Caulmert Limited

Engineering, Environmental & Planning Consultancy Services

Whisby Landfill Site

Lincwaste Limited

Whisby HRA

Hydrogeological Risk Assessment Update 2023

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DISCLAIMER

Hydrogeological Risk Assessment Update 2023

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1.0 INTRODUCTION

1.1 Background

1.1.1 FCC Environment (FCC) has appointed Caulmert Ltd (Caulmert) to undertake a review of the hydrogeological risk assessment (HRA) as part of the environmental permit variation application for Whisby Landfill Site, Lincoln. The site is operated by Lincwaste Ltd, a wholly owned subsidiary of FCC Environment.

1.1.2 The site is currently managed under Environmental Permit EPR/BW2978ID issued in May 2005. The permit has been varied several times since, the most recent variation issued in June 2018.

1.1.3 The Operator proposes to vary the existing permit to include the treatment of Incinerator Bottom Ash (IBA) within the boundary of the permitted installation.

1.1.4 The original HRA was written by Golder Associates as part of the permit application in 2005, with subsequent reviews undertaken every 6 years in compliance with condition 3.1.5 of the permit, in May 2009 (Golder Associates), March 2015 (FCC Environment) and May 2021 (Caulmert Ltd).

1.1.5 At the time of this review, Phase 2 and Phases 3,4 and 5 at the site have been permanently capped. Areas A and B within the permitted area currently remain undeveloped, however it is proposed to develop Area A to construct four additional Cells (IBA Cells 1-4) for the processing and filling of IBA materials.

1.1.6 This report will review the conceptual model and risk assessment for the site as a whole. The report will include a detailed review of monitoring data obtained since January 2015 and will determine if it is compliant with the Environmental Permitting Regulations (2010). Where significant changes to the conceptual model are noted, additional modelling will be undertaken as appropriate.

1.1.7 This report utilises the EA guidance 'Landfill Operators: Environmental Permits, what to include in your hydrogeological risk assessment' (October 2022) and adopts the terminology within the Groundwater Daughter Directive and Environmental Permitting Regulations 2014.

1.1.8 Third party information supplied by FCC Environment has been used in good faith within this document. Caulmert Ltd has not attempted to verify the information.

1.1.9 The following documents have been used for reference purposes:

- Whisby HRA (Golder Associates 2004)
- Whisby HRA review (FCC 2015)
- Whisby HRA Review (Caulmert Ltd 2021)
- Whisby Landfill Permit

2.0 REVIEW OF CONCEPTUAL HYDROGEOLOGICAL MODEL

2.1 Site Setting and Development

2.1.1 Whisby Landfill Site is located on Thorpe Road, Whisby and is centred at National Grid Reference SK 8980 6670. The landfill is bordered on the south by a railway line, to the north by sand and gravel extraction operations, Thorpe Road to the east and public footpaths to the west.

2.1.2 The site is operated as a non-hazardous landfill. Phase 2 (Cell 1-4) and Phase 3, 4 and 5 (Cells 1-8) on the southern side of the site are permanently capped and restored.

2.1.3 Areas A and B on the northern area of the permitted boundary are currently undeveloped. The operator proposes to vary to existing permit to include for the treatment of Incinerator Bottom Ash (IBA), in the area that currently makes up Area A. This includes the construction of four IBA Cells, in which processing and infilling of IBA materials will occur. A copy of the proposed development and phasing plan is shown on drawing WR7855/1/001.

2.1.4 The site is operated on the basis of hydraulic containment. Table 1 below summarises the engineering details for the site.

Table 2. Site engineering details

	Phase 2	Phase 3,4,5			IBA Cells 1-4
	Cells 1-4	Cells 1-4	Cell 5	Cells 6, 7 & 8	
Basal Lining	No engineered clay	No engineered clay	1m thick engineered clay	1m thick engineered clay	1m thick engineered clay and separation geotextile above
Basal drainage	No basal drainage	No basal drainage	Gravel drainage blanket	Radial piped gravel drainage system	spine drainage system
Side slope lining and drainage	1m engineered clay. No drainage				1m thick engineered clay. Geocomposite drainage layer with back wall drains to pump groundwater.
Cap details	Cell 1 cap: 1m engineered clay and soils	1m engineered clay and 1m cover soils	1m engineered clay and 1m cover soils	HDPE geomembrane. 1m cover soils	Inert soils cap with minimum hydraulic conductivity of $1x10^{-7}$ m/s

2.1.5 Groundwater is present in Area A and B (Are B also known as the lagoon area), and therefore groundwater will be required to be pumped from IBA Cells 1-4 to drains on the north western edge of the site, during the operational phase. A geocomposite drainage layer shall be installed against the sand and gravel side slopes on the northern and southern sides of the cell to relieve groundwater pressures and shall extend down to a drain which shall be installed beneath the base of the side slopes.

2.2 Source

Leachate Levels

2.2.1 Leachate levels are required to be monitored quarterly in all cells in accordance with the permit. Compliance limits are set on a cell by cell basis on the basis of hydraulic containment with values based on 1m below the surrounding groundwater. Table 2 below presents the recorded leachate levels for the review period 2015-2023. Leachate hydrographs are presented in Appendix 1.

Table 2. Summary of leachate levels in the current review period (2015-2023)

Monitoring Location		Leachate Level (mAOD)					Compliance Limit	No. of exceedances
		Min	Avg	95%ile	Max	Count		
Phase 3, 4, 5	LCP1	5.91	7.31	9.15	9.49	135	9.3	2
	LCP2	4.06	6.51	9.00	9.44	133	9.3	2
	LCP3	5.48	7.09	8.43	8.59	134	9.5	0
	LCP4	4.87	6.99	8.60	8.79	133	9.5	0
	LCP5	4.01	6.96	8.98	9.29	211	9.3	0
	Cell 6 sump	6.07	7.35	8.21	8.33	116	9	0
	Cell 7 sump	2.16	5.56	7.07	7.80	116	8	0
	Cell 8 sump	2.26	6.75	8.68	9.74	117	8	17
Phase 2	LW2.1B	2.56	3.96	6.59	6.74	102	5.5	18
	LW2.2	1.77	2.94	5.63	6.06	120	4.5	19
	LW2.3*	4.13	5.35	8.14	10.31	152	5.5	38
	LW2.4*	0.39	4.42	9.85	10.69	189	4.5	73
	LW2.5*	2.34	4.47	7.49	8.75	193	4.5	78
	LW2.6B*	2.81	5.60	9.68	10.41	172	5.5	88

* Leachate monitoring points in Phase 2 – Cells 2-4

2.2.2 Time series graphs presented in appendix 1 show that leachate levels in cells within phase 3,4,5 generally remain under respective compliance limits. Levels in Cell 8 sump were variable across the review period, where the most exceedances were recorded within this phase. Cells 3 and 4 within this phase show a steady increase in levels from January 2020 to 2023, however do not exceed the compliance limits.

2.2.3 LCP5 shows two isolated peaks in December 2015 and July 2016, which are likely to be erroneous values. Levels at this location remain under the compliance limit for the rest of the review period.

2.2.4 The majority of exceedances were recorded within Phase 2 Cells 2, 3 and 4. The original cap for these cells was stripped in circa 2005 during a period of overtip. Permanent restoration was achieved in Cell 1 however Cells 2-4 were temporarily restored until Autumn 2021, when a permanent cap was placed on top of these cells. The leachate levels in the uncapped areas would suggest that infiltration into the waste mass resulted in the high leachate levels observed. Levels are variable in these cells; however levels show a general decrease in Phase 2 Cells 2-4 in October 2021.

2.2.5 Levels within IBA Cells 1-4 will also be managed on the principal of hydraulic containment. Limits have been proposed at 4.5mAOD for the operational phase and 7.5mAOD for the non-operational phase. This is discussed in more detail in section 3 below.

Leachate Quality

2.2.6 Leachate Quality was analysed quarterly in operational cells and annually in non-operational cells in accordance with permit requirements. Summary statistics are presented below, and time series graphs are included in appendix 2.

2.2.7 In the original HRA the non-hazardous modelled determinands are ammoniacal nitrogen and chloride and nickel and the hazardous determinands mecoprop and cadmium. It is noted that mecoprop and cadmium have since been reclassified as non-hazardous substances.

Table 2: Summary of Leachate Quality Data (2015-2023)

Monitoring Location		Ammoniacal nitrogen (mg/l)					Chloride (mg/l)				
		Min	Avg	95%ile	Max	Count	Min	Avg	95%ile	Max	Count
Phase 3-5	Cell 6 sump	482	672	904	923	7	2420	3119	3876	3900	7
	Cell 7 sump	366	1101	1501	1570	7	892	1987	2666	2840	7
	Cell 8 sump	642	1612	2283	2300	8	590	1445	1953	2040	8
	LCP1	39	92	145	158	8	87	152	214	221	8
	LCP2	107	177	251	264	8	211	377	475	485	8
	LCP3	137	508	794	797	7	336	3565	6414	6720	7
	LCP4	133	816	1246	1300	7	333	6548	11159	11900	7
	LCP5	104	571	1000	1040	8	1010	2361	3939	4530	8
Phase 2	LW2.1B	858	949	1050	1070	6	1450	1667	1948	2020	6
	LW2.2	832	979	1251	1350	6	1310	1565	1878	1910	6
	LW2.3	450	1056	1273	1280	8	612	1559	2475	2730	8
	LW2.4	357	703	1043	1170	31	361	772	1245	1340	31
	LW2.5	525	1032	1186	1190	29	529	1293	1506	1670	29
	LW2.6B	590	1013	1179	1330	22	726	1262	1650	3090	22

Monitoring Location		Nickel (mg/l)					Mecoprop (ug/l)				
		Min	Avg	95%ile	Max	Count	Min	Avg	95%ile	Max	Count
Phase 3-5	Cell 6 sump	0.076	0.093	0.105	0.106	7	18.00	27.15	39.08	40.70	4
	Cell 7 sump	0.054	0.157	0.199	0.203	7	10.46	41.97	61.86	63.60	4
	Cell 8 sump	0.192	0.250	0.299	0.300	8	5.90	33.34	50.14	51.50	5
	LCP1	0.006	0.033	0.085	0.100	8	5.78	9.16	10.00	10.00	5
	LCP2	0.011	0.021	0.035	0.037	8	10.00	14.71	24.28	26.43	5
	LCP3	0.013	0.090	0.171	0.192	7	10.00	14.60	20.11	20.50	4
	LCP4	0.011	0.147	0.222	0.225	7	10.00	14.14	18.27	18.30	4
	LCP5	0.043	0.080	0.137	0.142	8	10.00	32.20	69.78	76.90	5
Phase 2	LW2.1B	0.254	0.280	0.325	0.339	6	70.00	99.40	143.62	151.00	3
	LW2.2	0.170	0.239	0.348	0.374	6	64.00	115.57	189.07	201.00	3
	LW2.3	0.221	0.286	0.345	0.349	8	10.00	54.22	69.04	69.40	5
	LW2.4	0.042	0.109	0.171	0.249	31	14.21	105.66	344.30	350.00	20
	LW2.5	0.057	0.147	0.190	0.202	29	35.00	310.35	560.00	680.00	17
	LW2.6B	0.088	0.142	0.173	0.205	22	47.40	117.34	199.20	282.00	13

Monitoring Location		Cadmium (mg/l)				
		Min	Avg	95%ile	Max	Count
Phase 3-5	Cell 6 sump	<0.0001	<0.0001	<0.001	<0.001	7
	Cell 7 sump	0.001	0.001	0.001	0.001	7
	Cell 8 sump	0.0008	0.001	0.0013	0.0014	8
	LCP1	<0.00002	<0.0001	<0.001	<0.001	8
	LCP2	<0.00002	<0.0001	<0.001	<0.001	8
	LCP3	<0.00002	0.0009	0.0012	0.0013	7
	LCP4	<0.00002	0.0008	0.0012	0.0012	7
	LCP5	<0.0001	0.0004	0.001	0.001	8
Phase 2	LW2.1B	0.00020	<0.001	<0.001	<0.001	6
	LW2.2	0.00042	<0.001	<0.001	<0.001	6
	LW2.3	0.00046	<0.001	<0.001	<0.001	8
	LW2.4	<0.0001	<0.0001	<0.001	<0.001	31
	LW2.5	<0.0001	<0.0001	<0.001	<0.001	29
	LW2.6B	<0.0002	<0.0001	<0.001	<0.001	22

Table 3: Comparison with the previous Review results

Parameter	Units	original HRA		2009 Review		2015 Review		2023 Review	
		Phase 2	Phase 3, 4, 5	Phase 2	Phase 3, 4, 5	Phase 2	Phase 3, 4, 5	Phase 2	Phase 3, 4, 5
Ammoniacal Nitrogen	mg/l	1870	568	1950	4100	1660	2720	1350	2300
Chloride	mg/l	2320	4300	2010	11,800	2200	16400	3090	11900
Nickel	mg/l	0.54	0.07	1.11	0.89	0.7	0.73	0.37	0.3
Mecoprop	ug/l	3	3	107	25	86	38	680	76.9
Cadmium	mg/l	0.004	<0.001	0.005	0.004	0.012	0.005	<0.001	0.0014

2.2.8 Ammoniacal nitrogen concentrations within Phase 2 remain lower than the modelled values. Concentrations within Phase 3,4 and 5 are higher than the modelled values, however, are lower than concentrations reported within the 2009 and 2015 review. It is not considered that these results represent a significant shift in ammoniacal nitrogen concentrations, and no remodelling is considered to be required.

2.2.9 Chloride concentrations across all cells are comparable to the previous review. The maximum concentration was recorded in Phase 2 in LW2.6B at 3090 mg/l, however it is considered this value may be erroneous as the 95%ile recorded at this location is 1650 mg/l. High chloride concentrations were reported within Phase 3,4 and 5 in both the 2009 and 2015 review and results over this review period show similar spatial trends to those previously reported. Therefore, it is not considered there is an increase in risk associated with chloride and that the source term remains valid.

2.2.10 Nickel concentrations within Phase 2 also remain below the modelled concentrations. Concentrations within Phase 3, 4, 5 are higher than the modelled concentrations, however, are significantly lower than those reported in the 2009 and the 2015 review.

2.2.11 No cadmium was detected within Cells 1,2, 6 and 7 within Phase 3,4 and 5 and Phase 2 cells 1 and 2. The maximum concentration was detected within Cell 8 at 0.0014 mg/l which is lower than the maximum values reported in the 2009 and 2015 review.

2.2.12 The leachate quality in the uncapped cells Phase 2 Cells 2-4, is slightly different in comparisons to the other monitoring locations. The ammoniacal nitrogen concentrations are similar in strength, however the average chloride concentrations appear to be slightly lower which may be reflective of the age of the waste or due to the increased infiltration into these cells. The most apparent difference is in the concentrations of mecoprop which appear to be significantly higher than all other areas and has increased between review periods. The cause of this increase is unclear however the decrease in chloride concentrations would suggest this is not associated with an overall increase in leachate strength.

2.2.13 With respect to the risks posed by the increased mecoprop concentrations, these are not considered to represent an increase in risk posed by the site due to the management of the site on the principle of hydraulic containment. The mecoprop concentrations are significantly below the maximum concentration gradient modelled for chloride which indicates that the advective flux is significantly greater than the diffusive flux. Therefore, it is not considered mecoprop is a risk to groundwater as the concentrations reported are significantly lower than the modelled concentrations of chloride within the original HRA.

Changes in Source Term

2.2.14 The majority of source term parameters are comparable to the previous review period. Monitoring data from 2015-2023 has indicated no discernible increasing trends and results show similar spatial trends to those previously reported. The site remains in hydraulic containment and therefore it is not considered the concentrations reported will have a significant impact on the modelled risks.

2.2.15 Although mecoprop concentrations are significantly higher than previous modelled values, the advection vs diffusion modelling undertaken within the original HRA remains valid. The above assessment therefore indicates that the leachate quality source term remains valid and no remodelling for Phases 2 and 3,4 and 5 is required.

2.2.16 The proposed IBA Cells (1-4) will be for the infilling of IBA material. Landfill leachate data is not appropriate to assess the source term for the IBA materials and the current datasets are not representative. Therefore, the source term from these cells has been established based on studies on IBA leaching behaviour. This is discussed more in section 3 below.

2.3 Pathway

2.3.1 The site is an excavation into the Balderton Sand and Gravel Member (Older Sands and Gravels), which are between 5.3m and 8.3m deep. Underlying the drift deposits is an unproven but substantial thickness of the Scunthorpe Mudstone Formation (Lias Clay).

2.3.2 The Balderton Sand and Gravel Member is classified by the Environment Agency as a secondary A aquifer which is defined as 'permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifer.'

2.3.3 The Scunthorpe Mudstone Formation underlying the sands and gravels is classified as a secondary B aquifer, defined as 'predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering'. The clay beneath the site is not considered to contain any significant water bearing parts.

2.3.4 The site does not lie within any source protection zones.

2.3.5 Two pathways have been specified and assessed in the original HRA review and subsequent 2009 and 2015 reviews and remain valid.

- When hydraulic containment is present at the site, advective movement of leachate out of the site cannot take place. Contaminants have the potential to migrate through the sidewall by diffusion, and perched leachate at an elevation above the surrounding groundwater elevation may migrate advectively through the sidewall.

- When leachate levels within the site are elevated above the external groundwater elevations, advective movement of leachate through the sidewall can occur.

Groundwater Levels

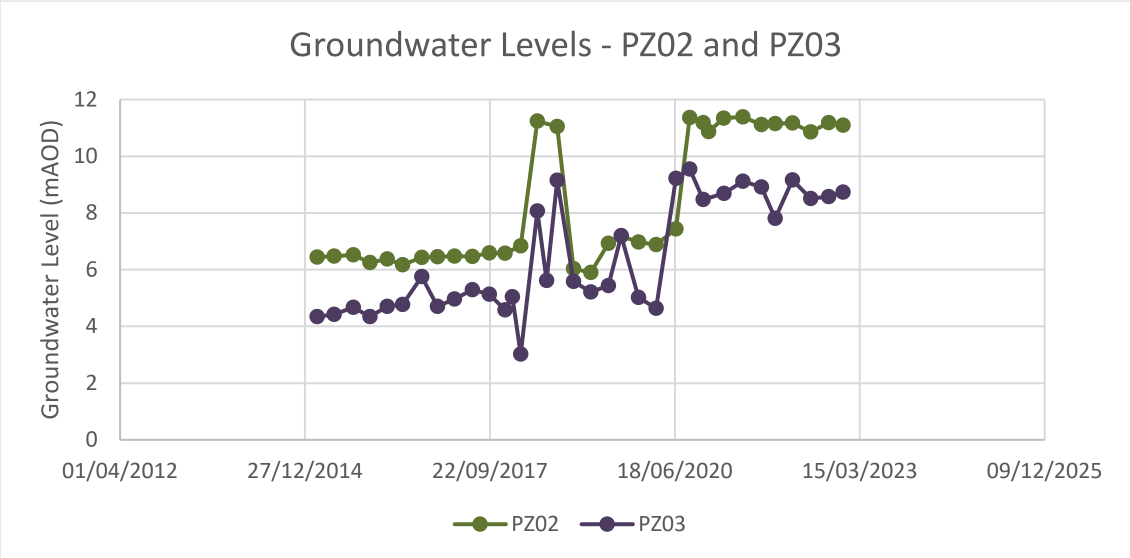
Table 4. Groundwater Elevation Data 2015-2023

	Monitoring Location	Groundwater Level (mAOD)				
		Min	Avg	95%ile	Max	Count
North	PZ02	5.90	8.38	11.35	11.39	33
	PZ03	3.02	6.42	9.18	9.55	34
East	BH02/14	10.15	10.71	11.14	11.17	33
	BH17Asand	9.10	9.96	10.83	11.41	33
	WBY1100	8.90	9.91	10.95	11.73	33
South	WBY4100	9.94	11.01	11.57	11.99	32
	WBY5100	9.06	11.00	11.73	12.13	32
	WBY6100	9.55	10.91	11.72	12.40	34
	BH13Csand	10.24	10.85	11.36	11.89	32
	BH08A	9.24	10.57	11.38	12.01	35
	BH02/04	9.71	11.13	11.91	12.78	28
West	BH01	7.03	8.01	9.19	9.98	29
	BH01/04	9.35	10.18	11.72	12.07	19
	BH03A	7.31	8.51	9.65	10.66	34
	WBY3100	7.18	8.16	9.78	11.31	31

2.3.6 Groundwater levels are presented in Table 4 above. Groundwater levels fluctuate over the monitoring period with some seasonal change evident. Highest groundwater levels were generally recorded in boreholes located in the south and east of the site and lowest groundwater levels in the north and west, indicating groundwater flows in a general north west direction. This is consistent with the groundwater flow direction reported in previous HRA reviews.

