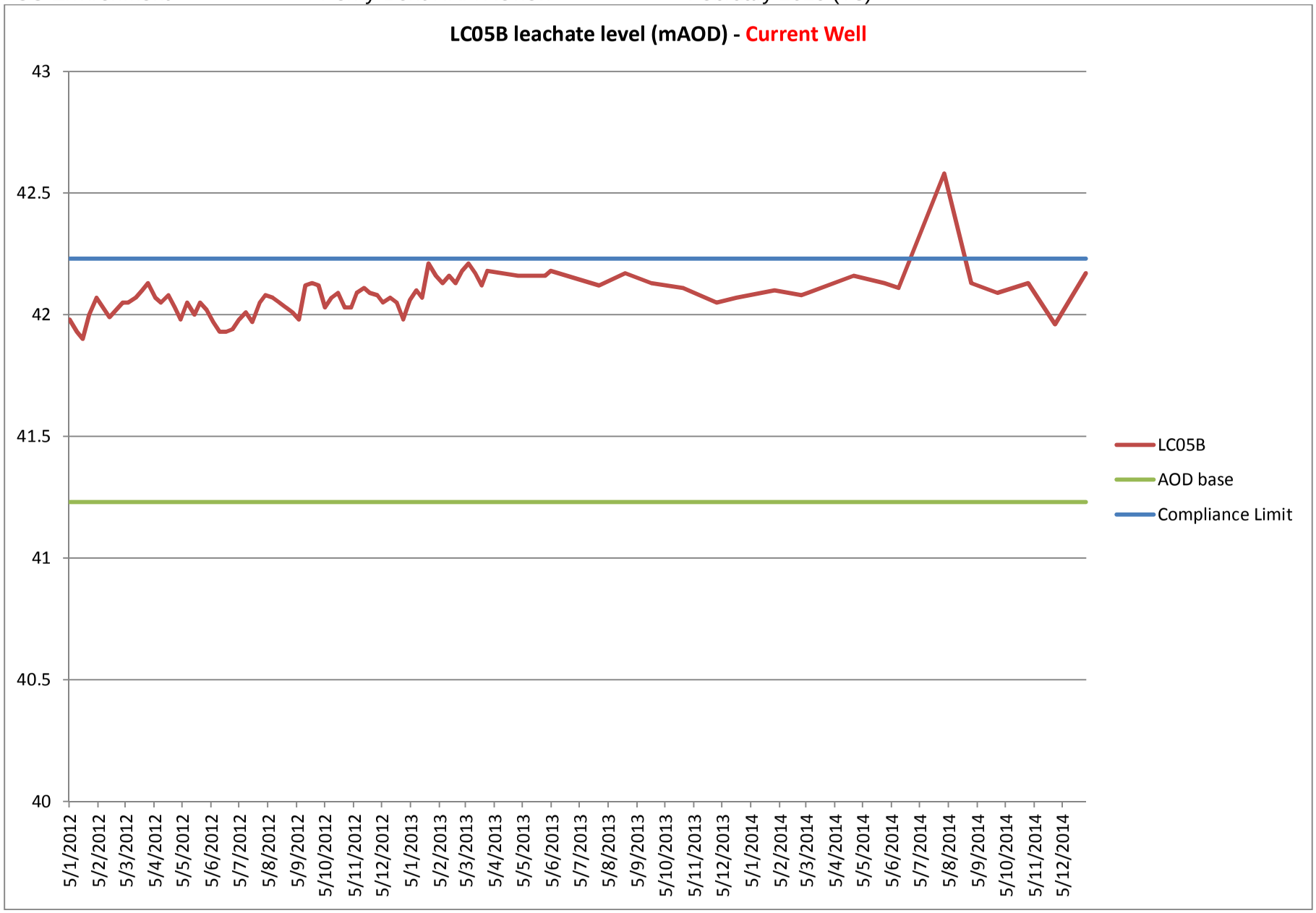

LC04A leachate level (mAOD) - Well replaced by LC04B in January 2012
45
44
43
42
41
40
39
9/1/2009
9/2/2009
9/3/2009
9/4/2009
9/5/2009
9/6/2009
9/7/2009
9/8/2009
9/9/2009
9/10/2009
9/11/2009
9/12/2009
9/1/2010
9/2/2010
9/3/2010
9/4/2010
9/5/2010
9/6/2010
9/7/2010
9/8/2010
9/9/2010
9/10/2010
9/11/2010
9/12/2010
9/1/2011
9/2/2011
9/3/2011
9/4/2011
9/5/2011
9/6/2011
9/7/2011
9/8/2011
9/9/2011
9/10/2011
9/11/2011
LC04A
AOD base
Compliance Limit