2.3.7 The reported average groundwater levels are higher than the 95th percentile value leachate levels and therefore it is considered that the site remains in hydraulic containment.

2.3.8 Groundwater levels within PZ02 and PZ03 on the north western area of the site, adjacent to Area A show a variation in groundwater levels over the review period, as shown in the graph below. Water has previously been pumped from this area, showing a reduction in groundwater level in these boreholes. It can be seen following the cessation of pumping in early 2020, the groundwater levels rapidly recover and remain fairly stable when no pumping is being undertaken.



Groundwater Quality

2.3.9 Groundwater quality is monitored in accordance with the permit conditions. Compliance limits have been assigned on an individual borehole basis. Summary statistics are presented in table 5 below and time series data is presented in appendix 4.

Table 5. Groundwater quality (2015-2023)

Monitoring Location	Compliance Limit (mg/l)	Ammoniacal Nitrogen (mg/l)				
		Min	Avg	95%ile	Max	Count
BH01	2.59	0.01	0.08	0.22	0.3	18
BH01/04		0.01	0.02	0.02	0.02	4
BH02/04		0.01	0.02	0.05	0.05	15
BH02/14		0.01	0.07	0.17	0.2	32
BH03A		0.01	1.17	5.58	20.9	33
BH17Asand		0.01	0.07	0.25	0.4	32
WBY1100		0.01	0.02	0.07	0.2	32

Monitoring Location	Compliance Limit (mg/l)	Ammoniacal Nitrogen (mg/l)				
		Min	Avg	95%ile	Max	Count
WBY4100	10	0.01	0.08	0.23	0.3	32
WBY6100		0.01	0.16	0.41	1.2	28
PZ02		0.01	0.32	0.90	1.1	32
WBY3100		0.02	0.41	1.03	1.1	8
BH08A	No limit	0.01	0.11	0.23	0.27	32
BH13Csand		0.02	0.52	0.80	1	30
PZ03		0.01	0.26	0.90	1.1	30
WBY5100		0.01	0.04	0.13	0.2	31

Monitoring Location	Compliance Limit (mg/l)	Chloride (mg/l)				
		Min	Avg	95%ile	Max	Count
BH01	200	39	51	58	62	18
BH01/04		32	38	42	43	4
BH02/04		22	39	48	48	15
BH03A		38	84	140	147	32
BH17Asand		44	57	73	80	33
WBY1100		9	59	106	114	32
WBY3100		15	42	57	59	8
WBY4100		47	61	89	92	32
WBY6100		5	46	82	154	28
BH02/14	No limit	38	84	140	147	32
BH08A		44	54	60	91	32
BH13Csand		49	62	88	117	30
PZ02		685	721	774	830	32
PZ03		810	884	929	996	30
WBY5100		49	87	144	181	31

Monitoring Location	Compliance Limit (mg/l)	Nickel (mg/l)				
		Min	Avg	95%ile	Max	Count
BH01	0.2	<0.001	0.003	0.004	0.006	18
BH01/04		<0.001	0.004	0.006	0.006	4
BH02/04		<0.001	0.004	0.008	0.009	15
BH03A		<0.001	0.002	0.005	0.007	31
BH17Asand		<0.001	0.001	0.002	0.003	31
WBY1100		0.001	0.002	0.003	0.005	31
WBY3100		0.004	0.006	0.010	0.011	8
WBY4100		0.011	0.052	0.087	0.100	31
WBY6100		<0.001	0.002	0.003	0.005	31
PZ02		<0.001	0.004	0.013	0.016	31
BH02/14	No limit	<0.001	0.002	0.004	0.005	31
BH08A		0.016	0.145	0.328	0.342	32
BH13Csand		0.008	0.035	0.048	0.053	29
PZ03		<0.001	0.005	0.010	0.022	29
WBY5100		0.014	0.051	0.108	0.119	30

Monitoring Location	Compliance Limit (mg/l)	Cadmium (mg/l)				
		Min	Avg	95%ile	Max	Count
BH01	0.03	<0.00002	0.00009	0.0001	0.0001	18
BH01/04		0.00008	0.0001	0.0001	0.0001	4
BH02/04		<0.00002	0.00009	0.0001	0.0001	15
BH03A		<0.00002	0.0001	0.0003	0.0007	31
BH17Asand		<0.00002	0.00009	0.00014	0.00016	31
WBY1100		<0.00002	0.00008	0.00011	0.00015	31
WBY3100		<0.00002	0.00008	0.00015	0.00017	8
WBY4100		<0.00002	0.0025	0.0052	0.0074	31

Monitoring Location	Compliance Limit (mg/l)	Cadmium (mg/l)				
		Min	Avg	95%ile	Max	Count
WBY6100		0.0001	0.00042	0.001	0.002	27
PZ02		<0.00002	0.00008	0.0001	0.00015	31
BH02/14	No limit	<0.00002	0.00008	0.00011	0.00013	31
BH08A		0.00009	0.0019	0.0045	0.0076	31
BH13Csand		<0.00002	0.0014	0.0041	0.0047	29
PZ03		<0.00002	0.00007	0.0001	0.0001	29
WBY5100		0.00043	0.0031	0.0090	0.0094	30

2.3.10 Ammoniacal nitrogen concentrations did not exceed the 2.59 mg/l compliance limit at BH01, BH02, BH01/04, BH02/04, BH17ASand, WBY1100, WBY4100 and WBY6100. A spike in concentrations was recorded at BH03A with a maximum concentration of 20.9 mg/l in September 2021. Concentrations have since decreased at this location and have remained below the compliance limit since May 2022. PZ02 and PZ03 did also not exceed their respective 10 mg/l compliance limit over the review period. A concentration of 13 mg/l was reported at PZ03 in September 2020; however this was considered an anomalous result.

2.3.11 Concentrations of chloride did not exceed the 200 mg/l compliance limit at any location throughout the review period. Concentrations remain comparable to those reported in previous review periods, with significantly higher chloride concentrations recorded at PZ02 and PZ03.

2.3.12 No exceedances of the 0.2 mg/l nickel compliance limit were recorded over the review period. Highest concentrations of nickel were recorded in upgradient borehole BH08A, with a maximum concentration of 0.342 mg/l.

2.3.13 Cadmium concentrations also remained below the 0.03 mg/l compliance limit throughout the review period. The maximum concentration was reported in upgradient borehole WBY5100 at 0.009 mg/l. Concentrations across the site are generally lower than those reported in previous reviews.

2.3.14 Mecoprop concentrations largely remained below the laboratory detection limit at all locations throughout the review period. Concentrations remained below the compliance limit with the exception of one sporadic peak recorded at BH03A of 0.52 ug/l in September 2021. BH08A also recorded a peak of 1.38 ug/l on the same date. PZ02 and PZ03 also recorded a sporadic peak of mecoprop in September 2022, with concentrations of 0.73 mg/l and 0.21 mg/l, respectively.

2.3.15 No discernible concentrations of hazardous substances were detected within groundwater over the review period.

2.4 Receptor

2.4.1 The following receptors were identified and assessed within the original HRA and the subsequent 2009 and 2015 reviews, and are considered to remain valid:

- Groundwater in the sand and gravel aquifer surrounding the site
- Surrounding surface water bodies, specifically The Pike Drain

Surface Water

2.4.2 Surface water from Phase 2 currently discharges directly to the Pike Drain, whereas surface water from Phase 3, 4 and 5 currently discharge to the Pike drain via a series of drainage ditches on the western and northern edge.

2.4.3 Surface water is monitored at the Pike Drain at both upstream and downstream locations and at the Pike drain discharge point. Area A lagoon is located on the northern side of the site, within the area where IBA Cells 1-4 are to be constructed. The SRC ditch monitors surface water runoff from the SRC area (Cells 1-4). Limits are stipulated in the permit for Pike Drain downstream and the SRC ditch.

2.4.4 Summary statistics are presented in Table 6 below and time series graphs are included in Appendix 5.

Table 6. Surface water quality results (2015-2023)

	Area A Lagoon	Pike Drain Discharge	Pike Drain Downstream	Pike drain Upstream	SRC Ditch
Ammoniacal Nitrogen (mg/l)					
Compliance Limit			2		2
Min	<0.01	<0.01	<0.01	<0.01	<0.01
Avg	0.06	0.10	0.06	0.07	0.14
95%ile	0.20	0.54	0.20	0.23	0.48
Max	0.90	1.10	0.50	0.41	1.30
Count	100	65	86	58	66
Chloride (mg/l)					
Compliance Limit			175		175
Min	24	40	39	29	93
Avg	53	53	53	47	450
95%ile	62	61	61	57	1120
Max	75	69	129	59	1370
Count	100	65	85	58	62
Nickel (mg/l)					
Compliance Limit			0.12		0.12
Min	<0.001	<0.001	<0.001	<0.001	0.005
Avg	0.001	0.001	0.002	0.002	0.016
95%ile	0.003	0.002	0.003	0.003	0.037
Max	0.005	0.003	0.006	0.004	0.045
Count	101	66	86	59	38

	Area A Lagoon	Pike Drain Discharge	Pike Drain Downstream	Pike drain Upstream	SRC Ditch
Suspended Solids (mg/l)					
Compliance Limit			50		50
Min	<5	<5	<5	<5	<5
Avg	9	10	12	13	23
95%ile	29	16	25	54	89
Max	84	237	212	129	237
Count	100	65	85	58	38

2.4.5 Ammoniacal nitrogen concentrations did not exceed the 2mg/l compliance limit at Pike Drain downstream or at the SRC ditch throughout the review period. The maximum concentration recorded at these locations was 1.3 mg/l at the SRC ditch. Concentrations at both the Pike Drain upstream and downstream locations were comparable.

2.4.6 Concentrations of chloride at Pike Drain downstream remain below the 175 mg/l compliance limit. Concentrations at the SRC ditch exceed the compliance limit on a number of occasions, showing a pattern of increasing in concentration during the summer months and decreasing during the winter months. The SRC ditch measures the runoff from the SRC area and where the chloride concentrations exceed the compliance emission limit, it is understood that the water is recirculated prior to discharge. Concentrations within the Pike Drain remain low, indicating there is no impact from the discharge of the SRC area.

2.4.7 Nickel concentrations at both the Pike Drain downstream and the SRC ditch also remained significantly below the 0.12 mg/l compliance limit.

2.4.8 Isolated sporadic peaks of suspended solids were recorded at both the Pike Drain downstream and the SRC ditch. A maximum concentration of 959 mg/l was recorded at Pike Drain downstream; however, this is considered an anomalous result, with the 95th percentile at this location recorded at 89 mg/l.

2.4.9 Mecoprop remained below the detection limit on all occasions. No visible oil or grease was recorded throughout the review period.

2.4.10 Selenium remained below the detection limit on all occasions at the SRC ditch and therefore did not exceed the 0.01 mg/l compliance limit.

2.4.11 No discernible concentrations of hazardous substances were recorded within the SRC ditch.

2.4.12 Concentrations in the Pike Drain remained comparable to previous review periods with upstream and downstream concentrations remaining similar, indicating the landfill is not having a detrimental impact on the surrounding surface water environment.

Summary of Conceptual Model

2.4.13 On review of the monitoring data across the review period, it is observed that some exceedances in leachate levels were recorded where cells were temporarily restored over the review period. Cells have now been permanently capped and levels have since reduced. Leachate quality remains comparable to the previous review for all source term parameters within Phase 2 and 3,4 and 5, with the exception of mecoprop. Higher concentrations of mecoprop do not represent an increase in risk as the site remains in hydraulic containment and therefore the advection vs diffusion modelling undertaken within the original HRA remains valid.

2.4.14 Groundwater quality remains comparable to the previous review, with no exceedances of compliance limits throughout the review period. Overall, there has not been any discernible changes in water quality over this review period.

2.4.15 The proposed construction of fur IBA Cells on the northern area of the site indicates a change in the conceptual model. It is considered the source term within this cell will be significantly different to the existing cells and therefore requires separate assessment.

3.0 HYDROGEOLOGICAL RISK ASSESSMENT

3.1 The nature of the hydrogeological risk assessment

Phases 2 and 3,4 and 5

3.1.1 The original HRA was undertaken as part of the permit process (Golder Associates). A complex risk assessment approach was carried out using the probabilistic Monte Carlo simulation package.

3.1.2 The leachate source term within phases 2 and 3-5 has been reviewed against the modelled values on each occasion. For all parameters, with the exception of mecoprop, there is no discernible difference between the 2021 and the 2015 HRA data ranges and therefore the 2015 assessment of the risks posed by the source term is considered also to reflect the risks posed currently by the site. It is noted that mecoprop and cadmium have been reclassified as non-hazardous substances in 2017, however this has no material effect on the current risk assessment. As no new waste is to be accepted within these cells the source term is considered to remain valid.

3.1.3 Mecoprop concentrations are higher than those previously reported, however as the site remains in hydraulic containment the advection vs diffusion modelling undertaken within the original HRA remains valid. Mecoprop in the original HRA was modelled conservatively. The conclusion from the original HRA was that as the high concentrations of chloride modelled did not represent a risk to the surrounding groundwater, other contaminants present in lower concentrations would also not represent a risk. Therefore, it is not considered mecoprop is a risk to groundwater as the concentrations reported are significantly lower than the modelled diffusive flux concentrations of chloride within the original HRA.

3.1.4 The review of the environmental monitoring data within these phases has identified the following:

3.1.5 The site experienced a period of elevated leachate levels with the timescales of this review, likely due to temporary restoration in areas of the site. These cells have now been permanently capped and levels have since reduced, however works are still ongoing to reduce these levels.

3.1.6 The leachate quality is generally comparable to the previous review, however higher concentrations of mecoprop were recorded. The concentrations for mecoprop were below the maximum concentration gradient (diffusive flux) modelled and therefore these higher concentrations are not considered to represent a risk to the surrounding environment.

3.1.7 Groundwater levels are consistent with previous results and the flow direct appears to be in a north westerly direction. The surrounding groundwater levels remain higher than the leachate levels, thus the site remains in hydraulic containment. PZ02 and PZ03 show a recovery in groundwater levels following the cessation of pumping within this area.

3.1.8 There are no discernible changes in groundwater quality, with concentrations remaining comparable to the previous review.

3.1.9 High levels of chloride were recorded at the SRC ditch. This location monitors the surface water runoff from the SRC area and where high concentrations are recorded the water is recirculated prior to discharge to the Pike Drain. Concentrations of leachate indicators remain comparable at both the upstream and downstream locations at the Pike Drain, indicating that there is no impact from the site.

3.1.10 Therefore, there is no evidence that these phases are having an unacceptable impact on groundwater or wider environment and there is no discernible change in the leachate source term. Based on current guidance, therefore, the existing risk assessment for these areas of the site is considered to be valid and there is no requirement to amend the existing risk assessment model.

IBA Cells 1-4

3.1.11 It is proposed to construct four additional cells, known as IBA Cells 1-4, on the northern area of the site (area formerly known as Area A), for the processing and infilling of IBA materials. This is a change in the current conceptual model and therefore these cells require further consideration. It is considered the source term within these cells will be significantly different to that modelled in the existing phases and therefore requires a separate assessment. As the site is managed on the basis of hydraulic containment, the EA's contaminant fluxes spreadsheets have been utilised to model the potential impact from these cells.

3.2 Contaminant Flux model – IBA Cells 1-4

3.2.1 Due to the proposed use of Area A to infill with IBA materials, the source term for this area of the site will be significantly different to that reported within the wider area of the landfill. The current leachate dataset is not considered appropriate to assess the source term of the IBA materials and therefore the source term for these cells has been established using studies on IBA leaching behaviour.

3.2.2 It is considered that the waste types are unlikely to contain a significant proportion of rapidly degradable organic content. Ammoniacal nitrogen is also not expected to be present within significant quantities in the IBA leachate. Similarly, solvents, refined petroleum fuels or other chemical spillages will either be excluded based on the waste acceptance criteria or destroyed during the incineration process, prior to the produce of the IBA.

3.2.3 The primary pollutants considered from IBA is chloride or sulphate, and non-hazardous and hazardous metals. There is limited readily available datasets from landfill sites which have a single waste type consisting of IBA or have a high proportion of IBA with limited to negligible organic content. However, information on IBA leaching behaviour is available from literature studies.

3.2.4 A number of studies have been undertaken to collate IBA leachate information, including Environment Agency studies[1], which reviewed field data studies, including a landfill site which is shown in the table below (Johnson et al 1999). This is also compared to data reviewed from laboratory tests on untreated IBA materials.[2]

Table 7. Literature study data on IBA material. All data is presented in mg/l.

Study	Johnson et al (1999)		Env Agency (2004)	DWS	Max Background Water Quality (BH2/14)
Source Type	Landfill Site		Laboratory Test Data Review		
Parameter	Piezometer (Ave)	Range (Ave-Max)	Range (Min-Max)		
SO4,	1027	1,190 – 2,141	8 - 500	250 (guide value)	231
Cl,	2574	1,190 – 3,657	360 - 2,700	250	104
Na,	1449	1,024 – 2,098	200 - 1,300	200	69
K,	757	460 – 944	160 - 1,300	None	12
Ca	265	329 – 644	40 - 1,000	None	153
Mg	<1.2	15 – 26	3 to 15	None	25.2
B		2 – 4		1	
Si	8	4 – 6			
Al	3.1	0.8 – 4.0		0.2	
NVOC, NH4-N	137	10 – 45	3 to 20	0.5 (guide value)	1.2
Cd	0.002		0.0002 - 0.001	0.005	0.00011
Hg			0.000002 -0.0001	0.001	<0.0001
As			0.0002 - 0.001	0.01	<0.001
Cr	0.007		0.002 - 0.025	0.05	<0.001
Cu	1.3	0.10 – 0.48	1.2 - 1.7	2	<0.001
Ni			0.016 - 0.18	0.02	0.006
Zn	0.006		0.01 - 1.3	5	0.013
Pb	0.005	0.003 – 0.007	0.06 - 5	0.01	<0.001

3.2.5 Preliminary screening of the source material parameters presented above indicates the following:

3.2.6 It is considered that the combustion process will remove the any solvents, refined petroleum products, pesticides and putrescible organic matter, and therefore it is considered highly unlikely that there will be sufficient organic substances present to produce sustained concentrations of concern within the leachate. It is also noted within the environment agency study (2004b), that modern incinerators are likely to meet a higher standard in terms of screening and burn-out efficiency in comparison to the leachate quality reported within the

[1] Environment Agency. (2004a). Improved definition of leachate source term from landfills. Phase 1: review of data from European landfills. Environment Agency Science Report P1-494/SR1.
[2] Environment Agency. (2004b). Testing of residues from incineration of municipal solid waste. Environment Agency Science Report P1-494/SR2

data sources above. Therefore, it is considered unlikely that organic substances will be present within the leachate and will not pose a risk to the surrounding groundwater, and therefore has not been considered within the source term for IBA Cells 1-4.

3.2.7 The resultant risk is therefore likely to be from substances that persist through the combustion process and are likely to be present in the waste types. This includes chloride and sulphate and non-hazardous and hazardous metals.

3.2.8 A number of metals are also shown to not be expected at concentrations of concern, due to the low concentrations reported within the data set sets (below DWS and background quality) such as arsenic and chromium. Hazardous metals cadmium and mercury also show expected concentrations below the DWS and background water quality. However, cadmium has been included within the modelled source term as to assess the potential impact of hazardous substances. Other metals, copper, zinc and lead are expected to have higher concentrations than those reported in the background water quality and therefore these have been considered in the source term.

3.2.9 Parameters sodium, potassium, calcium and magnesium show higher expected concentrations within the leachate than the DWS or reported background water quality. However, as these parameters are conservative tracers it is considered that the potential risks on the advection vs diffusion will be assessed and valid from the modelling of conservative tracers chloride and sulphate, which are likely to be present in higher concentrations.

3.2.10 Although ammoniacal nitrogen concentrations are expected higher than the background water quality data, the concentrations are significantly lower than those reported in the leachate in existing phases at the site. It is therefore considered the risk from the expected concentrations within IBA is not significant and this parameter is not considered further.

3.2.11 Therefore, considering the above discussion, table 8 shows the leachate source term considered within the models.

Table 8. Leachate Source Term for IBA Cells 1-4

Parameter	Unit	IBA Min	IBA Max
Sulphate	mg/l	8	2141
Chloride	mg/l	360	3657
Copper	mg/l	0.1	1.7
Zinc	mg/l	0.01	1.3
Lead	mg/l	0.06	5
Cadmium	mg/l	0.0002	0.001

3.2.12 The maximum values reported above have been used within the models as a worst case scenario, however it is considered that this a conservative approach.

3.2.13 The hydraulic containment model is a steady state model, which calculates the diffusion of contaminants through a geological strata or liner that does not take leachate depletion into account. Therefore, unlike models such as LandSim, the effects of the depletion as contaminants are removed, such by abstraction, are not considered within the model conclusions and any conclusions drawn are therefore conservative with regards to the immediate and long term.

3.2.14 Groundwater levels in adjacent groundwater wells PZ02 and PZ03, to the proposed IBA Cells are variable over the review period. There is a clear relationship showing groundwater levels rapidly responding when water is being pumped from Area A and subsequently recovering rapidly following the cessation of pumping. It is considered that the time taken for leachate breakout to occur through the liner is likely to be significantly longer than the operational phase at the site and therefore the natural rest groundwater levels have been used within the model.

3.2.15 Leachate compliance limits for IBA Cells 1-4 have been proposed on the basis of keeping the site in hydraulic containment. These have been based on the water levels reported at PZ02 and PZ03, with the operational limit based on the minimum groundwater levels reported when pumping has previously occurred at this part of the site, and non-operational limit based on the minimum recovered groundwater levels. These are as follows:

- Operational phase – 4.5 mAOD (1.5 above base of cell)
- Non-operational phase – 7.5 mAOD (4.5m above base of the cell)

Model Assumptions

3.2.16 The following assumptions are considered within the models:

- Leachate heads are maintained 1m below the minimum recovered groundwater level
- Sidewall liner comprising 1m engineered clay at $1x10^{-9}$ m/s
- Permeability of the sand and gravel aquifer has been selected to represent a mid-range value for a sand and gravel aquifer.

3.2.17 The downgradient distance to the compliance point from the landfill has been input as a generic value of 100m. Although it is recognised that this represents an average value, the models are not sensitive to this parameter and therefore changing the distance to the receptor does not change the predicted concentrations.

Table 9. IBA Cells 1-4: Emissions to groundwater

Parameter	Source Concentration (mg/l)	Predicted concentration at monitoring well (mg/l)
Sulphate	2141	0.313
Chloride	3657	0.53
Copper	1.7	6.86e-7
Zinc	1.3	6.014E-05
Lead	5	4.2E-4
Cadmium	0.001	1.27E-09

3.2.18 The above assessment indicates that there are no significant risks posed from the leachate in IBA Cells 1-4.

3.2.19 Leachate levels within this cell will be required to be maintained at 1m below the minimum surrounding groundwater levels during both the operational phase (during groundwater pumping) and the non-operational phase (following cessation of pumping and recovery in groundwater levels).

3.3 Review of Technical Precautions

Capping

3.3.1 There are to be no changes to the capping regime with capping systems in Cells 1-5 in Phase 3, 4 and 5 comprising of a minimum of 1m low permeability ($<1x10^{-9}$ m/s) engineered clay and covered by minimum 1m of soils. Capping systems in Phase 2 comprise of a 200mm thick soil binding layer and minimum 1m of soils. Capping systems in IBA Cells 1-4 will consist of inert soils, with a minimum hydraulic conductivity of $1x10^{-7}$ m/s.

Lining Design

3.3.2 Lining system properties have not changed since the previous HRA and therefore remain in compliance with the Landfill Directive and continue to be appropriate. IBA Cells 1-4 will be constructed with a 1m thick engineered layer with a minimum permeability of $1x10^{-9}$ m/s and an additional separation geotextile.

Leachate Management

3.3.3 Leachate elevations in all cells should be maintained within the limits stipulated in the site permit in order to maintain hydraulic containment. Leachate at the site is currently treated and effluent put through the SRCs and tankered off-site for disposal. Leachate drainage in IBA Cells 1-4 will consist of spine drains as detailed on Drawing WR7855 01 04. This reduced drainage design is considered to be suitable for IBA Cells 1-4, as the waste within these cells will consist of homogenous processed IBA materials. Due to the nature of the fine material, processed IBA materials are reported to have a higher permeability than that of traditional waste and are comparable to those reported for sand ($1.4x10^{-8}$ to $2.5x10^{-5}$).[3] Therefore, it is considered that due to the waste type, limited leachate will be generated within these cells and the higher permeability indicates that leachate will be easily extracted. Leachate from IBA Cells 1-4 will be tankered for off-site disposal.

3.3.4 Leachate levels within this cell will be required to be maintained at 1m below the surrounding groundwater levels during both the operational phase (during groundwater pumping) and the non-operational phase (following cessation of pumping and recovery in groundwater levels).

[3]. B. Muhunthan , R. Taha & J. Said. Geotechnical Engineering Properties of Incinerator Ash Mixes. Journal of the Air & Waste Management Association. February 2012.

Groundwater Management

3.3.5 Groundwater is controlled via a sump in the northwest corner of Area A. Groundwater will be collected from a back wall drains in IBA Cells 1-4. The proposed groundwater management is shown on drawing WR7855 01 06.

Surface Water Management

3.3.6 Surface water from Phase 2 drains into Area B to the north, Surface water from Phase 3, 4 and 5 discharges to the Pike Drain via drainage ditches on the western and northern edges.

4.0 REQUISITE SURVEILLANCE

4.1 Leachate Monitoring

4.1.1 The current monitoring schedule is shown in the Tables below. Leachate Limits have been proposed for IBA Cells 1-4 based on the operational phase and the non-operational phase. This is due to the pumping of groundwater surrounding the cell affecting the surrounding groundwater levels whilst the cell is operational. Water levels have shown a rapid recovery in levels within the sand and gravel aquifer to the north of the site following the cessation of pumping. Therefore, the proposed limits have been based on 1m below the minimum surrounding groundwater in the operational phase and non-operational phase so that the cell is maintained within hydraulic containment.

4.1.2 There are no proposed changes to the leachate quality monitoring requirements. IBA Cells 1-4 should be monitored in accordance with operational cells.

Table 10. Leachate levels and compliance monitoring requirements

Monitoring point reference / Description	Limit (mAOD)	Monitoring frequency	Monitoring standard and method
LCP1	9.3	Quarterly	In accordance with Environment Agency document LFTGN02 (February 2003) ‘Guidance on Monitoring of Landfill Leachate, Groundwater and Surface Water’
LCP2	9.3		
LCP3	9.5		
LCP4	9.5		
LCP5	9.3		
Cell 6 Sump	9.0		
Cell 7 Sump	8.0		
Cell 8 Sump	8.0		
LW2.1B	5.5		
LW2.2	4.5		
LW2.3	5.5		
LW2.4	4.5		
LW2.5	4.5		
LW2.6B	5.5		
IBA Cells 1-4 – Operational Phase	4.5	Monthly	
IBA Cells 1-4 – Non-Operational Phase (following completion of the cell and cessation of groundwater pumping)	7.5	Quarterly	

Table 11. Leachate quality monitoring parameters

Monitoring point reference/description	Parameter	Monitoring frequency	Monitoring standard or method	Other specifications
Operational Cells or Phases (Any cells or phases that do not have a final engineered cap agreed in accordance with the existing 'landfill engineering' condition)			At leachate compliance point as listed in table S3.1 As specified in Environment Agency Guidance TGN02 'Monitoring of Landfill Leachate, Groundwater and Surface Water' (February 2003) or such subsequent guidance	None
MEPP	pH, EC, total alkalinity, ammoniacal nitrogen, Chloride, COD, BOD, cadmium, chromium, copper, lead, nickel, iron, arsenic, magnesium, potassium, total sulphates, calcium, sodium, zinc, manganese	Quarterly		
MEPP	Hazardous substances	Annually		
MEPP	Depth to base (mAOD)	Annually		
Non Operational Cells or Phases (Any cells or phases that have a final engineered cap agreed in accordance with the existing 'landfill engineering' condition)				
MEPP	pH, EC, total alkalinity, ammoniacal nitrogen, Chloride, COD, BOD, cadmium, chromium, copper, lead, nickel, iron arsenic, magnesium,	Annually		

Monitoring point reference/description	Parameter	Monitoring frequency	Monitoring standard or method	Other specifications
	potassium, total sulphates, calcium, sodium, zinc, manganese			
MEPP	Hazardous substances	Once every four years		
MEPP	Depth to base (mAOD)	Annually		

4.2 Groundwater Monitoring

4.2.1 The groundwater monitoring regime is shown in the tables below. There are no proposed changes to the monitoring regime, however it is noted that the mecoprop and cadmium compliance limits have not been adjusted since the reclassification of these parameters as non hazardous in 2017.

Table 9. Groundwater emission limits and monitoring requirements

Monitoring point reference	Parameter	Limit	Reference Period	Monitoring frequency	Monitoring standard and method
BH01, BH02/14, BH01/04, BH02/04, BH3A, BH17ASand, WBY1100, WBY4100 and WBY6100	Ammoniacal Nitrogen	2.59 mg/l	Spot Sample	Quarterly	In accordance with Environment Agency document LFTGN02 (February 2003) 'Guidance on Monitoring of Landfill Leachate, Groundwater and Surface Water'.
PZ02, WBY3100	Ammoniacal Nitrogen	10 mg/l			
BH01, BH01/04, BH02/04, BH3A, BH17Asand, WBY1100, WBY3100, WBY4100 and WBY6100	Chloride	200 mg/l			
BH01, BH01/04, BH02/04, BH3A, BH17Asand, WBY1100,	Nickel	0.2 mg/l			
	Cadmium	0.03 mg/l			

WBY3100, WBY4100, WBY6100 and PZ02	Mecoprop	0.1 µg/l		Annually	
PZ03	Ammoniacal Nitrogen	[no limit]	Spot Sample	Quarterly	
	Chloride				
	Nickel				
	Cadmium				
	Mecoprop			Annually	

Table 10. Groundwater monitoring requirements

Monitoring point reference/ Description	Parameter	Monitoring frequency	Monitoring standard or method
Up gradient MEPP	Water level, electrical conductivity, chloride, ammoniacal nitrogen, pH	Quarterly	As specified in Environment Agency Guidance TGN02 ‘Monitoring of Landfill Leachate, Groundwater and Surface Water’ (February 2003) and Horizontal Guidance Note H1 – Environmental Risk Assessment for permits, Annex J, version 2, April 2010)
	total alkalinity, magnesium, potassium, total sulphates, calcium, sodium, chromium, copper, iron, lead, nickel, zinc, manganese	Annually	
	Hazardous substances	Annually for first six years of operation	
Down or cross gradient MEPP	Water level, electrical conductivity, chloride, ammoniacal nitrogen, pH	Quarterly	As specified in Environment Agency Guidance TGN02 ‘Monitoring of Landfill Leachate, Groundwater and Surface Water’ (February 2003) After the initial 6 year monitoring period for hazardous substances, if the results of quarterly or annual monitoring suggest an
	Total alkalinity, magnesium, potassium, total sulphates, calcium, sodium, chromium, copper, iron, lead, nickel, zinc, manganese	Annually	

Monitoring point reference/ Description	Parameter	Monitoring frequency	Monitoring standard or method
	Hazardous substances detected in leachate	Annually for first six years of operation then every two years	increase in contamination, the operator shall also undertake a full hazardous substances screen.
MEPP	Base of monitoring point (mAOD)	Annually	

4.3 Surface Water Monitoring

4.3.1 Surface water monitoring is carried out at 5 locations, including at the SRC ditch. There are no proposed changes to the monitoring regime which is presented in the tables below.

Table 11. Point source emissions to water (other than sewer)-emission limits and monitoring requirements

Emission Point	Parameter	Source	Limit	Reference Period	Monitoring Frequency	Other specifications
W1 Pike Drain (Downstream)	Ammoniacal Nitrogen	Surface water collection system	2 mg/l	Spot Sample	Monthly	As specified in Environment Agency Guidance TGN02 'Monitoring of Landfill Leachate, Groundwater and Surface Water' (February 2003)
	Chloride		175 mg/l			
	Nickel		0.12 mg/l			
	Suspended Solids		50 mg/l			
SRC Ditch monitoring points	Ammoniacal Nitrogen		2 mg/l	Spot Sample	Prior to discharge	
	Chloride		175 mg/l			
	Nickel		0.12 mg/l			
	Suspended Solids		50 mg/l			
	Selenium		0.01 mg/l			
	Hazardous substance suite		10 µg/l			

4.3.2 Selenium is not required to be monitored at any other location associated with the permit area. The specific requirement for selenium to be monitored in just the SRC is unclear and the benefit of undertaking this monitoring is questionable when the assessment of non hazardous metals are provided through the monitoring and assessment of nickel. It is recommended that selenium is removed from the compliance monitoring of the SRC Ditch. This would result in a consistent approach across the site.

Table 12. Surface water monitoring requirements.

<table>
<tr><th>Monitoring point reference/ description</th><th>Parameter</th><th>Monitoring frequency</th><th>Monitoring standard or method</th><th>Other specifications</th></tr>
<tr><td>MEPP</td><td>Ammoniacal Nitrogen, Chloride, Suspended Solids, Visual Oil and Grease, pH, electrical conductivity</td><td>Monthly</td><td>Spot Sample</td><td rowspan="2">As specified in Environment Agency Guidance TGN02 ‘Monitoring of Landfill Leachate, Groundwater and Surface Water’ (February 2003)</td></tr>
<tr><td>SRC Ditch monitoring points</td><td>Ammoniacal Nitrogen, Chloride, Suspended Solids, Visual oil and grease, pH, Electrical Conductivity, Calcium, Copper (d), Chromium (total), Magnesium (d), Manganese, Nickel, Lead, Zinc (d), Hazardous substances including Cadmium and Mercury</td><td>Prior to discharge</td><td>Spot sample</td></tr>
</table>

5.0 CONCLUSIONS

5.1.1 This hydrogeological risk assessment review has been undertaken in line with the Environment Agency guidance on Hydrogeological Risk Assessment reviews.

5.1.2 On review of the monitoring data across the review period, it is observed that some exceedances in leachate levels were recorded in Phase 2 where cells were previously temporarily restored. These cells have now been permanently capped and levels have since reduced.

5.1.3 Leachate quality remains comparable to the previous review for all source term parameters, with the exception of mecoprop. Higher concentrations of mecoprop are not considered to represent an increase in risk posed by the site. The site remains in hydraulic containment and therefore the current risk assessment models for phases 2 and 3,4 and 5 are considered to remain valid.

5.1.4 The construction of IBA Cells 1-4 on the northern area of the site (Area A), for the processing and infilling of IBA materials, indicates a change in the conceptual model. The source term for these cells is considered to be significantly different to that reported within the existing phases at the site and have been modelled using source term values from a literature review.

5.1.5 IBA Cells 1-4 were modelled utilised the EA's contaminant flux spreadsheet models for hydraulic containment landfills. Results indicated there was no significant risk to the surrounding groundwater from the leachate in IBA Cells 1-4, provided that these cells are managed at 1m below the surrounding groundwater levels.

5.1.6 Leachate levels in IBA Cells 1-4 are to be managed on the principal of hydraulic containment, and limits have been proposed for both the operational phase at 4.5mAOD (whilst groundwater pumping in this area is taking place), and for the non-operational phase at 7.5 mAOD (when groundwater levels have recovered following the cessation of pumping).

5.1.7 In general, the groundwater quality remains comparable to the previous review, with no exceedances of compliance limits throughout the review period. Overall, the groundwater quality represents a stable trend.

5.1.8 High levels of chloride were recorded within the SRC ditch; however, this surface water runoff is associated with the coppice area and is monitored prior to discharge. It is understood that any water is recirculated prior to discharge. Concentrations of many leachate indicators within the Pike Drain remain comparable at upstream and downstream locations which therefore indicate no discernible impact from the site on surface water environments.

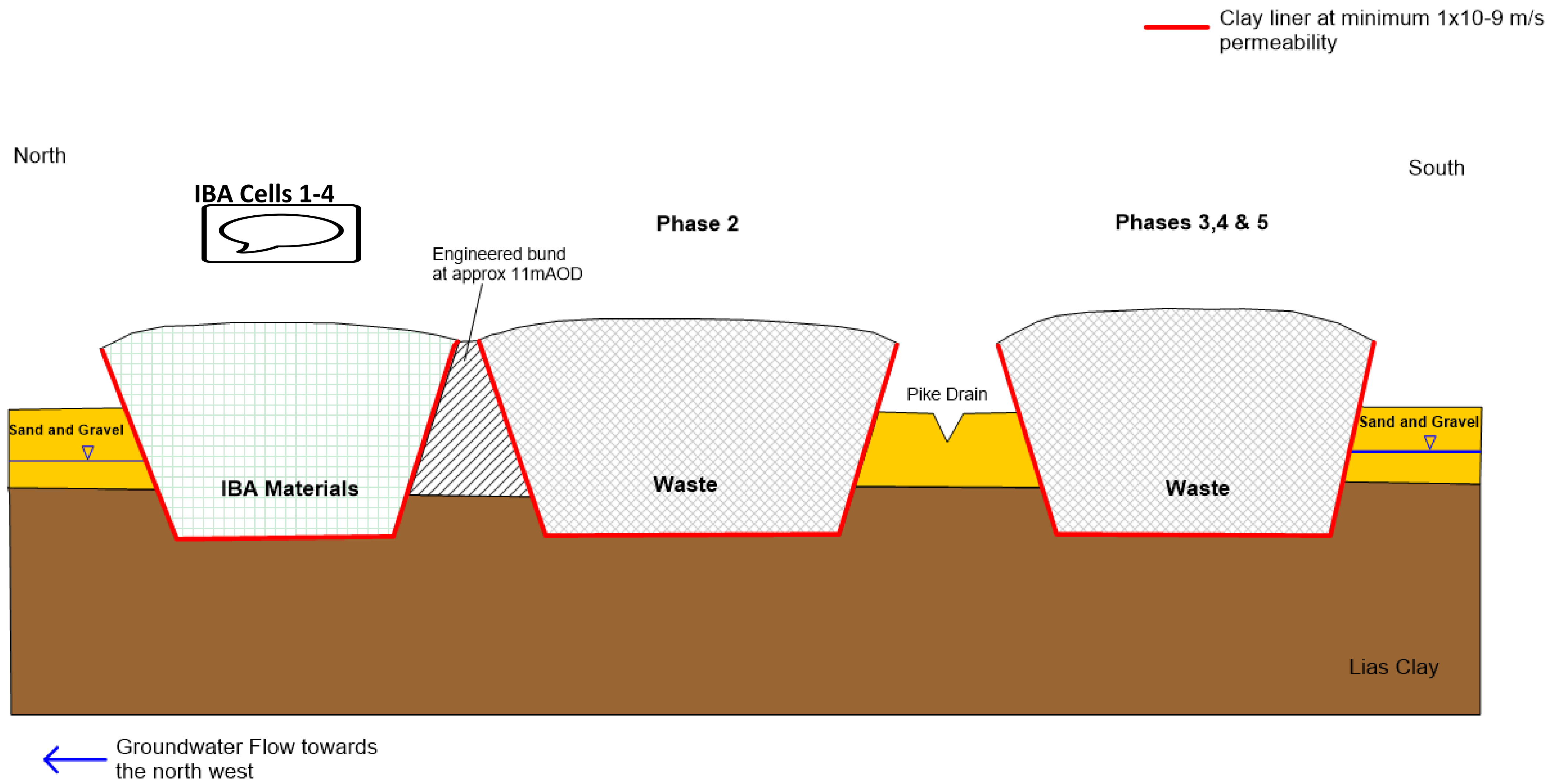
5.1.9 The risk assessment review concludes that the site remains in compliance with section 22 of the Environmental Permitting Regulations.