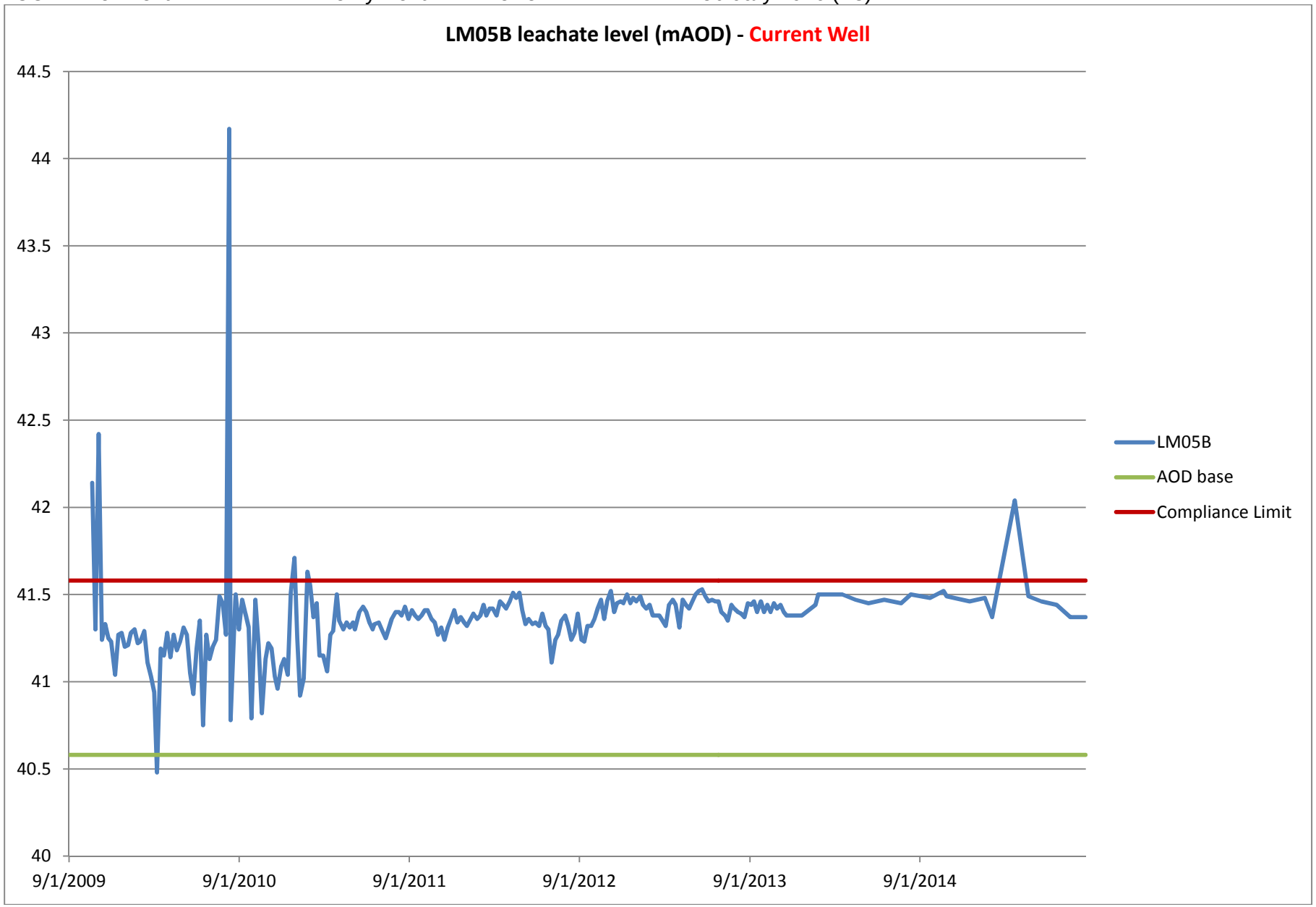

LC04B leachate level (mAOD) - Current Well
42
41.5
41
40.5
40
39.5
39
5/1/2012
5/2/2012
5/3/2012
5/4/2012
5/5/2012
5/6/2012
5/7/2012
5/8/2012
5/9/2012
5/10/2012
5/11/2012
5/12/2012
5/1/2013
5/2/2013
5/3/2013
5/4/2013
5/5/2013
5/6/2013
5/7/2013
5/8/2013
5/9/2013
5/10/2013
5/11/2013
5/12/2013
5/1/2014
5/2/2014
5/3/2014
5/4/2014
5/5/2014
5/6/2014
5/7/2014
5/8/2014
5/9/2014
5/10/2014
5/11/2014
5/12/2014
LC04B
AOD base
Compliance Limit

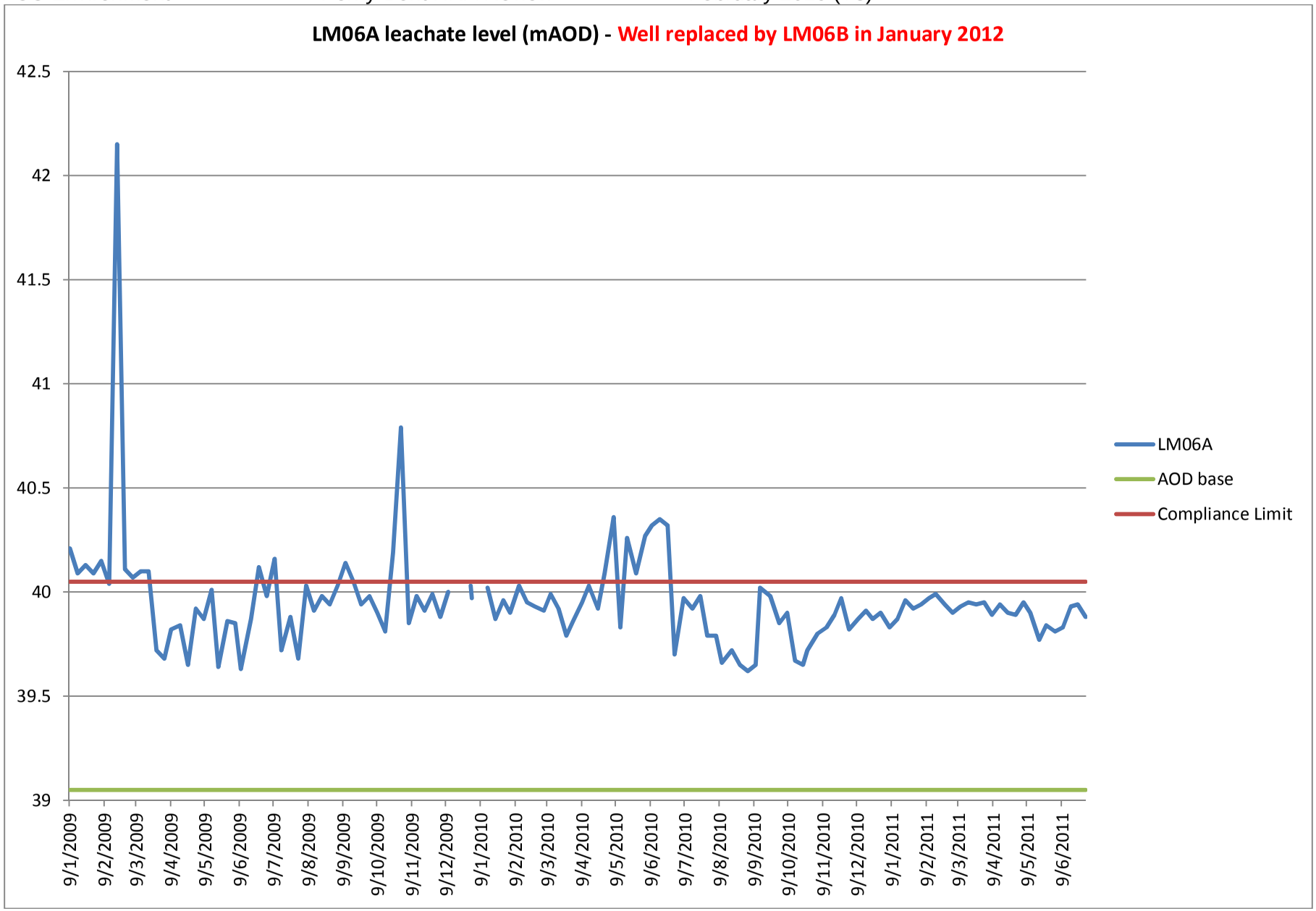

LM04A leachate level (mAOD) - Well replaced by LM04B in October 2009
49
48
47
46
45
44
43
42
41
40
39
9/1/2009
9/2/2009
9/3/2009
9/4/2009
9/5/2009
9/6/2009
9/7/2009
9/8/2009
9/9/2009
9/10/2009
LM04A
AOD base
Compliance Limit