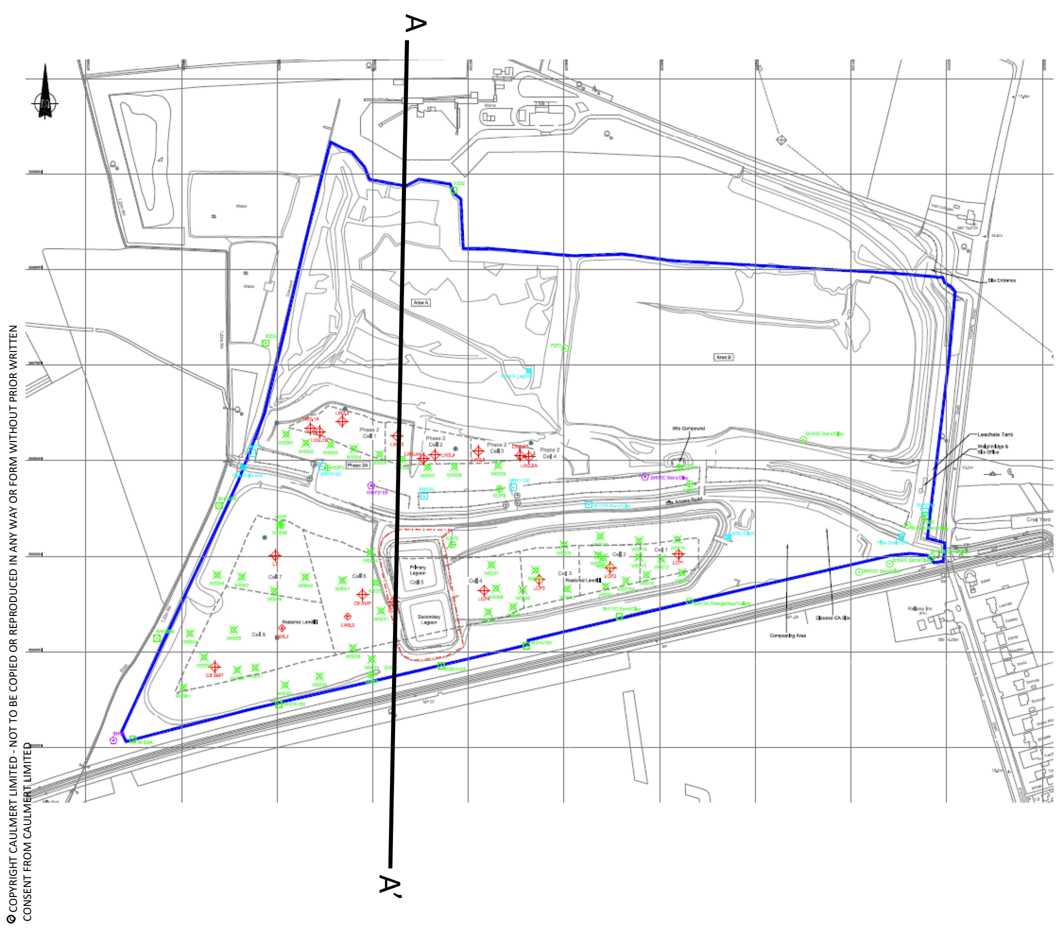
DRAWINGS

NOTES

1. DO NOT SCALE FROM THIS DRAWING, WORK FROM FIGURED DIMENSIONS ONLY. ALL DIMENSIONS ARE IN METRES AND ALL LEVELS ARE IN METRES ABOVE ORDNANCE DATUM UNLESS NOTED OTHERWISE.

2. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL RELEVANT ARCHITECTS, ENGINEERS AND SPECIALIST DRAWINGS AND SPECIFICATIONS.





REV	MODIFICATIONS	BY	RE	AP	DATE
P01	ISSUED FOR INFORMATION	EJD	AD	AD	12.06.23

PURPOSE OF ISSUE: FOR INFORMATION

STATUS: S2

CLIENT: FCC Environment

PROJECT: WHISBY IBA FACILITY

TITLE: SCHEMATIC CONCEPTUAL MODEL

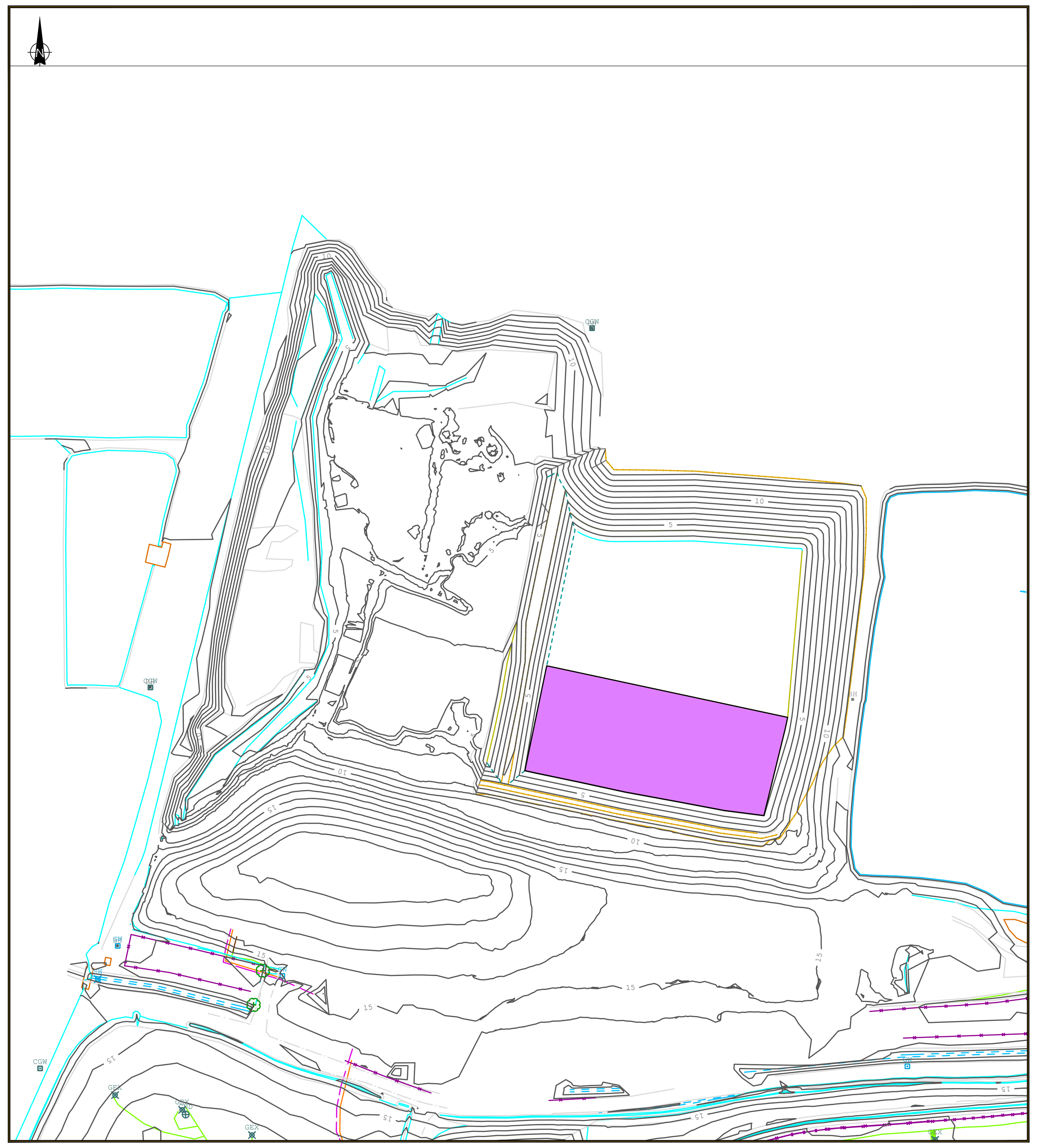
DESIGNED BY	DRAWN BY	REVIEWED BY	AUTHORISED BY
AD	EJD	AD	AD

DATE	SCALE @ A3	JOB REF:	REVISION
12.06.2023	NTS	5671	P01

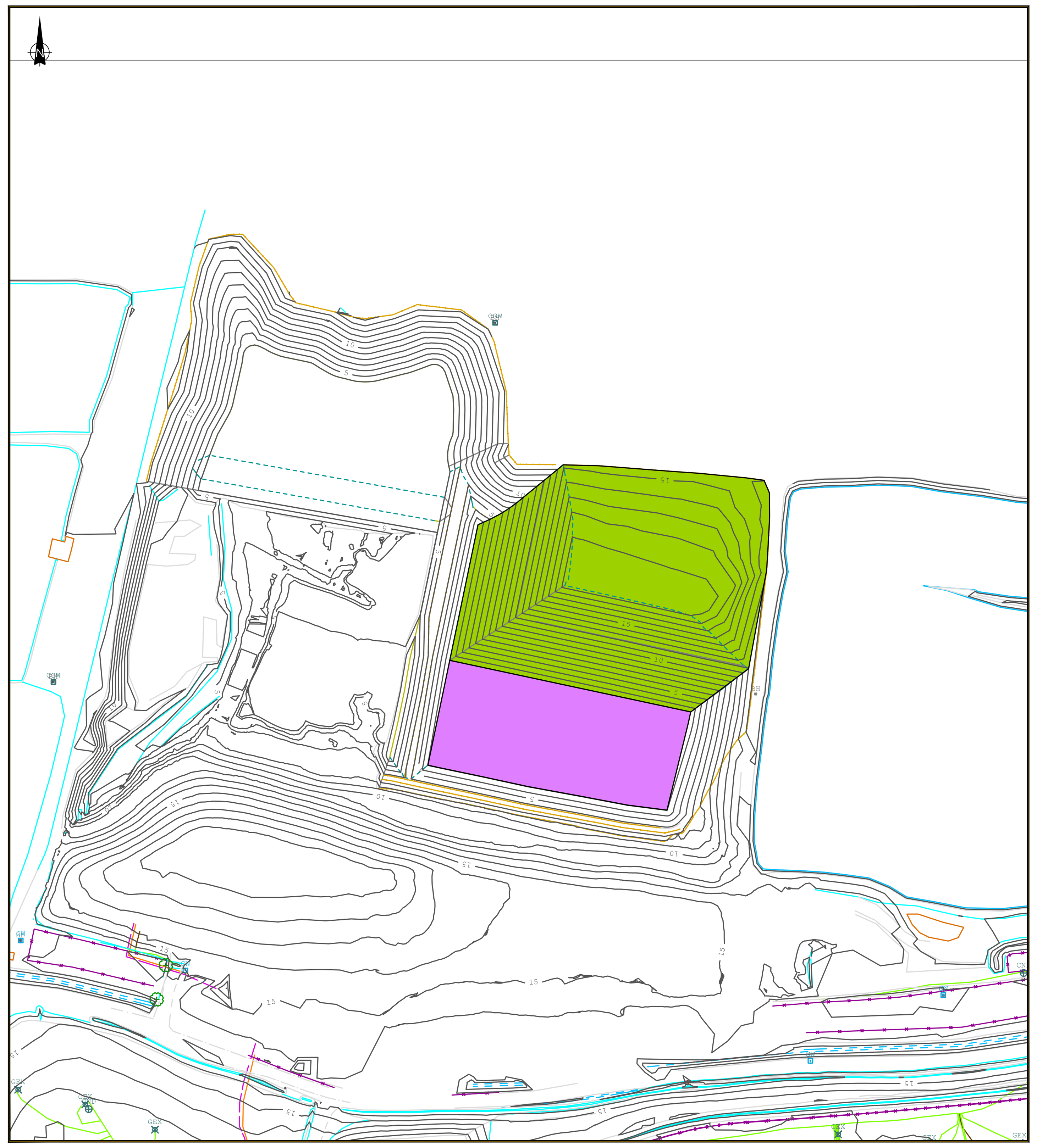
DRAWING NUMBER: 5671-CAU-XX-XX-DR-V-1801

Caulmert
engineering environmental planning

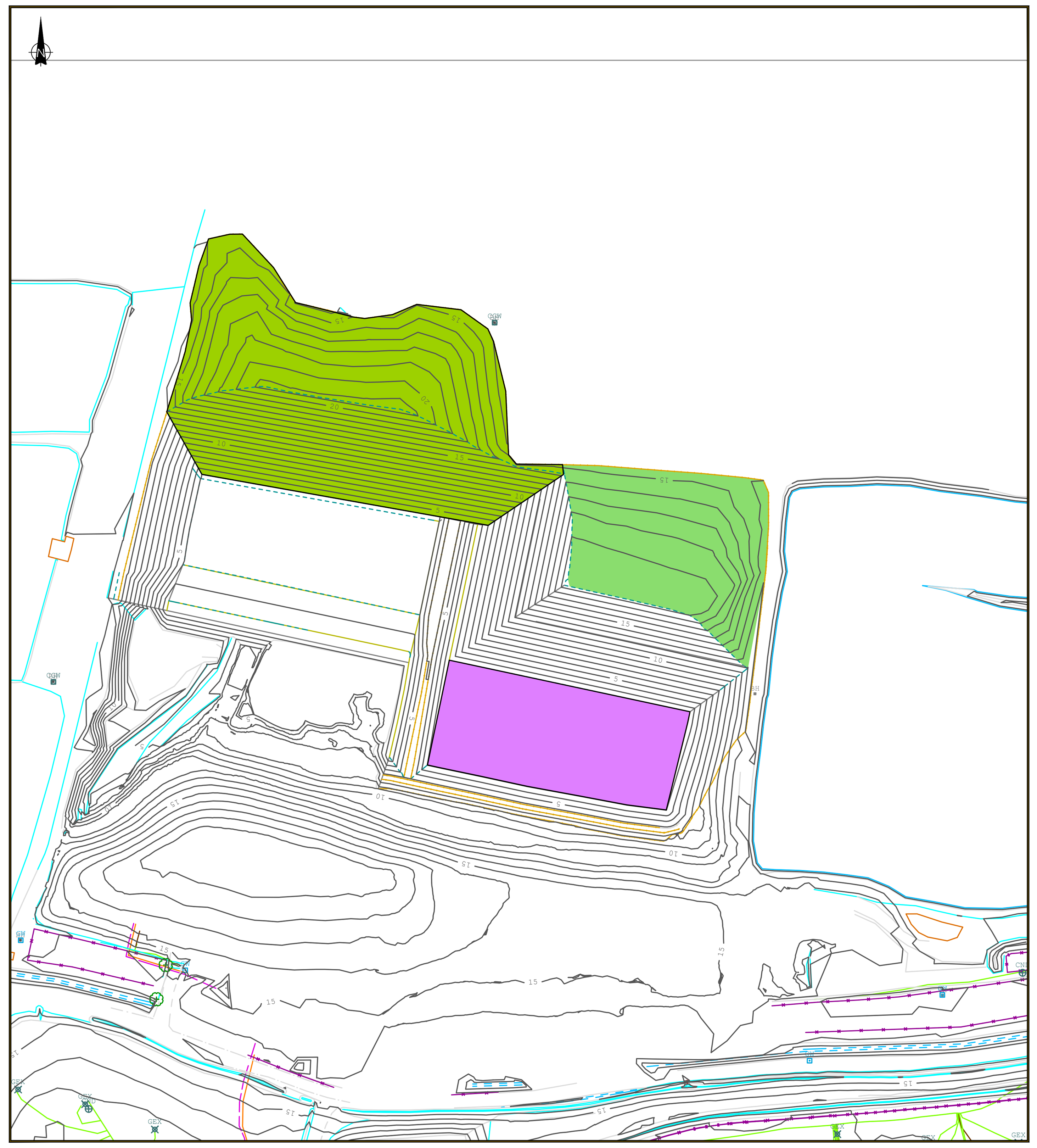
WWW.CAULMERT.COM



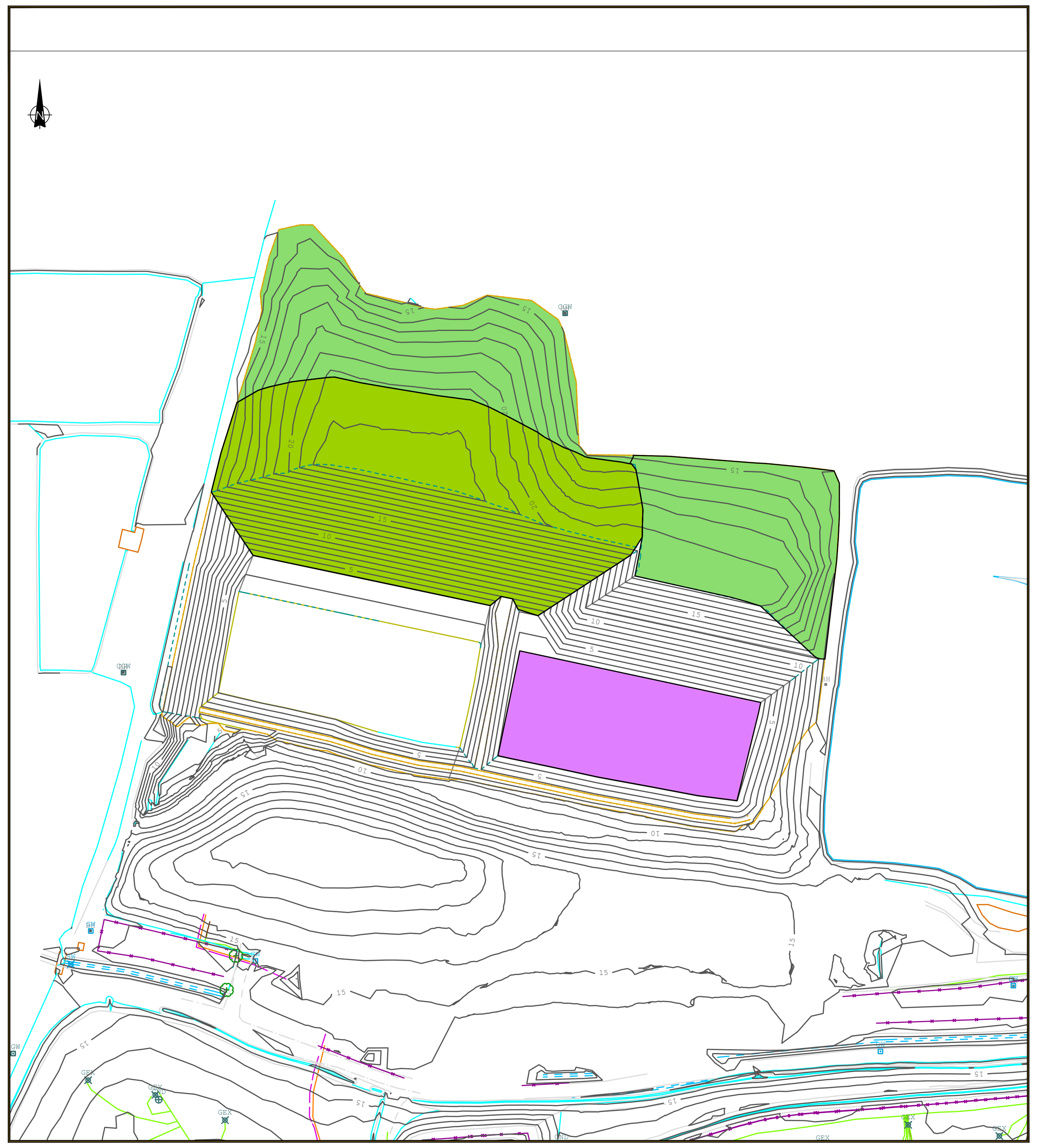
CELL 1 & IBA PAD - 2023 WORKS
SCALE 1:2000



PROPOSED CELL 1 FILLED, CELL 2 ENGINEERED
SCALE 1:1250



PROPOSED CELL 1 RESTORED, CELL 2 FILLED & CELL 3 ENGINEERED
SCALE 1:1250



PROPOSED CELL 1 & 2 RESTORED, CELL 3 FILLED & CELL 4 ENGINEERED
SCALE 1:1250

PROPOSED CELL 1, 2 & 3 RESTORED, CELL 4 FILLED - IBA PAD IN CELL 1 RE-PURPOSED
SCALE 1:1250

PROPOSED CELL 1, 2, 3 & 4 RESTORED - IBA PAD FILLED
SCALE 1:1250

NOTES

1. ALL DIMENSIONS IN MILLIMETRES AND ALL LEVELS IN METRES ABOVE ORDNANCE DATUM.

2. DO NOT SCALE FROM THIS DRAWING.

3. ANY ANOMALIES IDENTIFIED WITH THE DETAILS SHOWN ON THIS DRAWING ARE TO BE BROUGHT TO THE ATTENTION OF SIRIUS ENVIRONMENTAL PRIOR TO CONSTRUCTION WORKS COMMENCING.

LEGEND

- IBA PAD
- RECENT CELL FILLED TO POST SETTLEMENT LEVELS
- OLDER CELL(S) FILLED TO POST SETTLEMENT LEVELS

REV	DESCRIPTION	DATE	BY
3	CELL REFERENCES AMENDED	28/06/2023	JE
2	COMPLETE RE-MODEL FOR ALTERNATIVE SEQUENCE	21/11/2022	JE
1	COMPLETE RE-MODEL TO ACHIEVE MINIMUM FINAL EARTHWORKS BALANCE	13/9/2022	JE

CLIENT

FCC Environment

FCC Environment (UK) Limited
Ground Floor West, 900 Pavilion Drive, Northampton Business Park, Northampton, NN4 7RG

sirius Environmental

4245 Park Approach, Thorpe Park, Leeds. LS15 8GB. 0113 264 9960

JOB TITLE

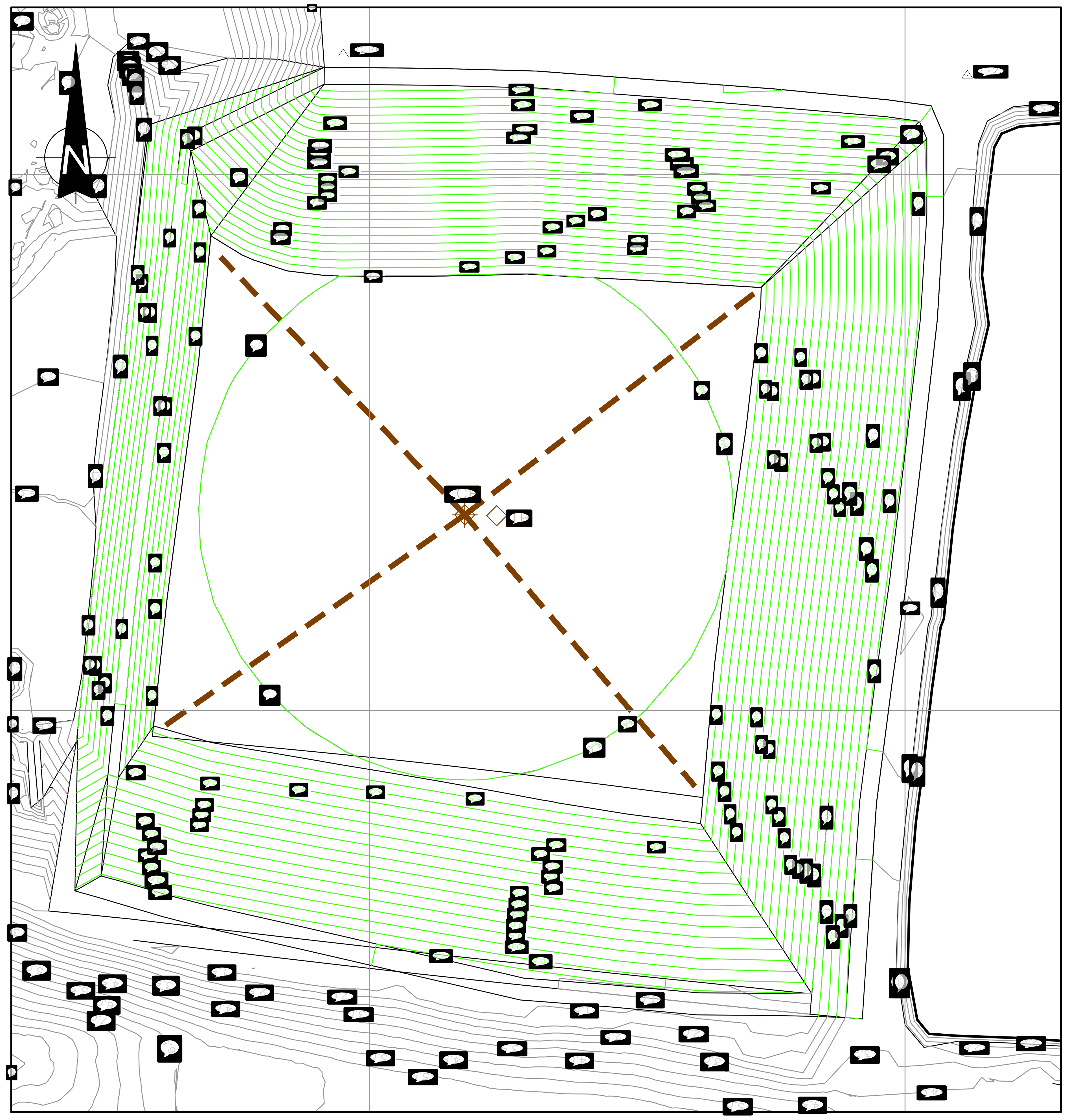
WHISBY LANDFILL SITE

DRAWING TITLE

PROPOSED IBA PAD & CELLS DEVELOPMENT

DRAWN	DATE	APPROVED	DATE
J.E	01/09/2022	A.K	06/09/2022

SCALE	SHEET	DRAWING NUMBER	REVISION
1:1000	A1L	WR7855/1/001	3



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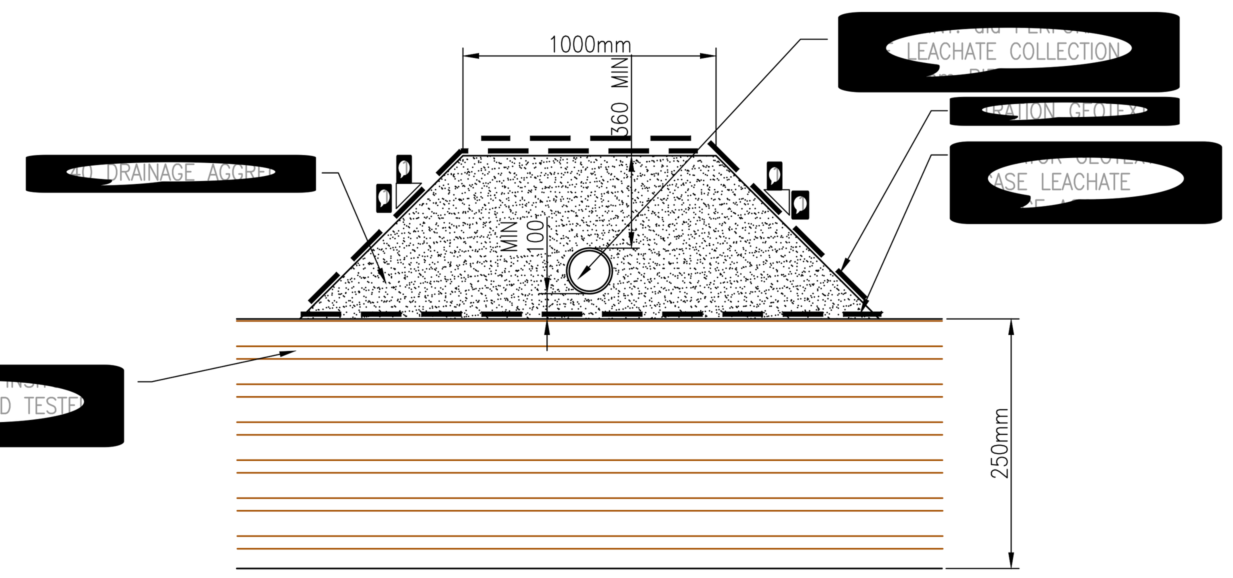

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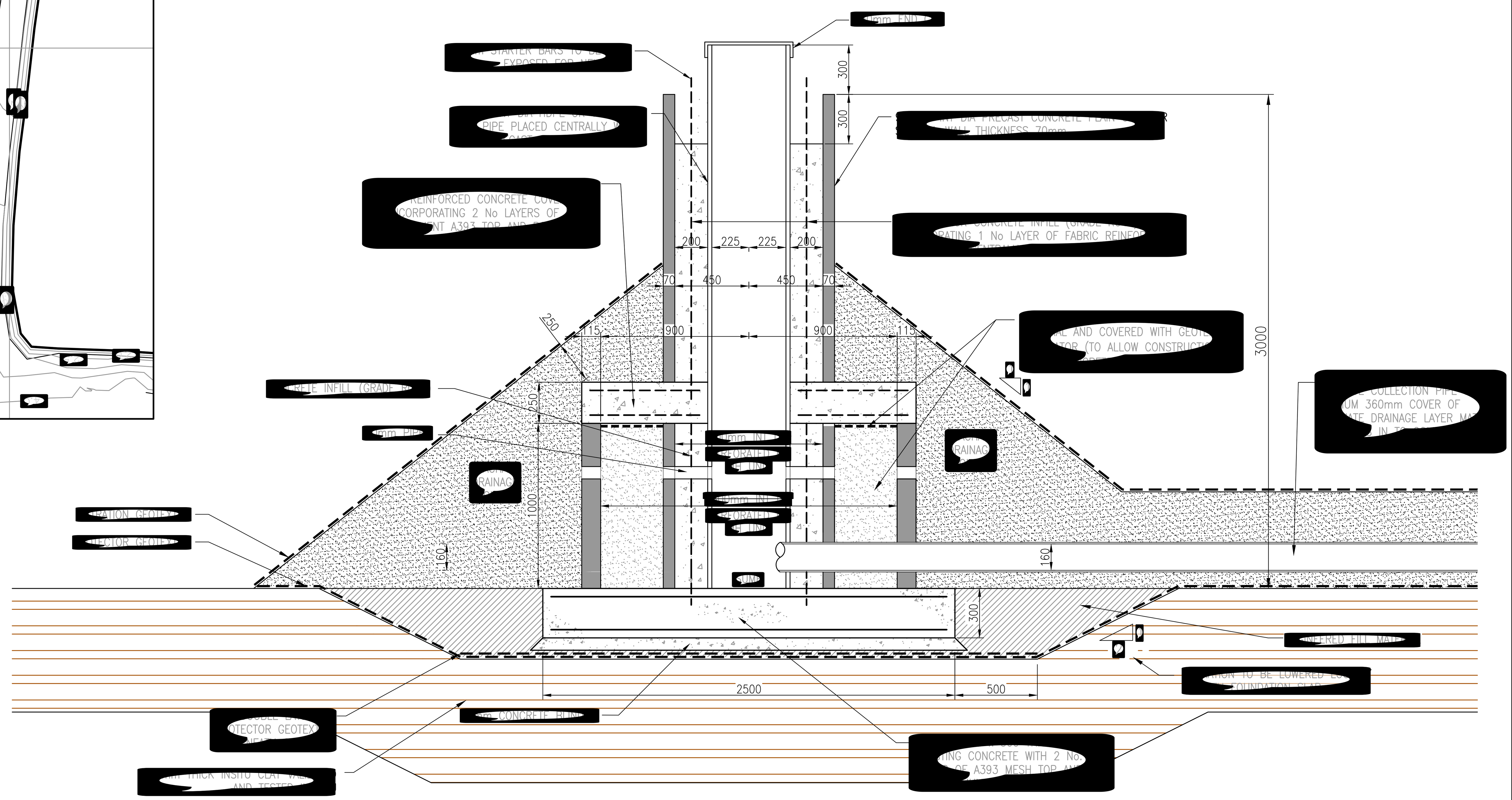

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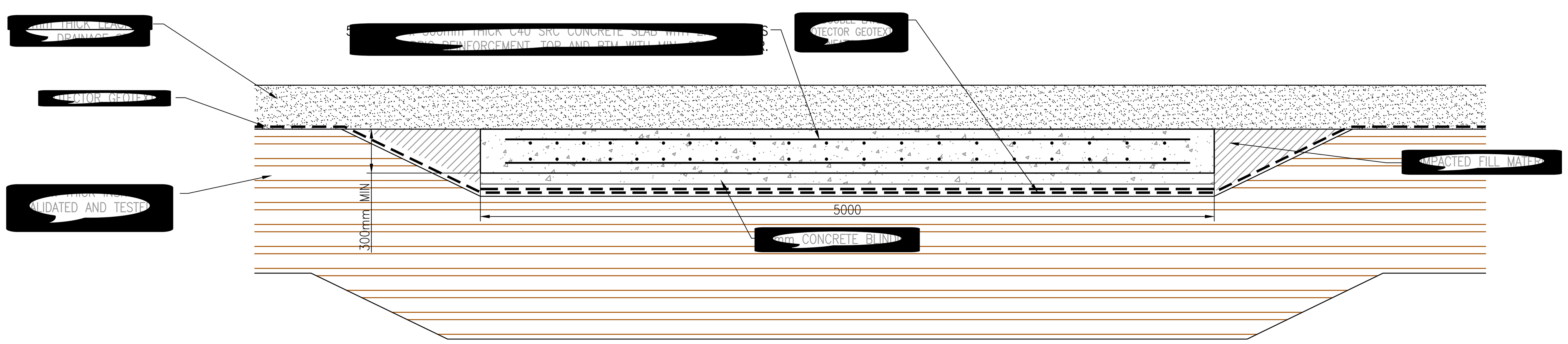

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NOTES

1. ALL DIMENSIONS IN MILLIMETRES AND ALL LEVELS IN METRES ABOVE ORDNANCE DATUM.
2. DO NOT SCALE FROM THIS DRAWING.
3. ANY ANOMALIES IDENTIFIED WITH THE DETAILS SHOWN ON THIS DRAWING ARE TO BE BROUGHT TO THE ATTENTION OF SIRIUS ENVIRONMENTAL PRIOR TO CONSTRUCTION WORKS COMMENCING.
4. FOR SECTION DETAILS SEE DRAWING WR7885 01 03

LEGEND

- SITE SURVEY
- PROPOSED TOP OF LINER
- PROPOSED LEACHATE COLLECTION / MONITORING POINT
- 160mm OD SDR PERFORATED HDPE LEACHATE COLLECTION PIPE
- PROPOSED TARGET PAD

REV	DESCRIPTION	DATE	BY
1	SOUTHERN BATTER AMENDED	04.04.2023	ARK

CLIENT

FCC Environment

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

Sirius Environmental
4245 Park Approach, Thorpe Park, Leeds. LS15 8GB. 0113 264 9960