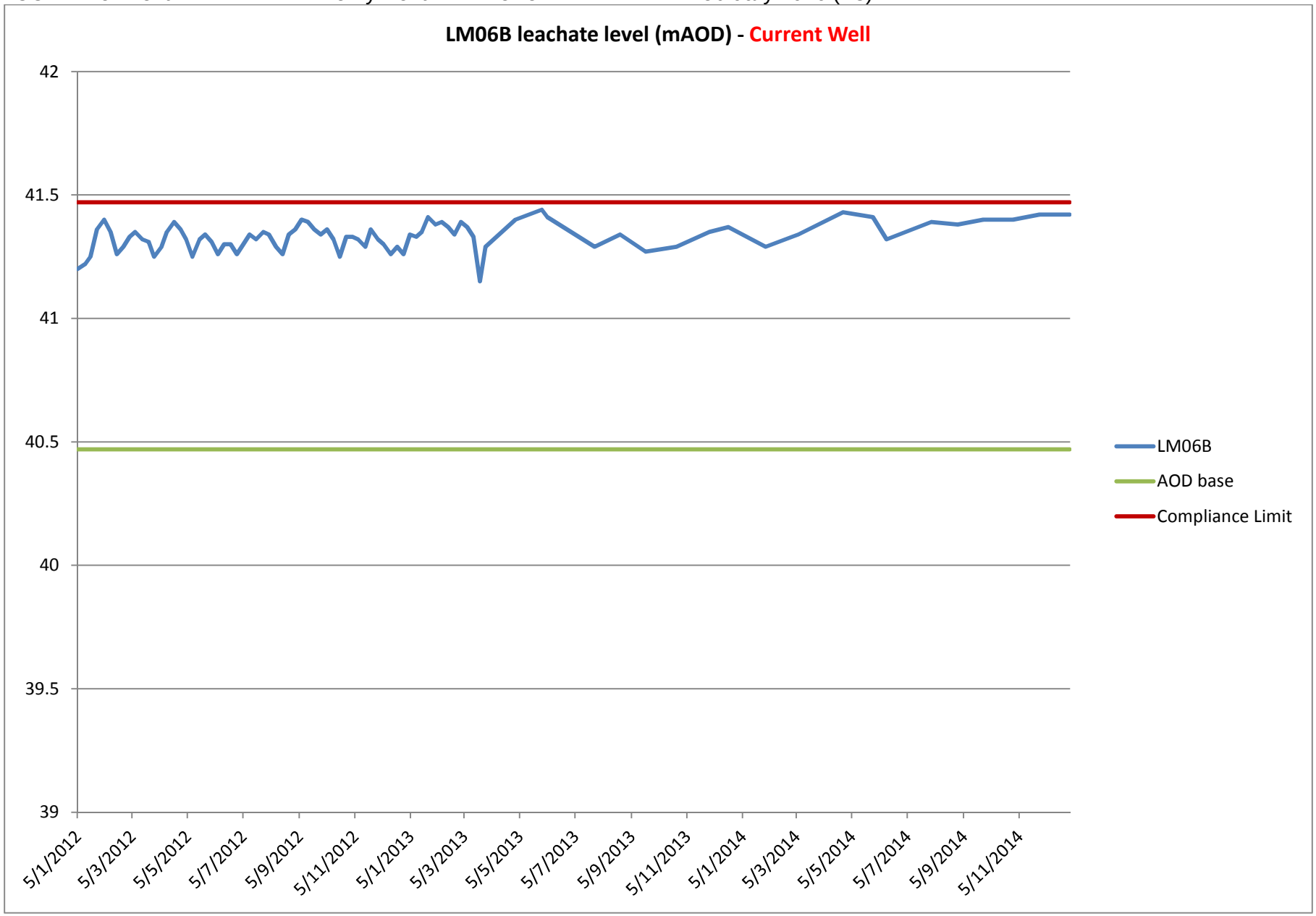

LM04B leachate level (mAOD) - Current Well
45
44
43
42
41
40
39
30/10/2009
30/12/2009
28/2/2010
30/4/2010
30/6/2010
31/8/2010
31/10/2010
31/12/2010
28/2/2011
30/4/2011
30/6/2011
31/8/2011
31/10/2011
31/12/2011
29/2/2012
30/4/2012
30/6/2012
31/8/2012
31/10/2012
31/12/2012
28/2/2013
30/4/2013
30/6/2013
31/8/2013
31/10/2013
31/12/2013
28/2/2014
30/4/2014
30/6/2014
31/8/2014
31/10/2014
LM04B
AOD base
Compliance Limit

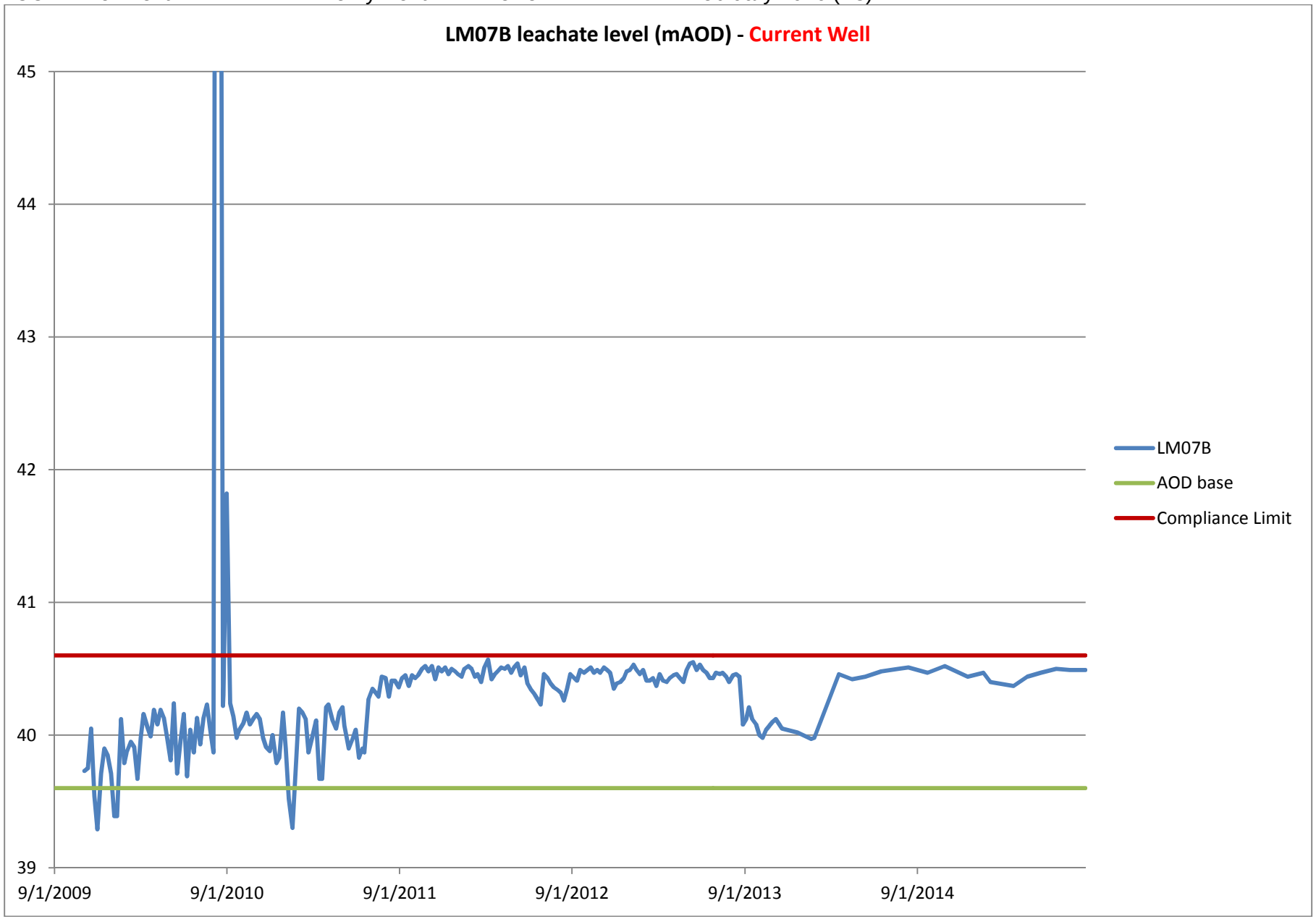

LC005A leachate level (mAOD) - Well replaced by LC05B in January 2012
47
46
45
44
43
42
41
40
9/1/2009
9/2/2009
9/3/2009
9/4/2009
9/5/2009
9/6/2009
9/7/2009
9/8/2009
9/9/2009
9/10/2009
9/11/2009
9/12/2009
9/1/2010
9/2/2010
9/3/2010
9/4/2010
9/5/2010
9/6/2010
9/7/2010
9/8/2010
9/9/2010
9/10/2010
9/11/2010
9/12/2010
9/1/2011
9/2/2011
9/3/2011
9/4/2011
9/5/2011
9/6/2011
9/7/2011
9/8/2011
9/9/2011
9/10/2011
9/11/2011
9/12/2011
LC05A
AOD base
Compliance Limit