JOB TITLE

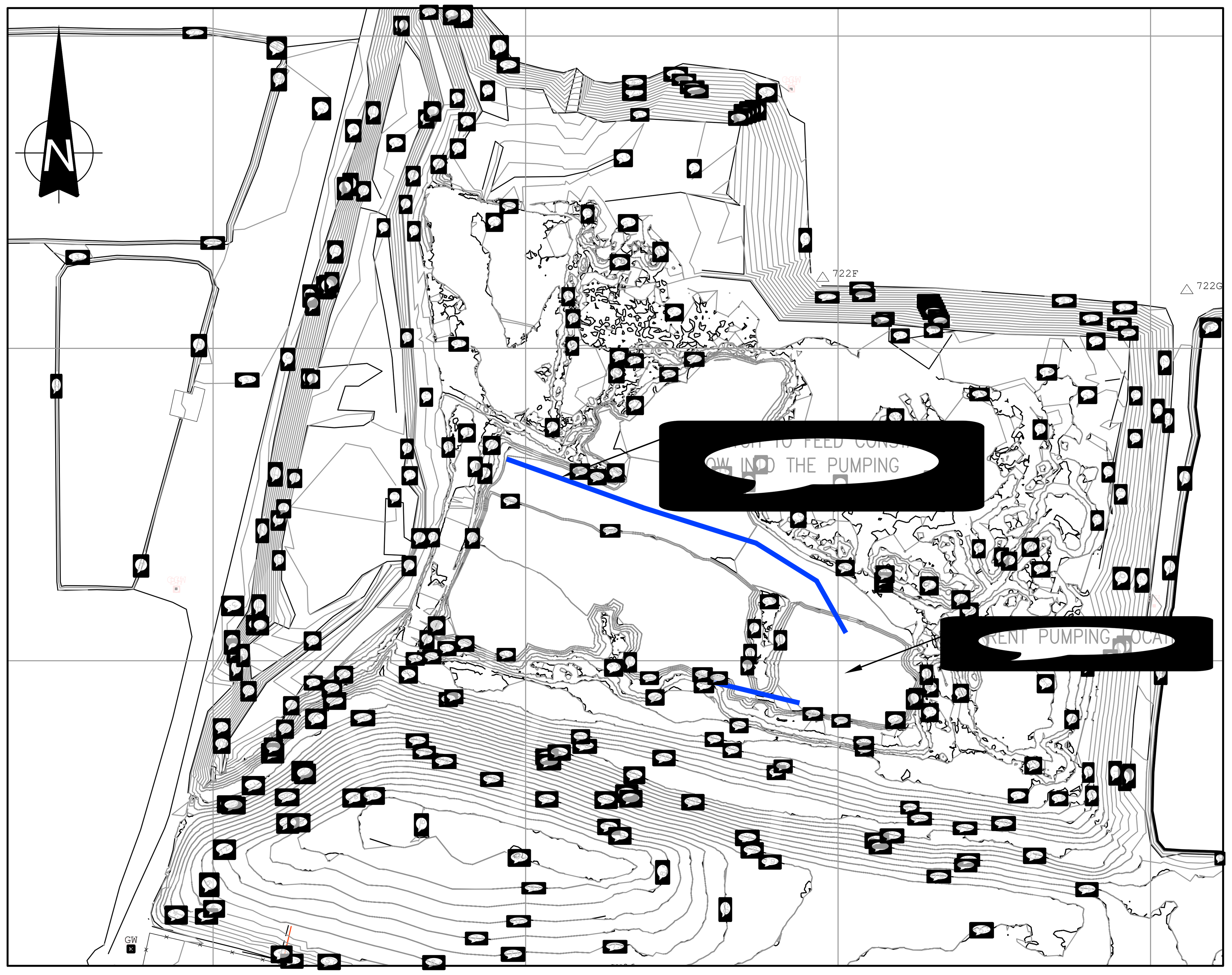
WHISBY LANDFILL SITE
IBA CELL 1 CONSTRUCTION

DRAWING TITLE

PROPOSED LEACHATE DRAINAGE LAYOUT

DRAWN	DATE	APPROVED	DATE
ARK	02/03/2023	A.K	02/03/2023

SCALE	SHEET	DRAWING NUMBER	REVISION
As Shown	A1L	WR7855 01 04	1



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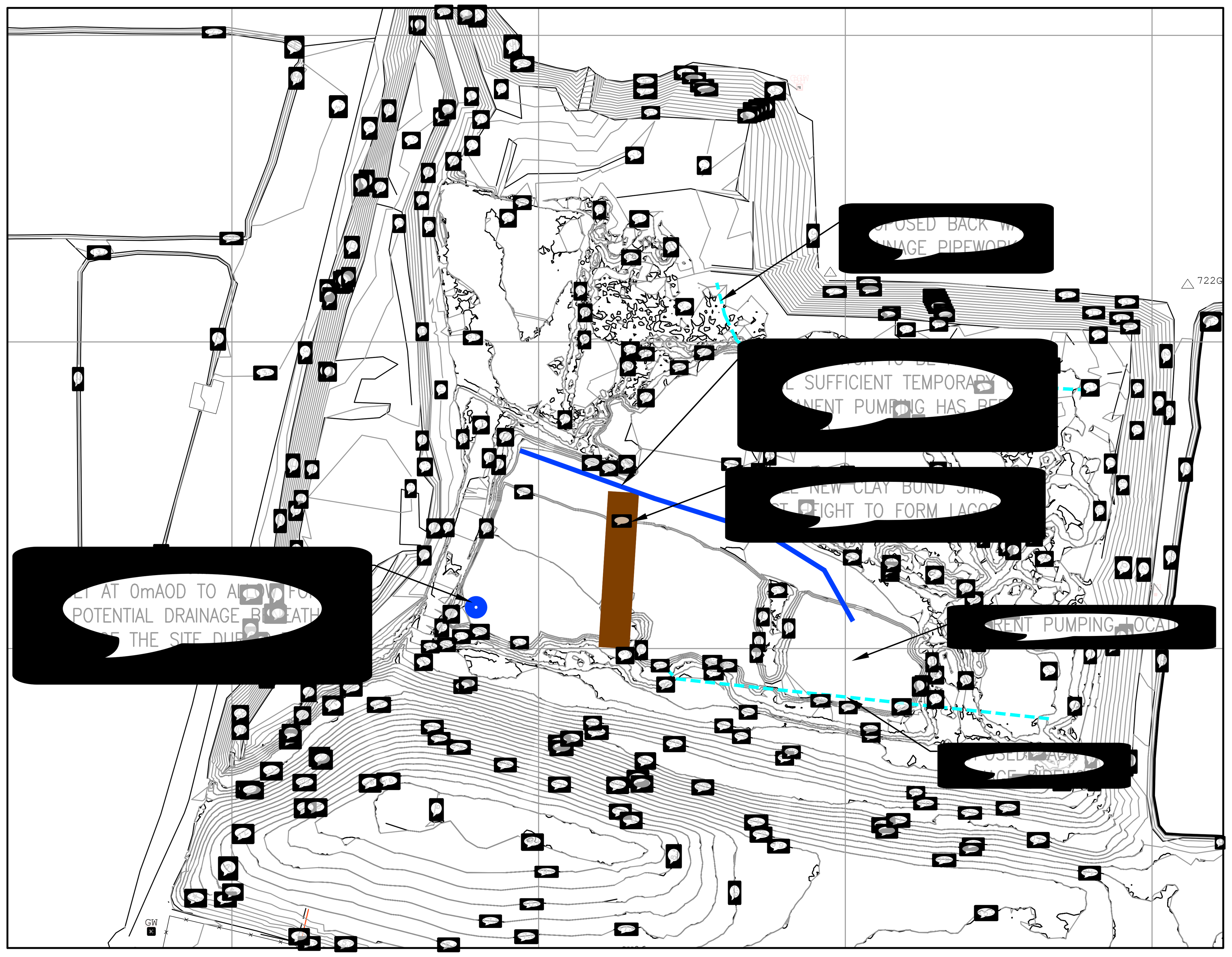

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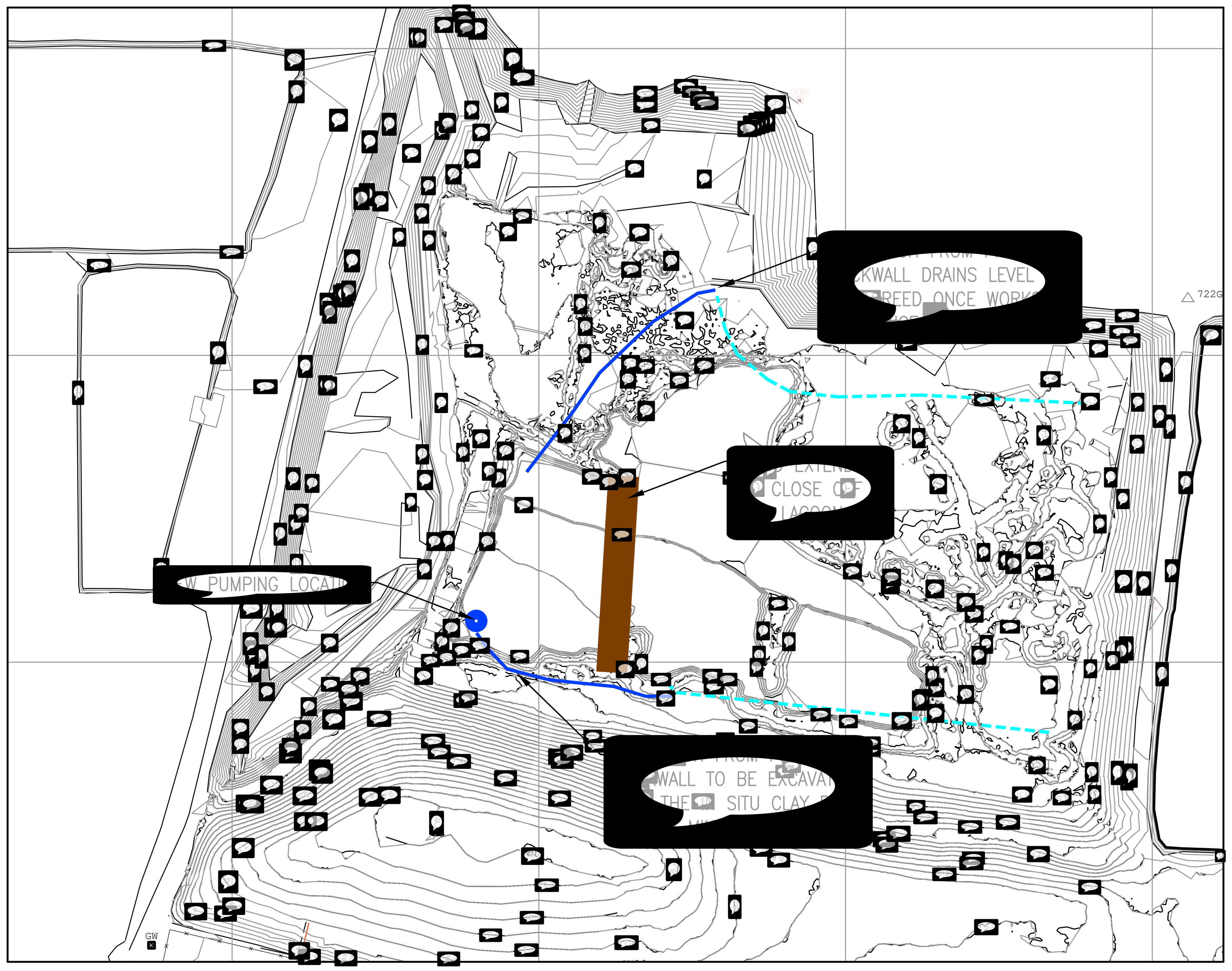

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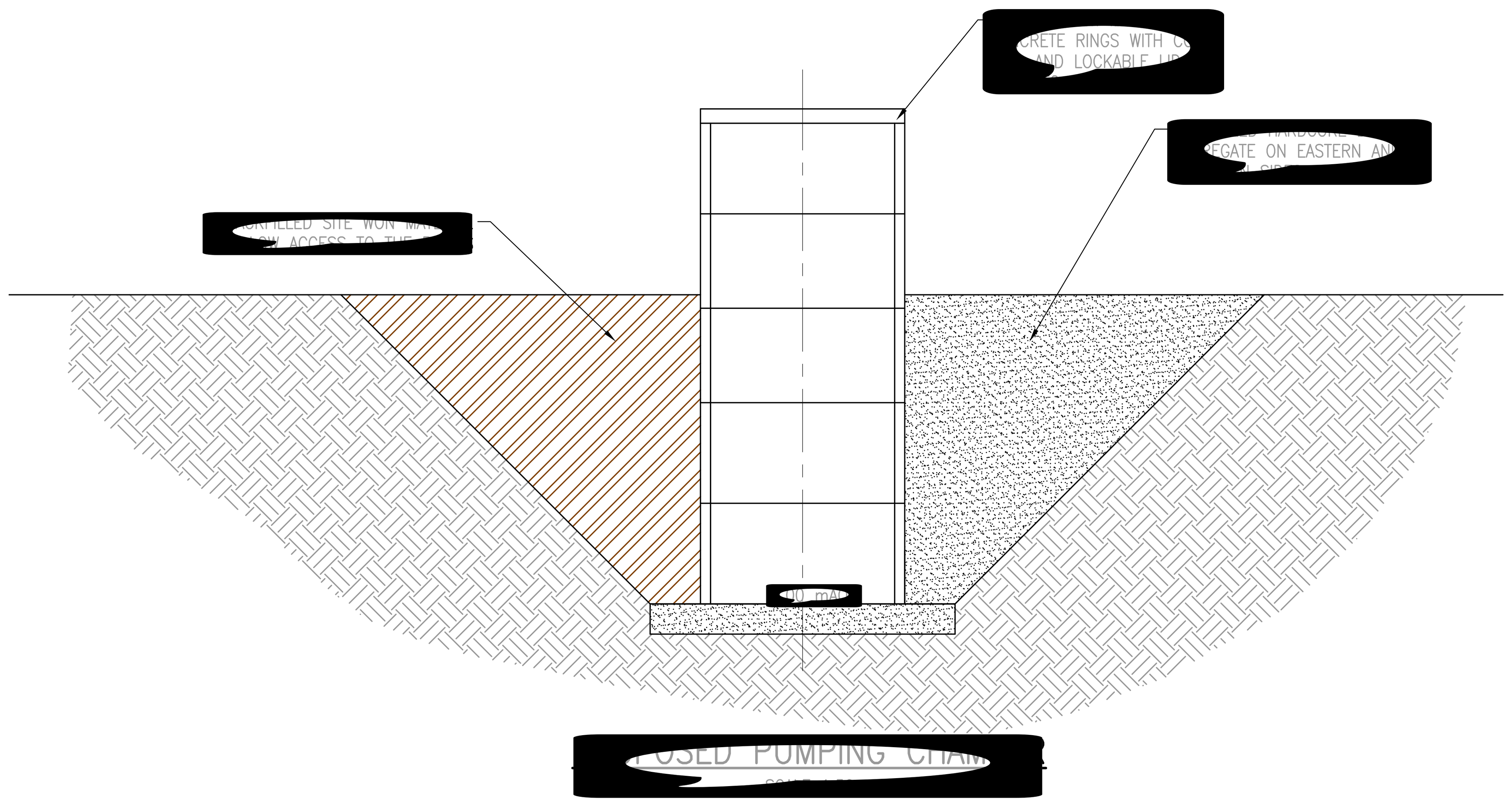

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NOTES

1. ALL DIMENSIONS IN MILLIMETRES AND ALL LEVELS IN METRES ABOVE ORDNANCE DATUM.
2. DO NOT SCALE FROM THIS DRAWING.
3. ANY ANOMALIES IDENTIFIED WITH THE DETAILS SHOWN ON THIS DRAWING ARE TO BE BROUGHT TO THE ATTENTION OF SIRIUS ENVIRONMENTAL PRIOR TO CONSTRUCTION WORKS COMMENCING.

LEGEND

- SITE SURVEY
- EXTENTS OF PROPOSED IBA CELL 1 WORKING AREA
- STOCKPILE AREA FOR UNSUITABLE / EXCESS MATERIALS FROM CELL EXCAVATION

REV	DESCRIPTION	DATE	BY

CLIENT

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

sirius Environmental
4245 Park Approach, Thorpe Park, Leeds. LS15 8GB. 0113 264 9960

JOB TITLE
WHISBY LANDFILL SITE
IBA CELL 1 CONSTRUCTION

DRAWING TITLE
Proposed Water Management

DRAWN	DATE	APPROVED	DATE
ARK	14/03/2023	ARK	14/03/2023

SCALE	SHEET	DRAWING NUMBER	REVISION
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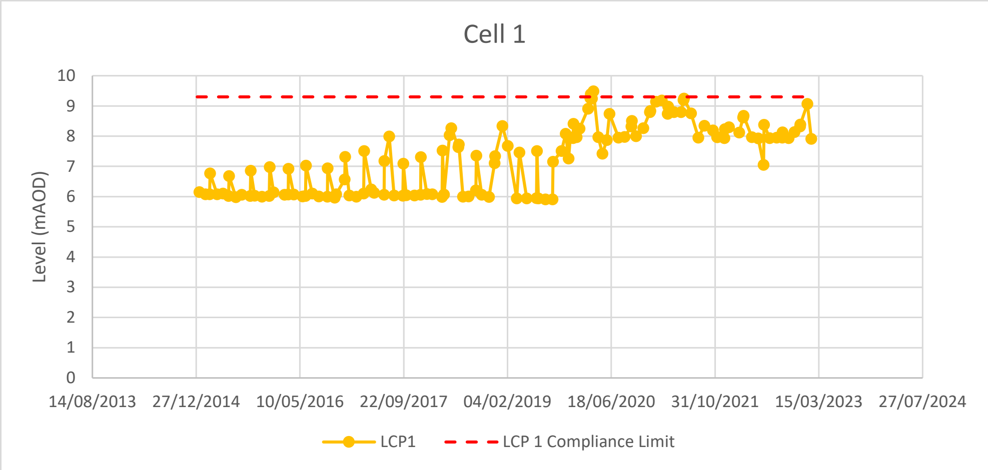
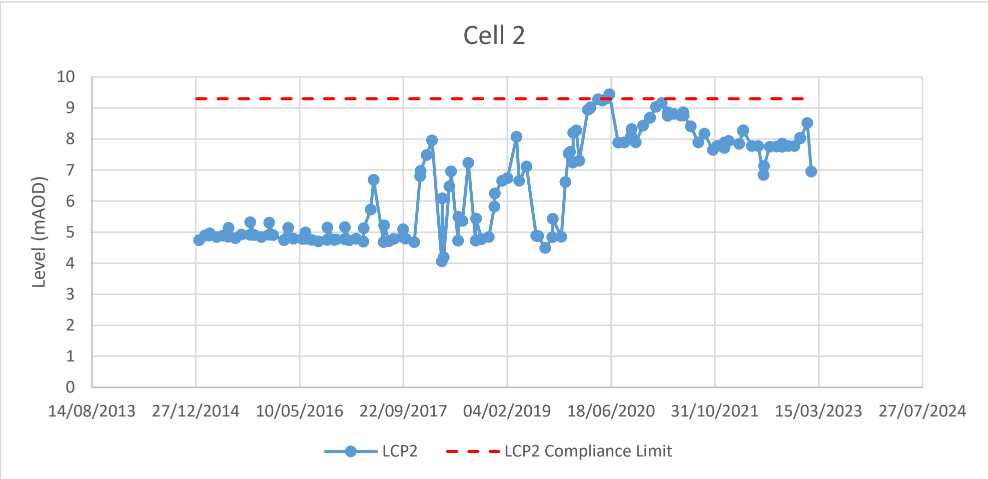
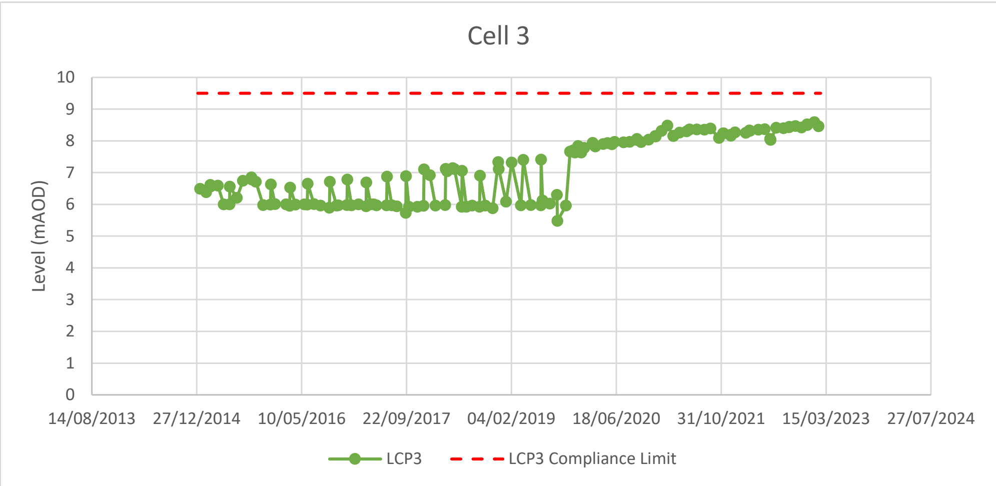
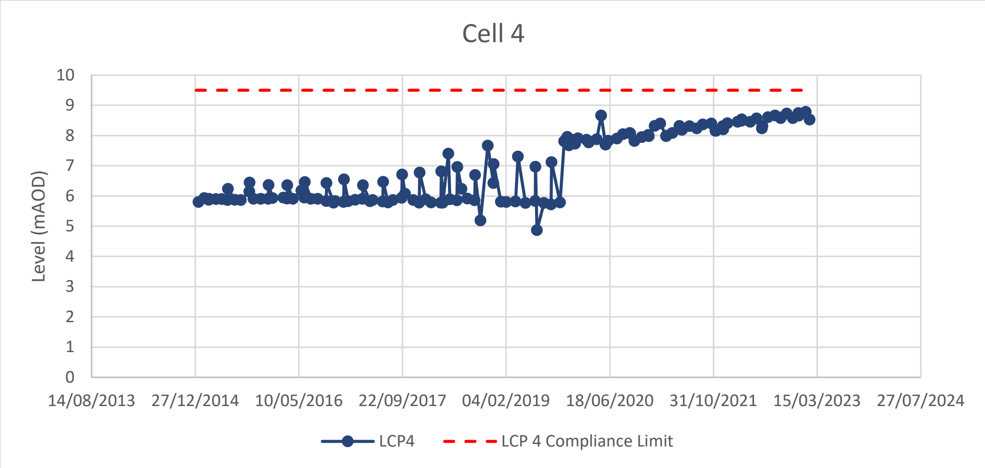
APPENDIX 1