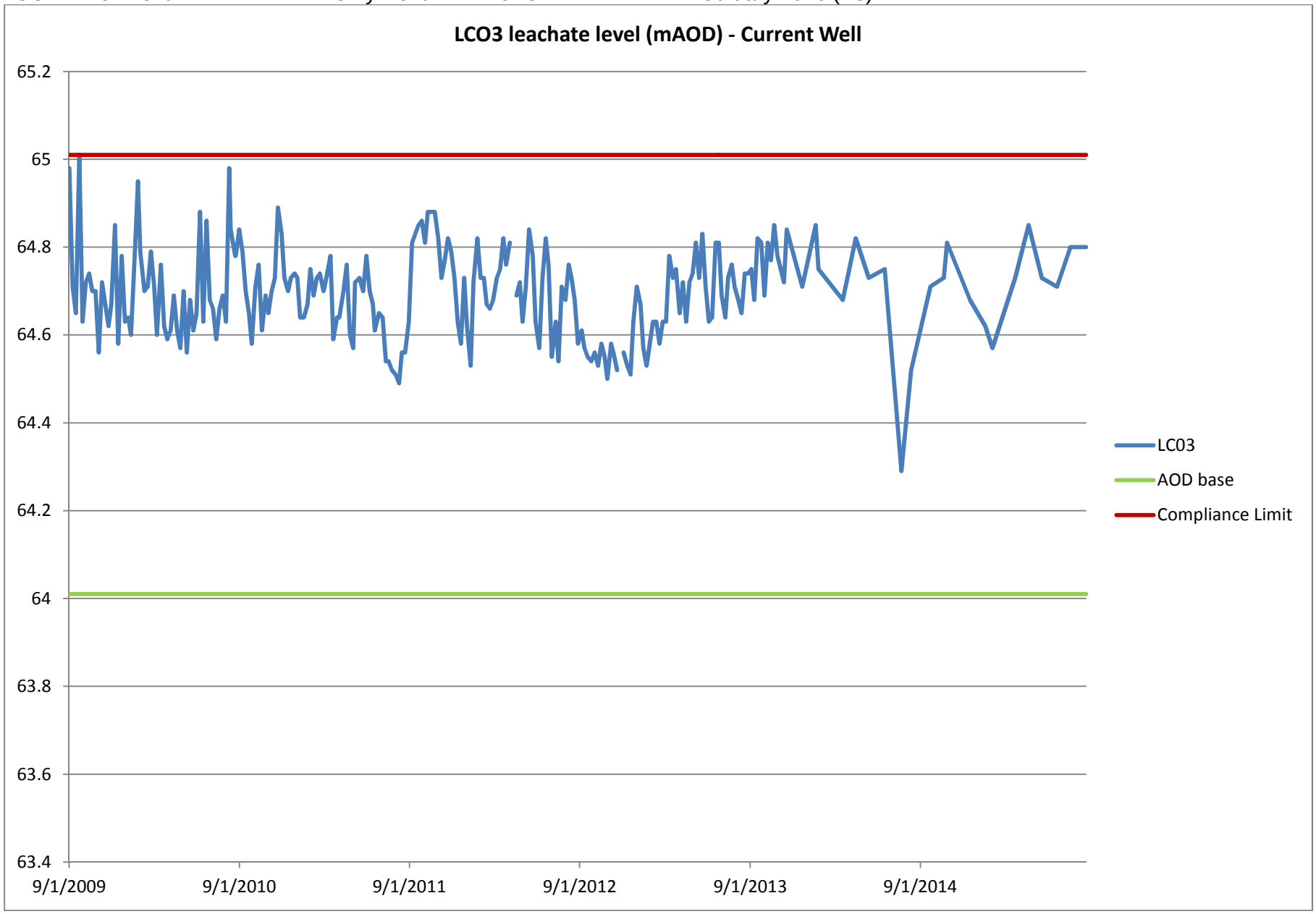

LC05B leachate level (mAOD) - Current Well
43
42.5
42
41.5
41
40.5
40
5/1/2012
5/2/2012
5/3/2012
5/4/2012
5/5/2012
5/6/2012
5/7/2012
5/8/2012
5/9/2012
5/10/2012
5/11/2012
5/12/2012
5/1/2013
5/2/2013
5/3/2013
5/4/2013
5/5/2013
5/6/2013
5/7/2013
5/8/2013
5/9/2013
5/10/2013
5/11/2013
5/12/2013
5/1/2014
5/2/2014
5/3/2014
5/4/2014
5/5/2014
5/6/2014
5/7/2014
5/8/2014
5/9/2014
5/10/2014
5/11/2014
5/12/2014
LC05B
AOD base
Compliance Limit


LM05B leachate level (mAOD) - Current Well
44.5
44
43.5
43
42.5
42
41.5
41
40.5
40
9/1/2009
9/1/2010
9/1/2011
9/1/2012
9/1/2013
9/1/2014
LM05B
AOD base
Compliance Limit

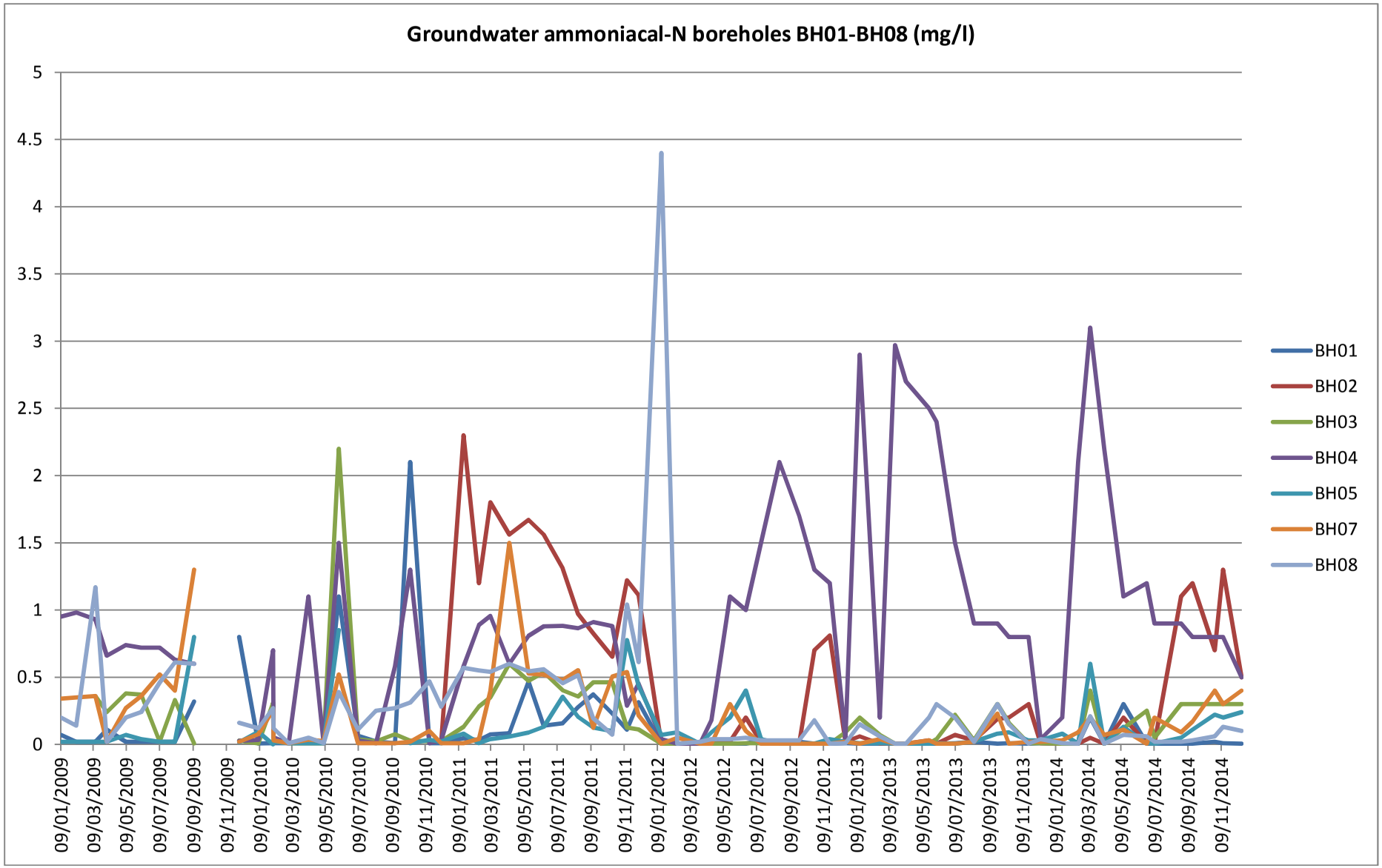

LM06A leachate level (mAOD) - Well replaced by LM06B in January 2012
42.5
42
41.5
41
40.5
40
39.5
39
9/1/2009
9/2/2009
9/3/2009
9/4/2009
9/5/2009
9/6/2009
9/7/2009
9/8/2009
9/9/2009
9/10/2009
9/11/2009
9/12/2009
9/1/2010
9/2/2010
9/3/2010
9/4/2010
9/5/2010
9/6/2010
9/7/2010
9/8/2010
9/9/2010
9/10/2010
9/11/2010
9/12/2010
9/1/2011
9/2/2011
9/3/2011
9/4/2011
9/5/2011
9/6/2011
LM06A
AOD base
Compliance Limit

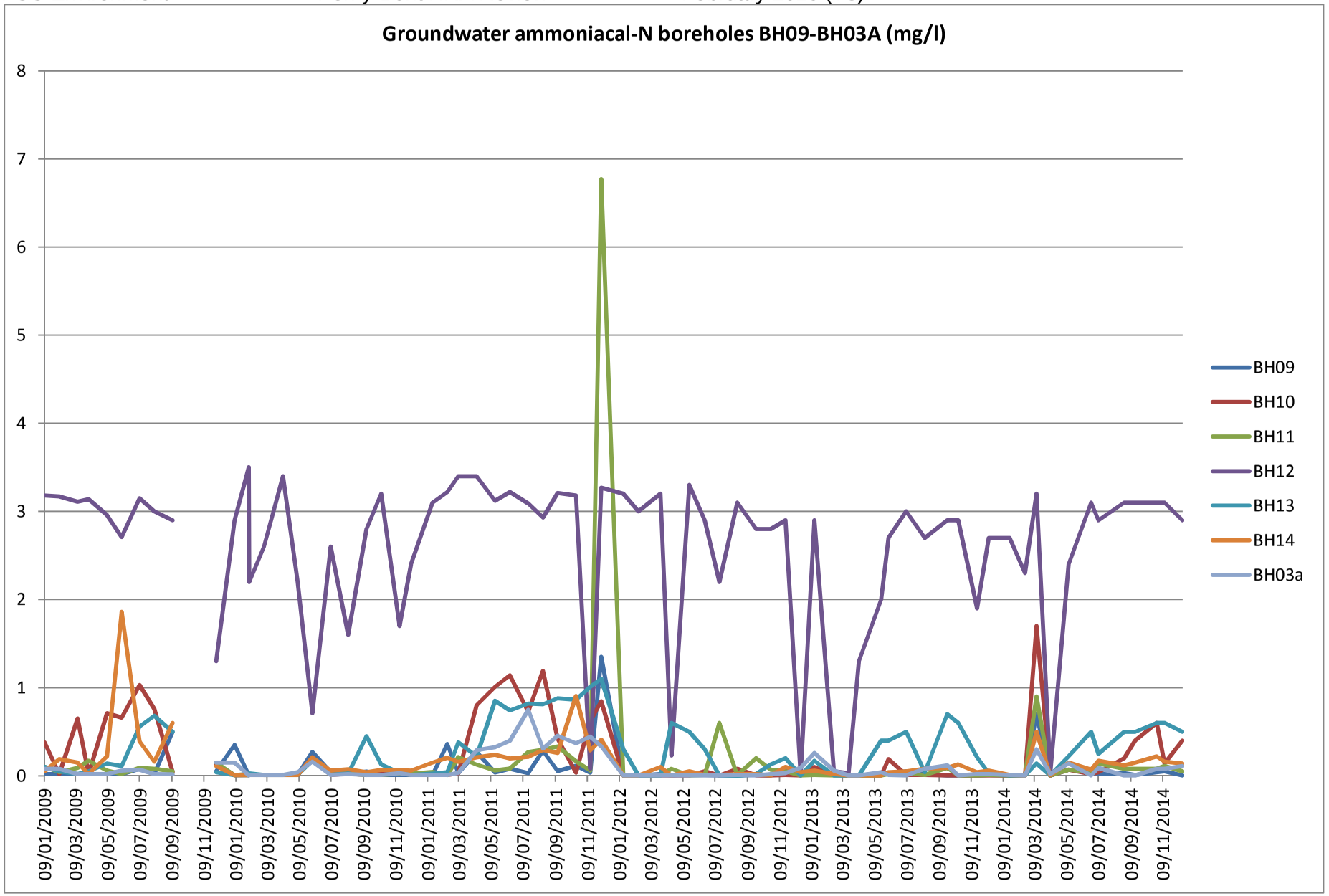

LM06B leachate level (mAOD) - Current Well
42
41.5
41
40.5
40
39.5
39
5/1/2012
5/3/2012
5/5/2012
5/7/2012
5/9/2012
5/11/2012
5/1/2013
5/3/2013
5/5/2013
5/7/2013
5/9/2013
5/11/2013
5/1/2014
5/3/2014
5/5/2014
5/7/2014
5/9/2014
5/11/2014
LM06B
AOD base
Compliance Limit