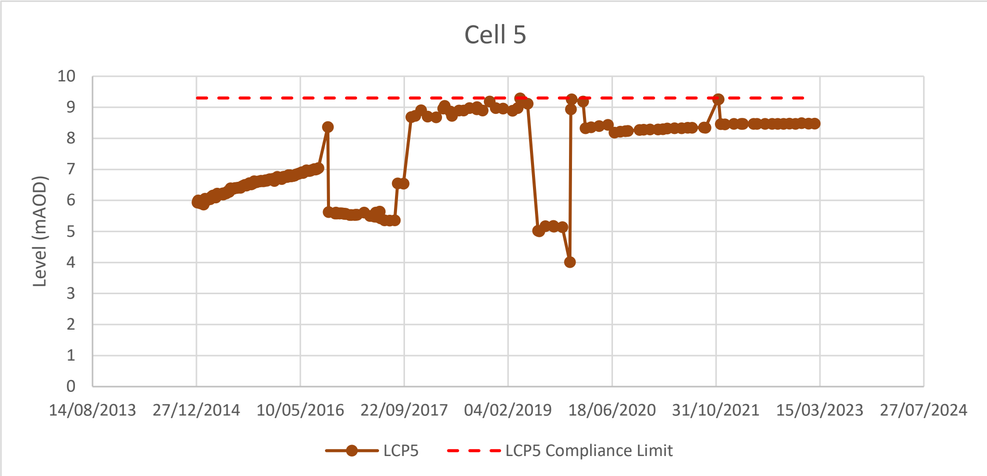
Leachate Levels

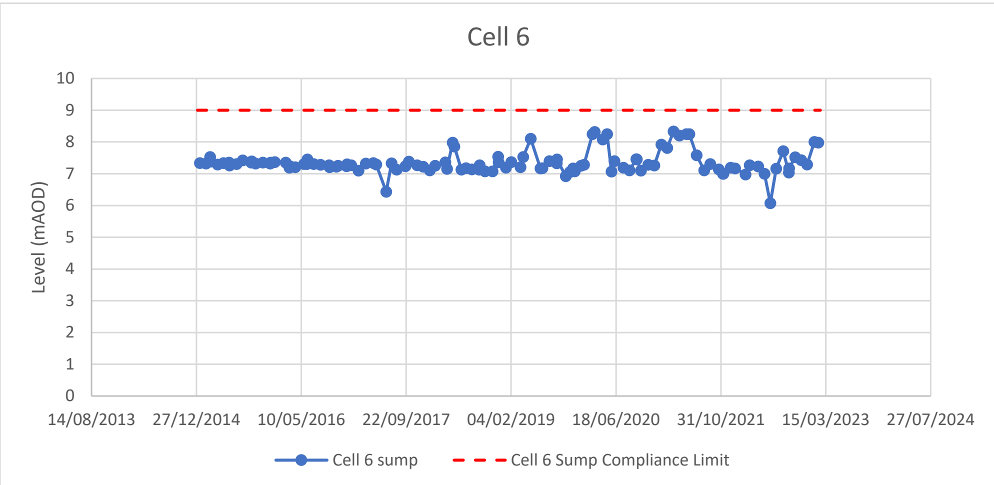

Cell 1
Level (mAOD)
10
9
8
7
6
5
4
3
2
1
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
LCP1
LCP 1 Compliance Limit

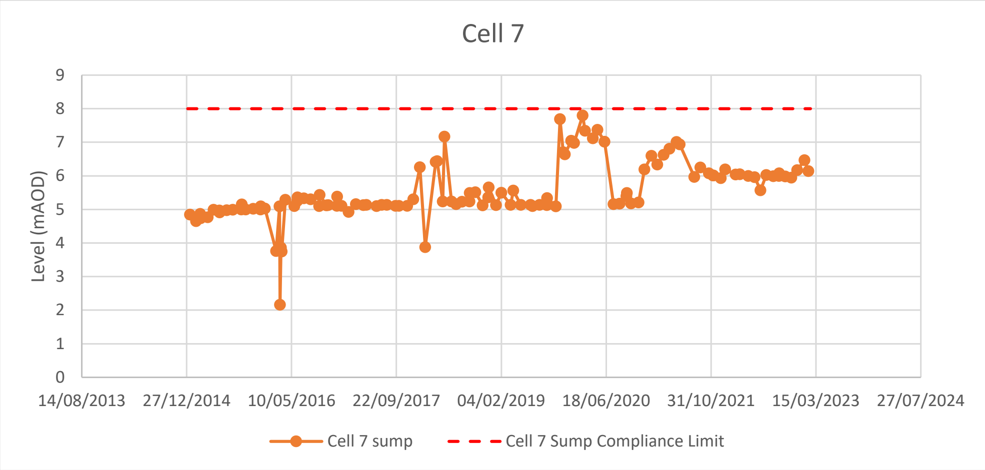

Cell 2
Level (mAOD)
10
9
8
7
6
5
4
3
2
1
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
LCP2
LCP2 Compliance Limit

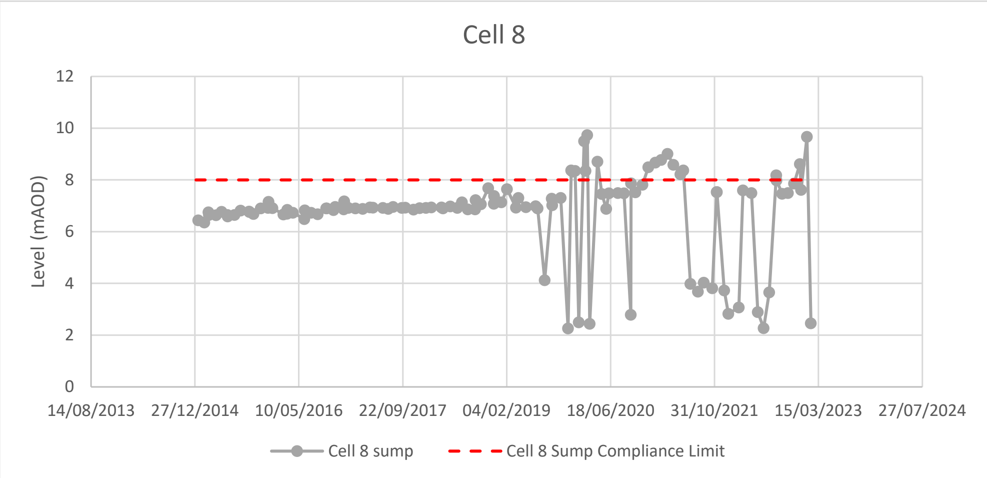

Cell 3
Level (mAOD)
10
9
8
7
6
5
4
3
2
1
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
LCP3
LCP3 Compliance Limit

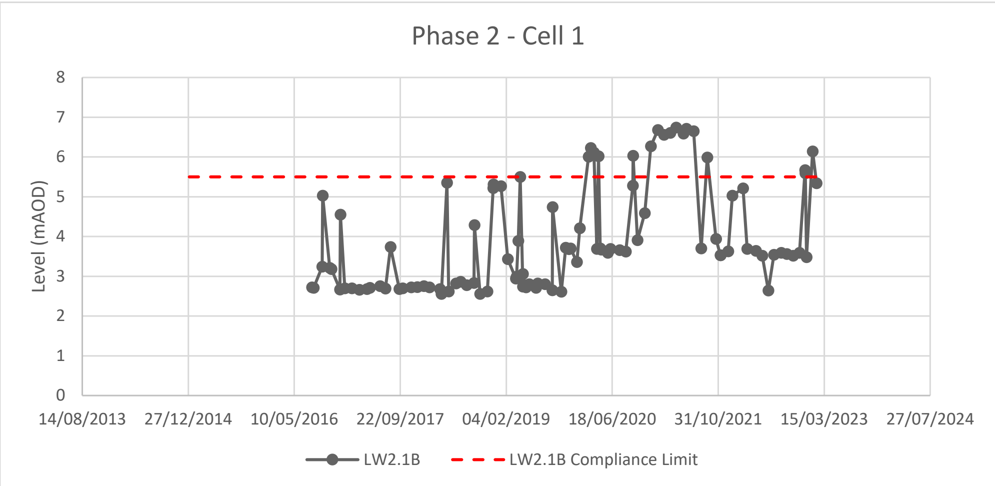

Cell 4
Level (mAOD)
10
9
8
7
6
5
4
3
2
1
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
LCP4
LCP 4 Compliance Limit

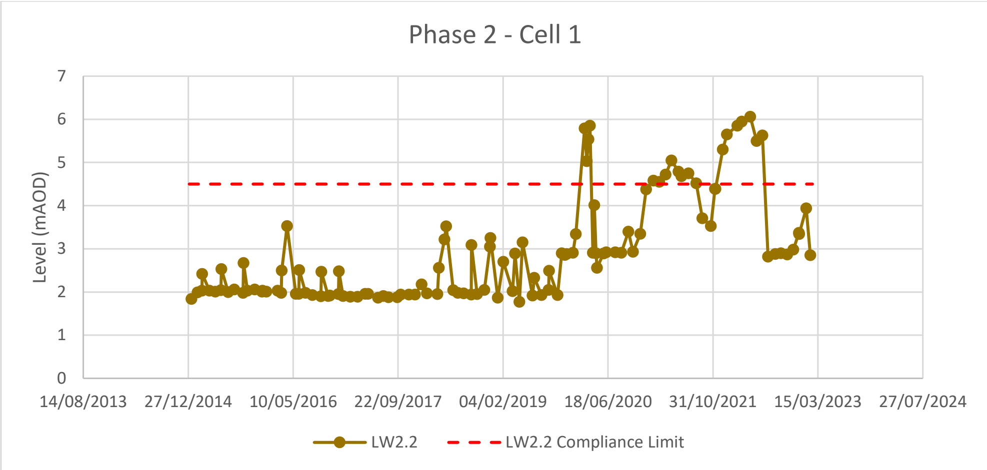

Cell 5
Level (mAOD)
10
9
8
7
6
5
4
3
2
1
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
LCP5
LCP5 Compliance Limit

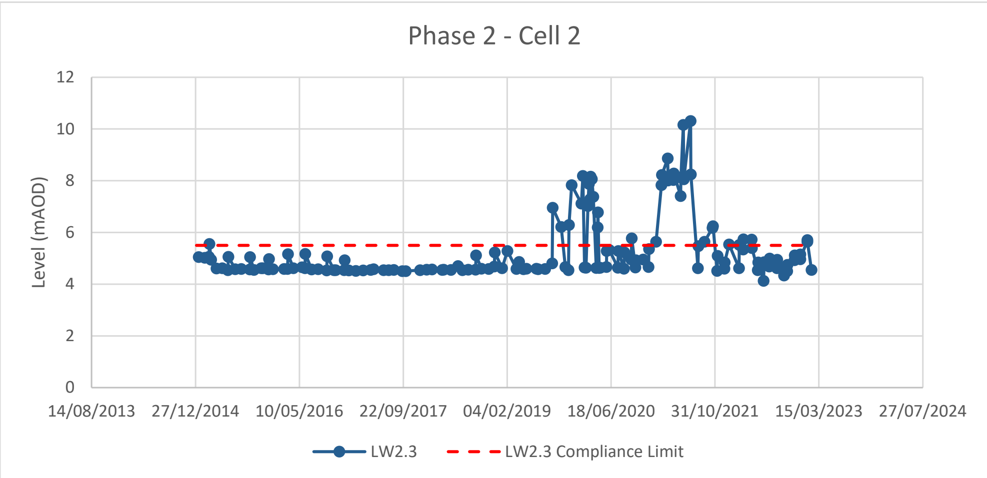

Cell 6
Level (mAOD)
10
9
8
7
6
5
4
3
2
1
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
Cell 6 sump
Cell 6 Sump Compliance Limit

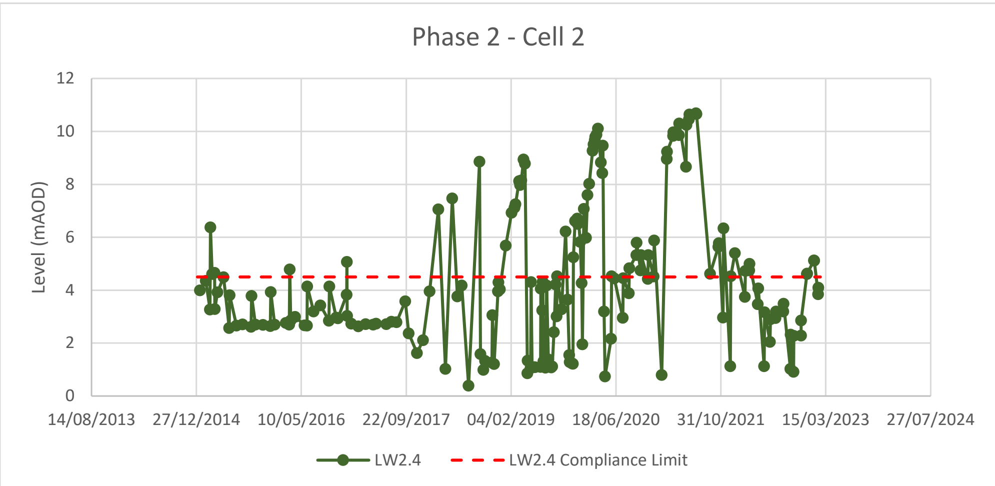

Cell 7
Level (mAOD)
9
8
7
6
5
4
3
2
1
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
Cell 7 sump
Cell 7 Sump Compliance Limit

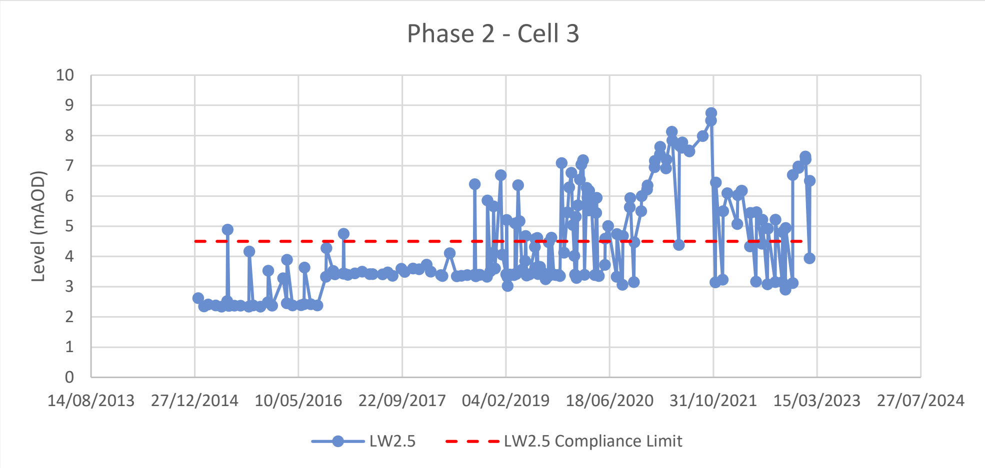

Cell 8
Level (mAOD)
12
10
8
6
4
2
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
Cell 8 sump
Cell 8 Sump Compliance Limit


Phase 2 - Cell 1
Level (mAOD)
8
7
6
5
4
3
2
1
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
LW2.1B
LW2.1B Compliance Limit


Phase 2 - Cell 1
7
6
5
4
3
2
1
0
Level (mAOD)
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
LW2.2
LW2.2 Compliance Limit


Phase 2 - Cell 2
12
10
8
6
4
2
0
Level (mAOD)
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
LW2.3
LW2.3 Compliance Limit


Phase 2 - Cell 2
12
10
8
6
4
2
0
Level (mAOD)
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
LW2.4
LW2.4 Compliance Limit


Phase 2 - Cell 3
Level (mAOD)
10
9
8
7
6
5
4
3
2
1
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
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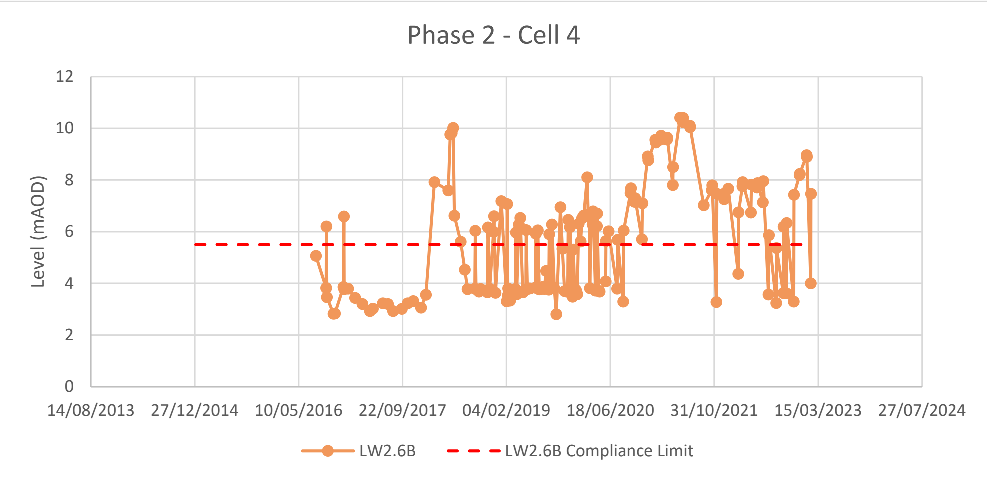
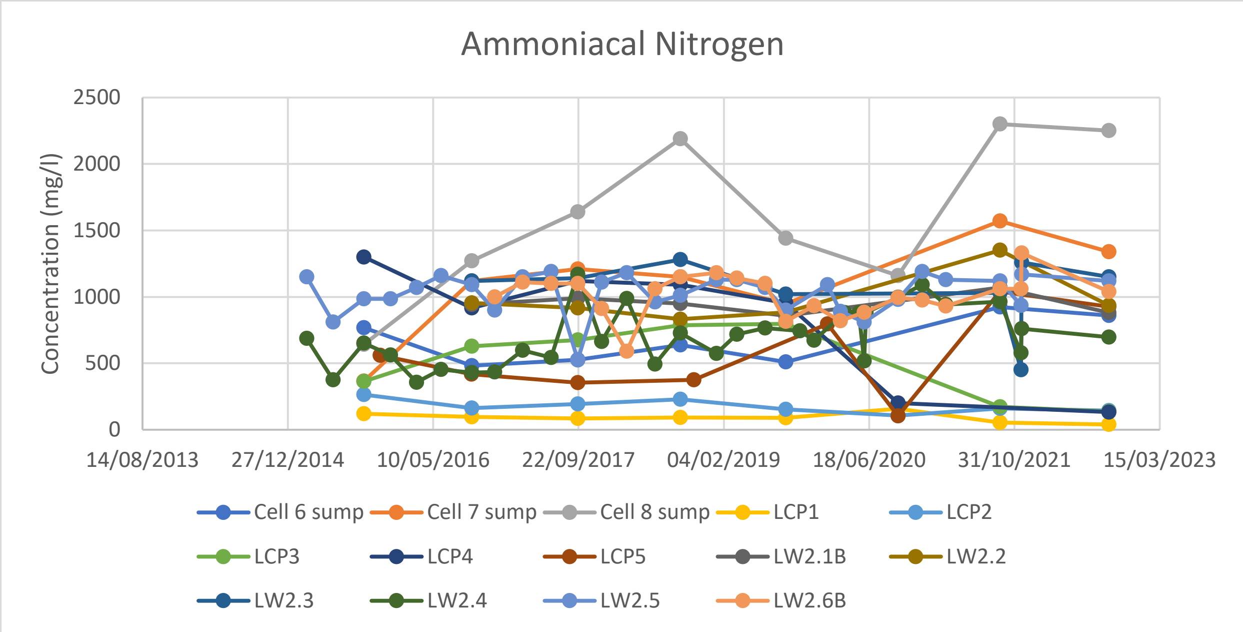
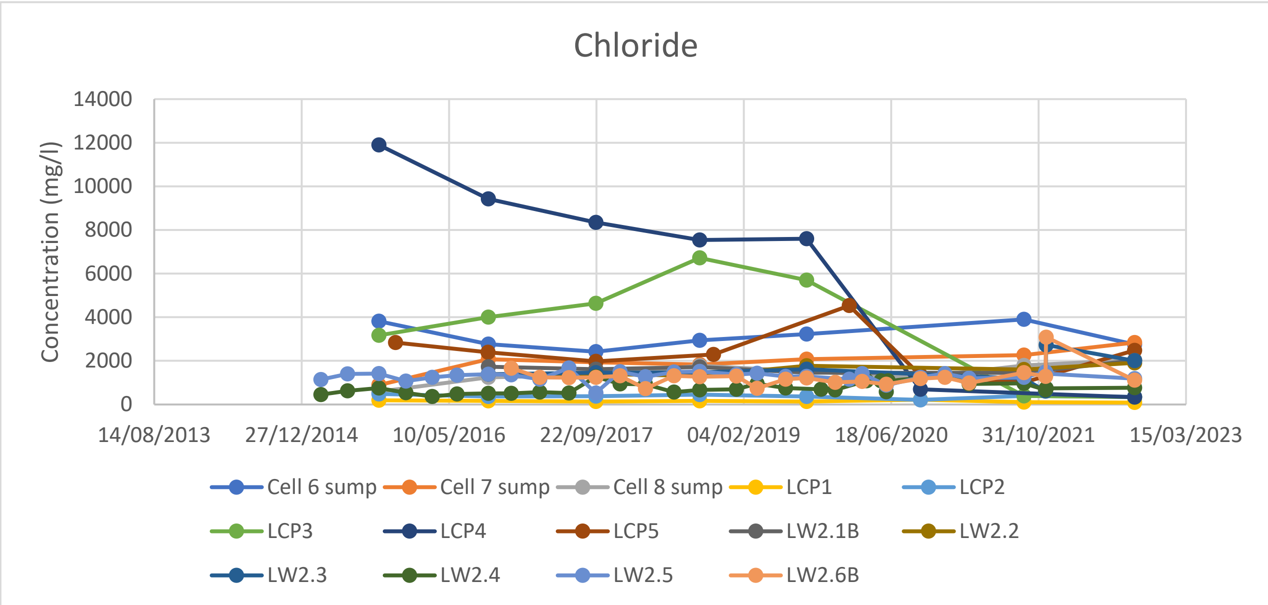
15/03/2023
27/07/2024
LW2.5
LW2.5 Compliance Limit