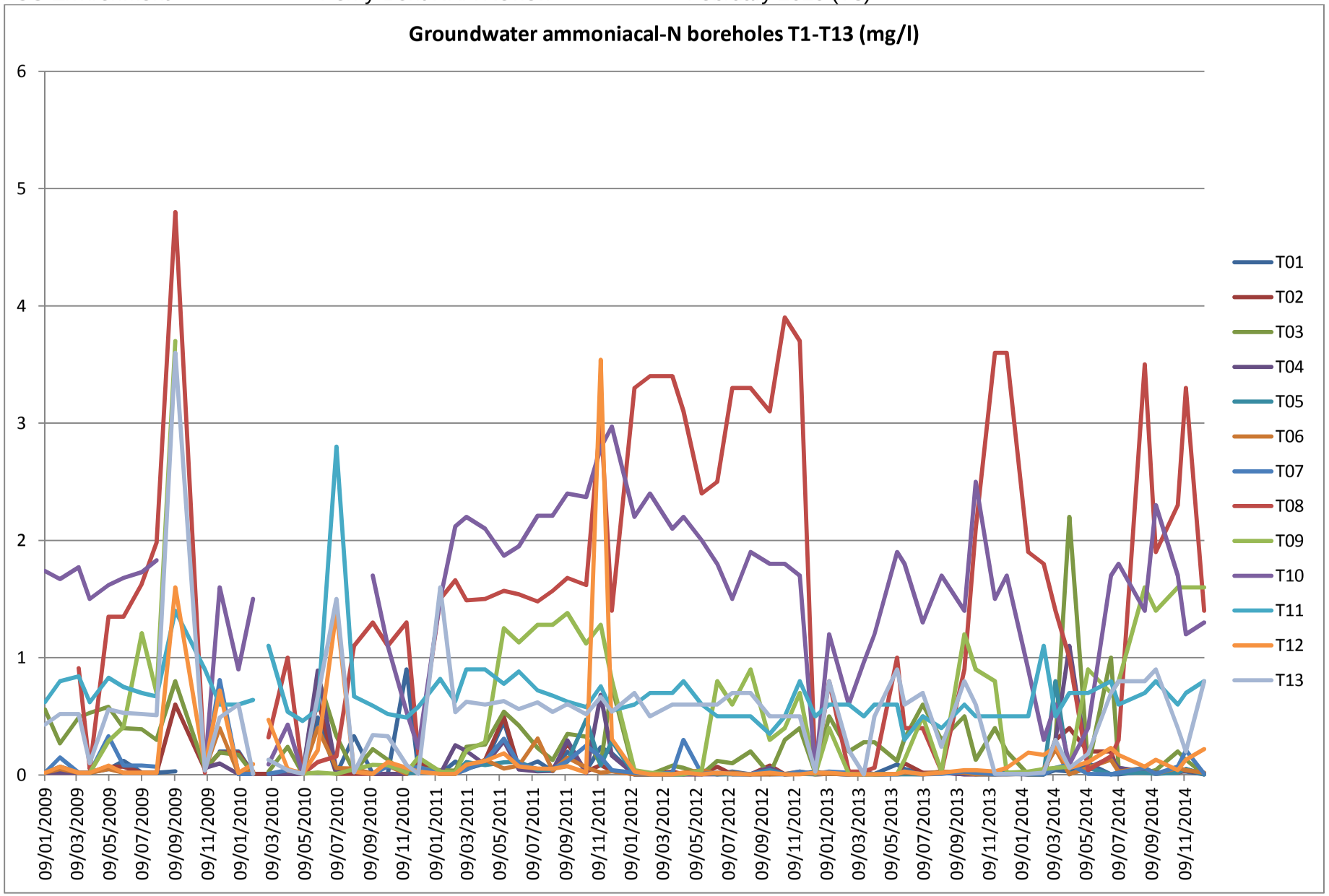

LM07B leachate level (mAOD) - Current Well
45
44
43
42
41
40
39
9/1/2009
9/1/2010
9/1/2011
9/1/2012
9/1/2013
9/1/2014
LM07B
AOD base
Compliance Limit

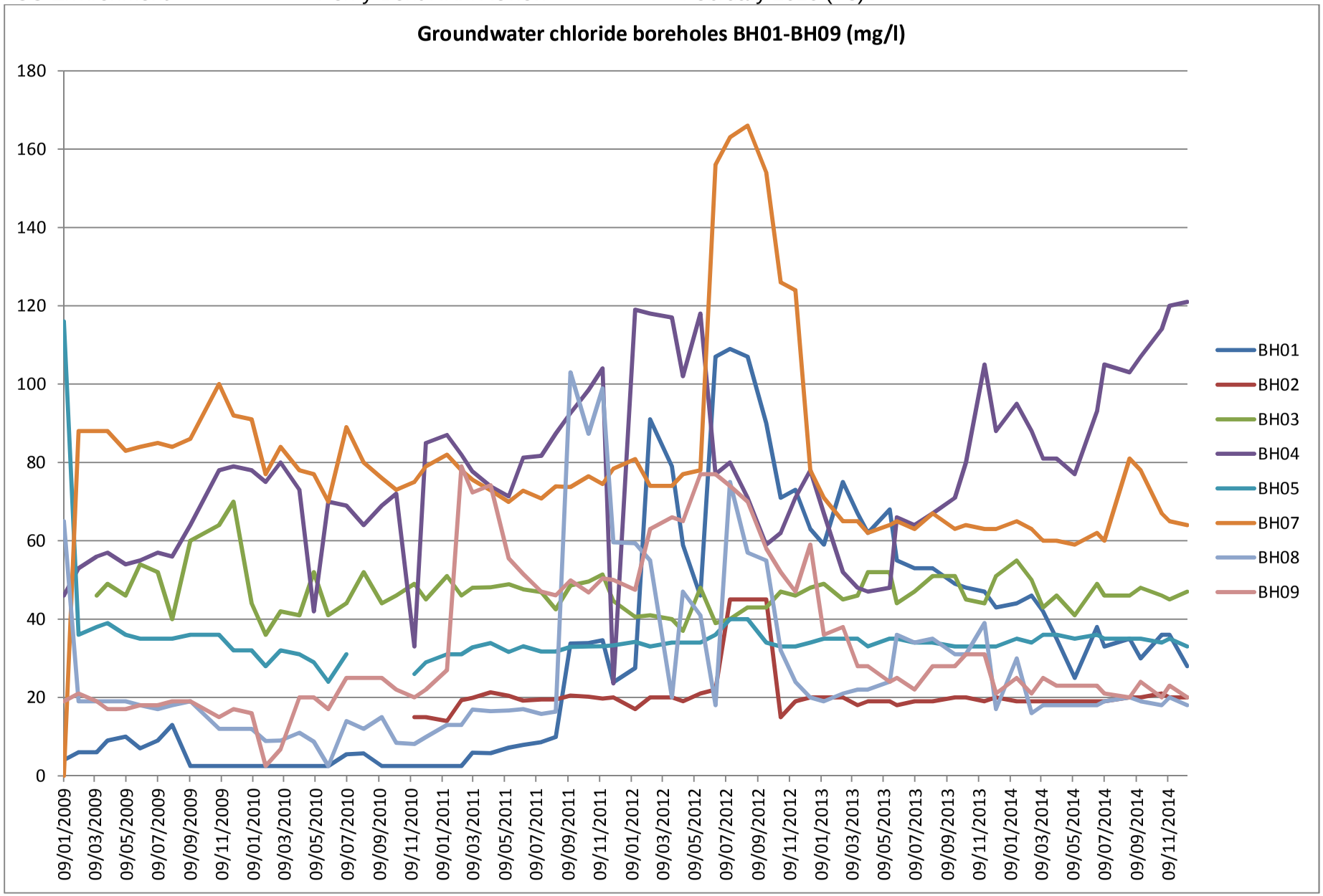

LCO3 leachate level (mAOD) - Current Well
65.2
65
64.8
64.6
64.4
64.2
64
63.8
63.6
63.4
9/1/2009
9/1/2010
9/1/2011
9/1/2012
9/1/2013
9/1/2014
LC03
AOD base
Compliance Limit

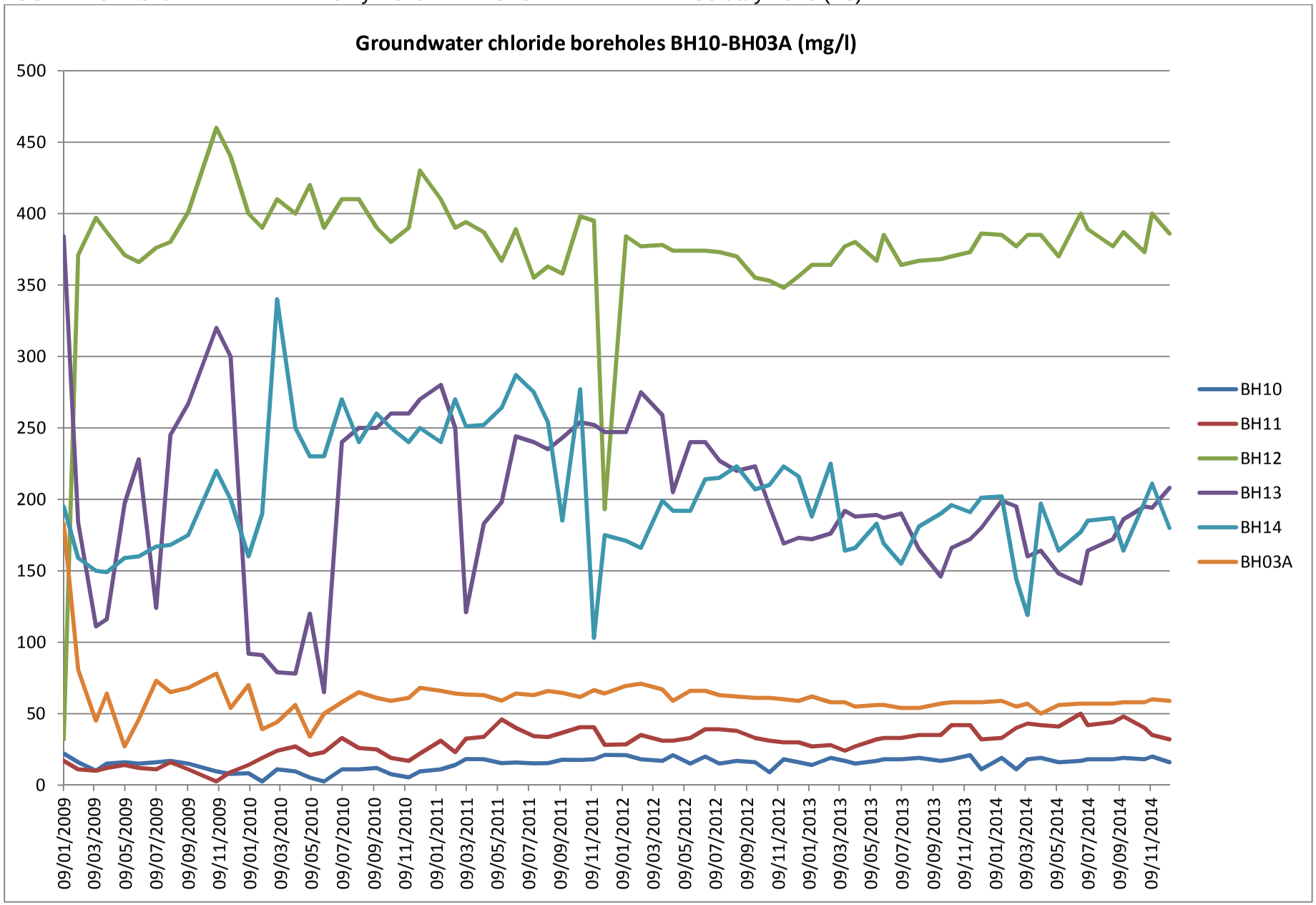
Appendix 4 Time Series graphs of groundwater quality

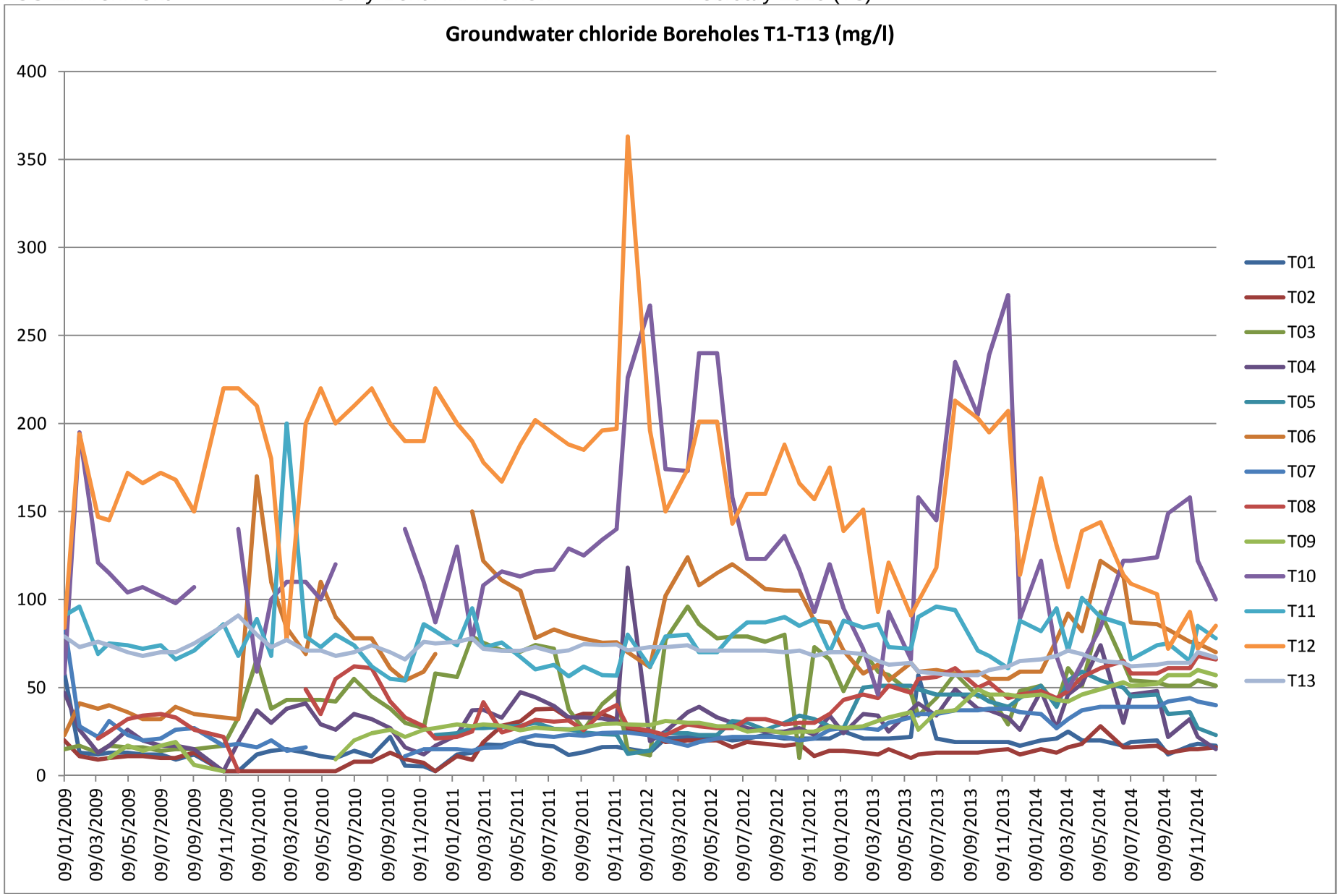



Groundwater ammoniacal-N boreholes BH09-BH03A (mg/l)
8
7
6
5
4
3
2
1
0
09/01/2009
09/03/2009
09/05/2009
09/07/2009
09/09/2009
09/11/2009
09/01/2010
09/03/2010
09/05/2010
09/07/2010
09/09/2010
09/11/2010
09/01/2011
09/03/2011
09/05/2011
09/07/2011
09/09/2011
09/11/2011
09/01/2012
09/03/2012
09/05/2012
09/07/2012
09/09/2012
09/11/2012
09/01/2013
09/03/2013
09/05/2013
09/07/2013
09/09/2013
09/11/2013
09/01/2014
09/03/2014
09/05/2014
09/07/2014
09/09/2014
09/11/2014
BH09
BH10
BH11
BH12
BH13
BH14
BH03a


Groundwater ammoniacal-N boreholes T1-T13 (mg/l)
6
5
4
3
2
1
0
09/01/2009
09/03/2009
09/05/2009
09/07/2009
09/09/2009
09/11/2009
09/01/2010
09/03/2010
09/05/2010
09/07/2010
09/09/2010
09/11/2010
09/01/2011
09/03/2011
09/05/2011
09/07/2011
09/09/2011
09/11/2011
09/01/2012
09/03/2012
09/05/2012
09/07/2012
09/09/2012
09/11/2012
09/01/2013
09/03/2013
09/05/2013
09/07/2013
09/09/2013
09/11/2013
09/01/2014
09/03/2014
09/05/2014
09/07/2014
09/09/2014
09/11/2014
T01
T02
T03
T04
T05
T06
T07
T08
T09
T10
T11
T12
T13


Groundwater chloride boreholes BH01-BH09 (mg/l)
180
160
140
120
100
80
60
40
20
0
09/01/2009
09/03/2009
09/05/2009
09/07/2009
09/09/2009
09/11/2009
09/01/2010
09/03/2010
09/05/2010
09/07/2010
09/09/2010
09/11/2010
09/01/2011
09/03/2011
09/05/2011
09/07/2011
09/09/2011
09/11/2011
09/01/2012
09/03/2012
09/05/2012
09/07/2012
09/09/2012
09/11/2012
09/01/2013
09/03/2013
09/05/2013
09/07/2013
09/09/2013
09/11/2013
09/01/2014
09/03/2014
09/05/2014
09/07/2014
09/09/2014
09/11/2014
BH01
BH02
BH03
BH04
BH05
BH07
BH08
BH09


Groundwater chloride boreholes BH10-BH03A (mg/l)
500
450
400
350
300
250
200
150
100
50
0
09/01/2009
09/03/2009
09/05/2009
09/07/2009
09/09/2009
09/11/2009
09/01/2010
09/03/2010
09/05/2010
09/07/2010
09/09/2010
09/11/2010
09/01/2011
09/03/2011
09/05/2011
09/07/2011
09/09/2011
09/11/2011
09/01/2012
09/03/2012
09/05/2012
09/07/2012
09/09/2012
09/11/2012
09/01/2013
09/03/2013
09/05/2013
09/07/2013
09/09/2013
09/11/2013
09/01/2014
09/03/2014
09/05/2014
09/07/2014
09/09/2014
09/11/2014
BH10
BH11
BH12
BH13
BH14
BH03A


Groundwater chloride Boreholes T1-T13 (mg/l)
400
350
300
250
200
150
100
50
0
09/01/2009
09/03/2009
09/05/2009
09/07/2009
09/09/2009
09/11/2009
09/01/2010
09/03/2010
09/05/2010
09/07/2010
09/09/2010
09/11/2010
09/01/2011
09/03/2011
09/05/2011
09/07/2011
09/09/2011
09/11/2011
09/01/2012
09/03/2012
09/05/2012
09/07/2012
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09/01/2013
09/03/2013
09/05/2013
09/07/2013
09/09/2013
09/11/2013
09/01/2014
09/03/2014
09/05/2014
09/07/2014
09/09/2014
09/11/2014
T01
T02
T03
T04
T05
T06
T07
T08
T09
T10
T11
T12
T13

Appendix 5 Monitoring data

Supplied electronically

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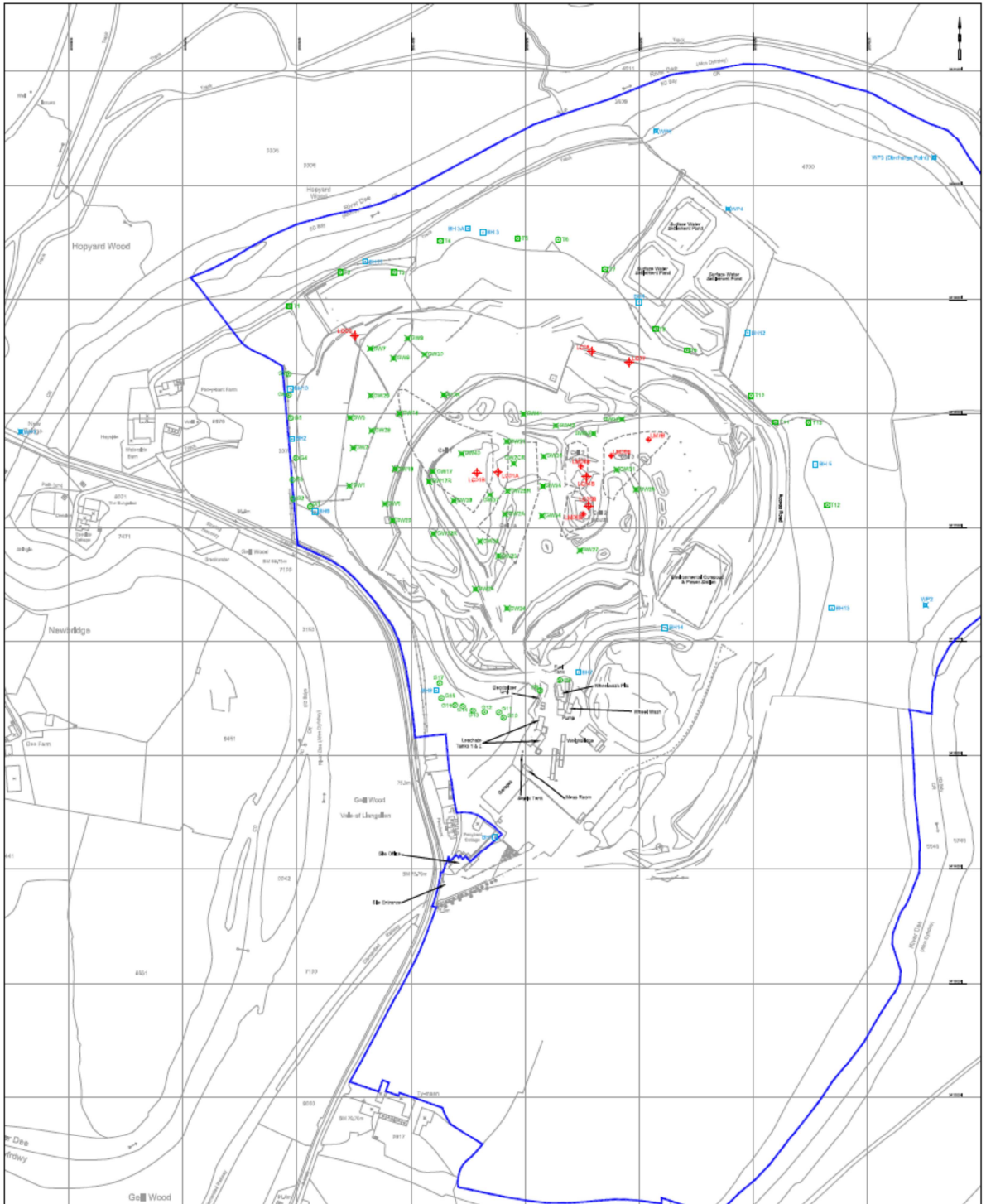
Appendix 4 Site Layout and Monitoring plan

Drawing 2: Monitoring plan


Hopyard Wood
Newsbridge
Gelli Wood
Gelli Wood