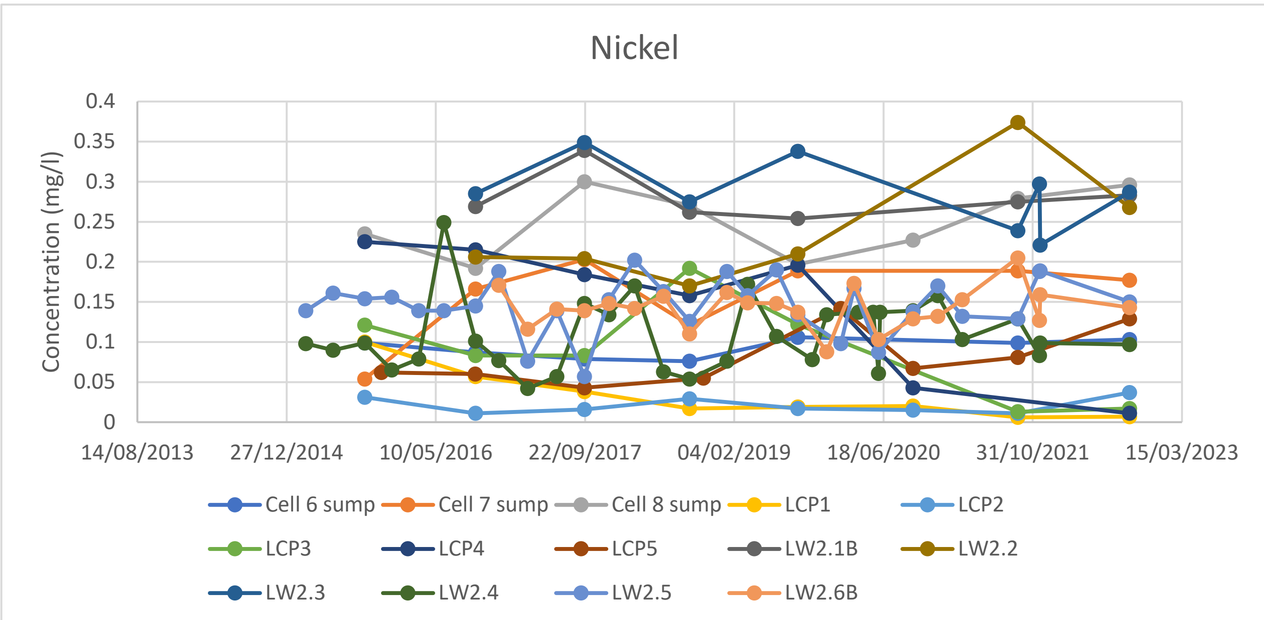

Phase 2 - Cell 4
Level (mAOD)
12
10
8
6
4
2
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
LW2.6B
LW2.6B Compliance Limit

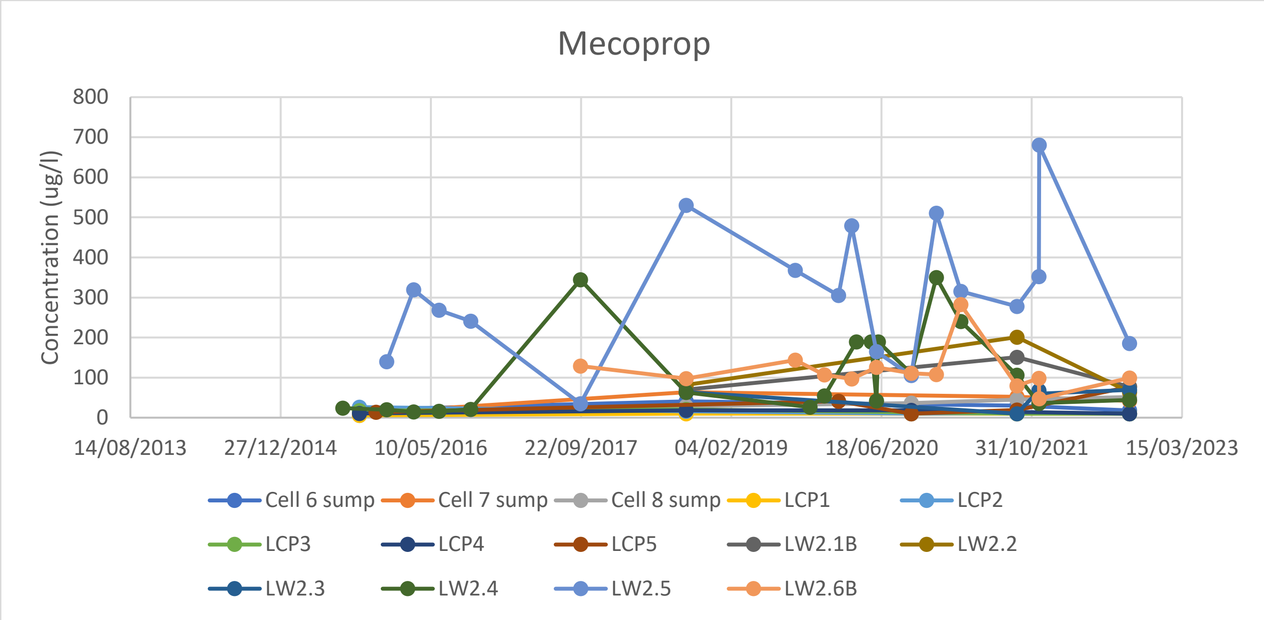
APPENDIX 2

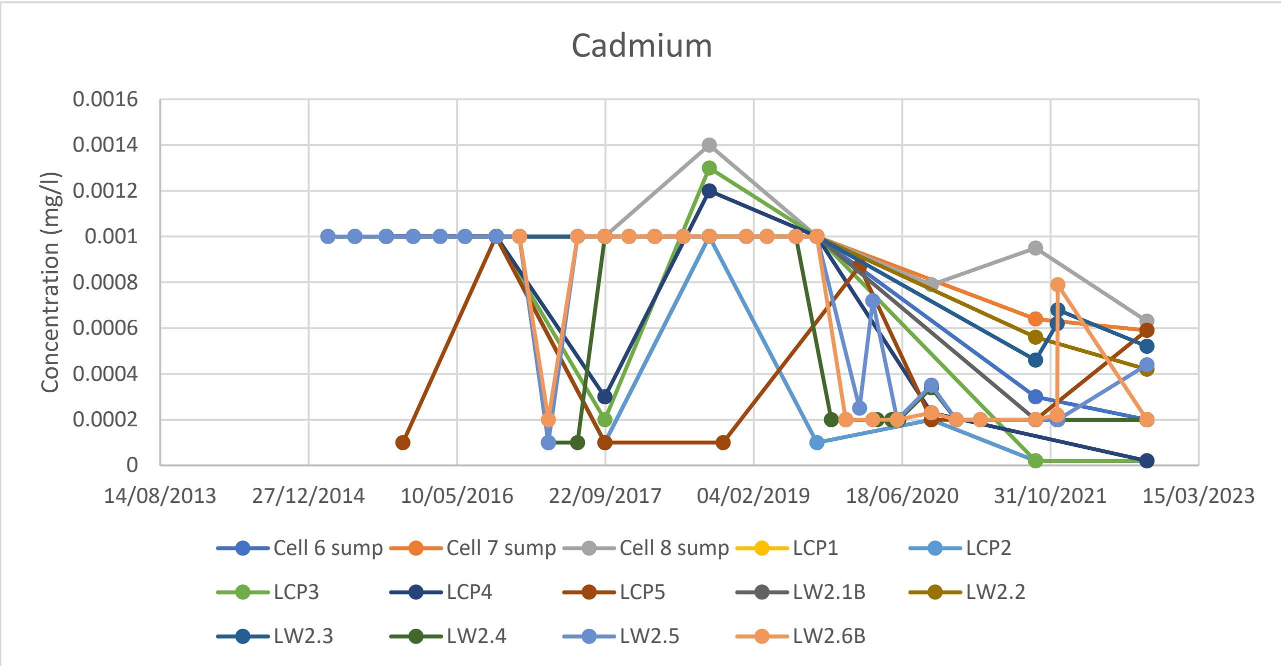
Leachate Quality

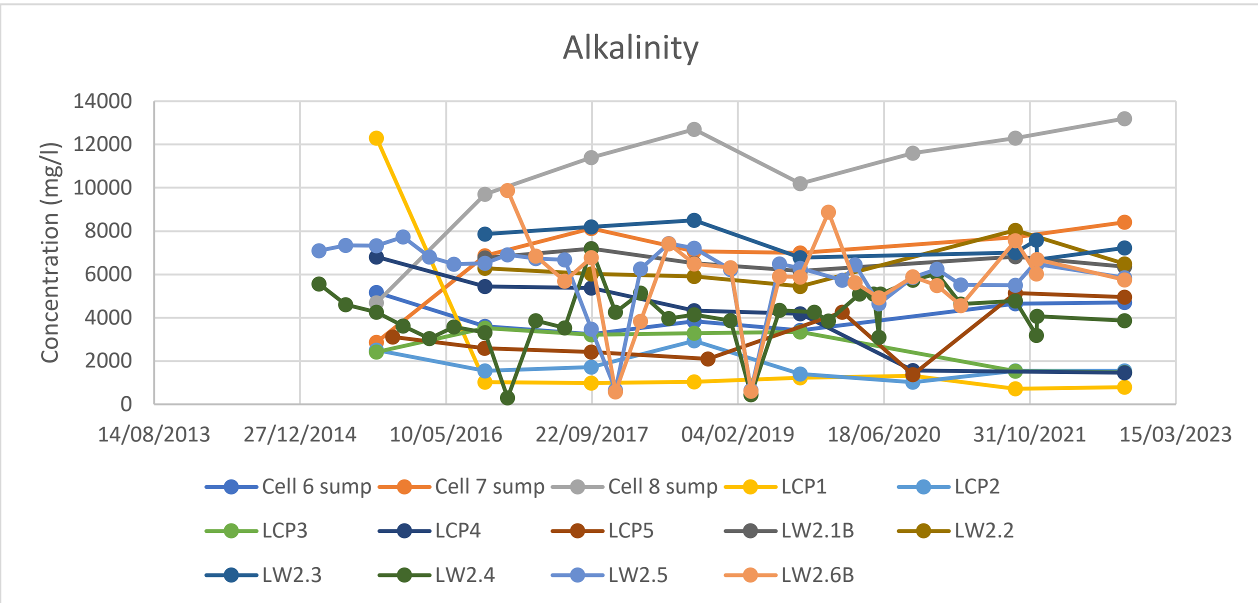

Ammoniacal Nitrogen
Concentration (mg/l)
2500
2000
1500
1000
500
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
Cell 6 sump
Cell 7 sump
Cell 8 sump
LCP1
LCP2
LCP3
LCP4
LCP5
LW2.1B
LW2.2
LW2.3
LW2.4
LW2.5
LW2.6B

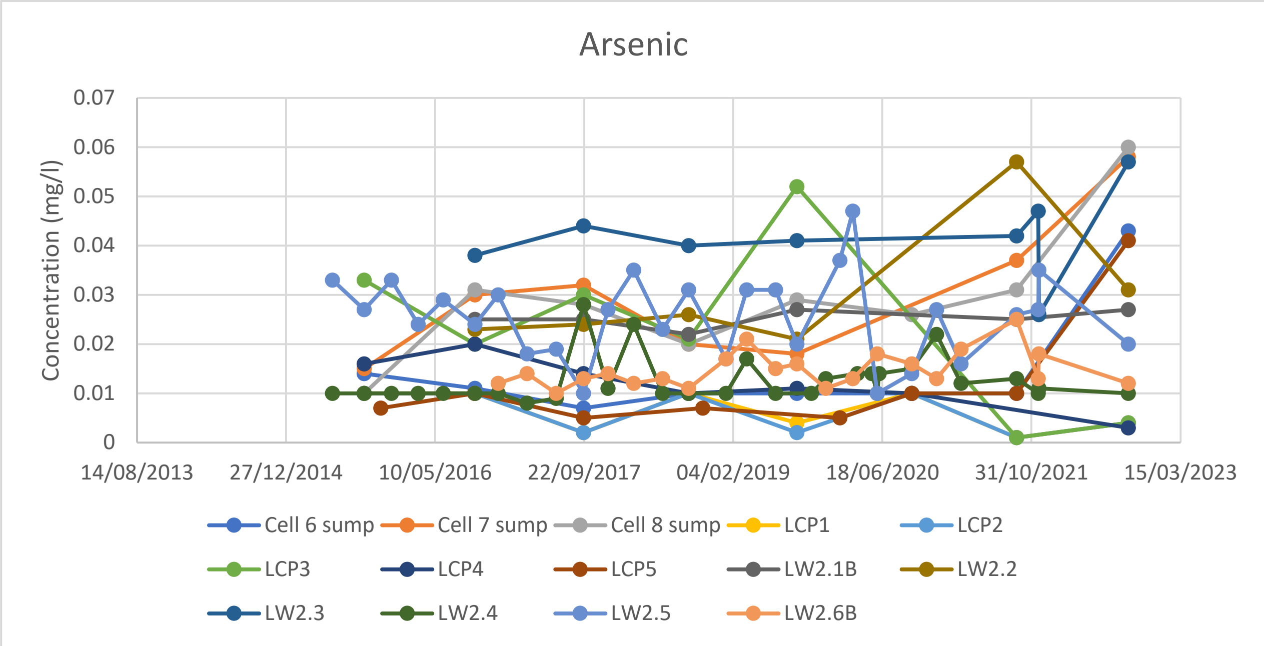

Chloride
Concentration (mg/l)
14000
12000
10000
8000
6000
4000
2000
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
Cell 6 sump
Cell 7 sump
Cell 8 sump
LCP1
LCP2
LCP3
LCP4
LCP5
LW2.1B
LW2.2
LW2.3
LW2.4
LW2.5
LW2.6B

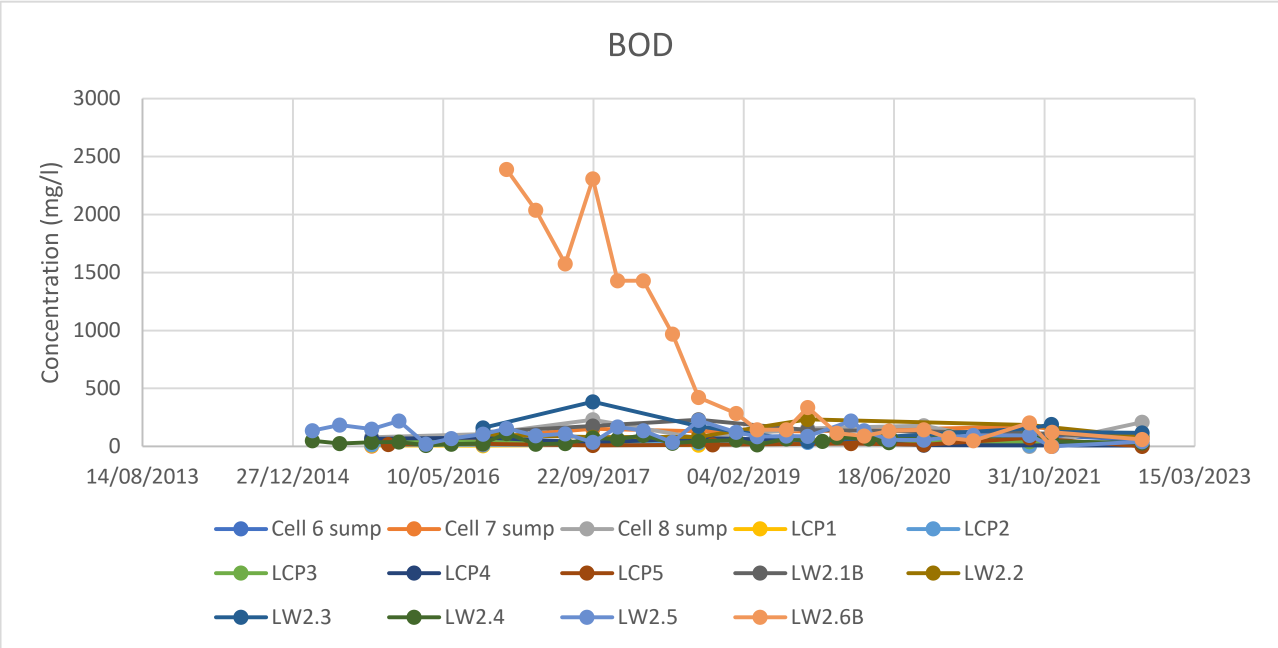

Nickel
Concentration (mg/l)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
Cell 6 sump
Cell 7 sump
Cell 8 sump
LCP1
LCP2
LCP3
LCP4
LCP5
LW2.1B
LW2.2
LW2.3
LW2.4
LW2.5
LW2.6B

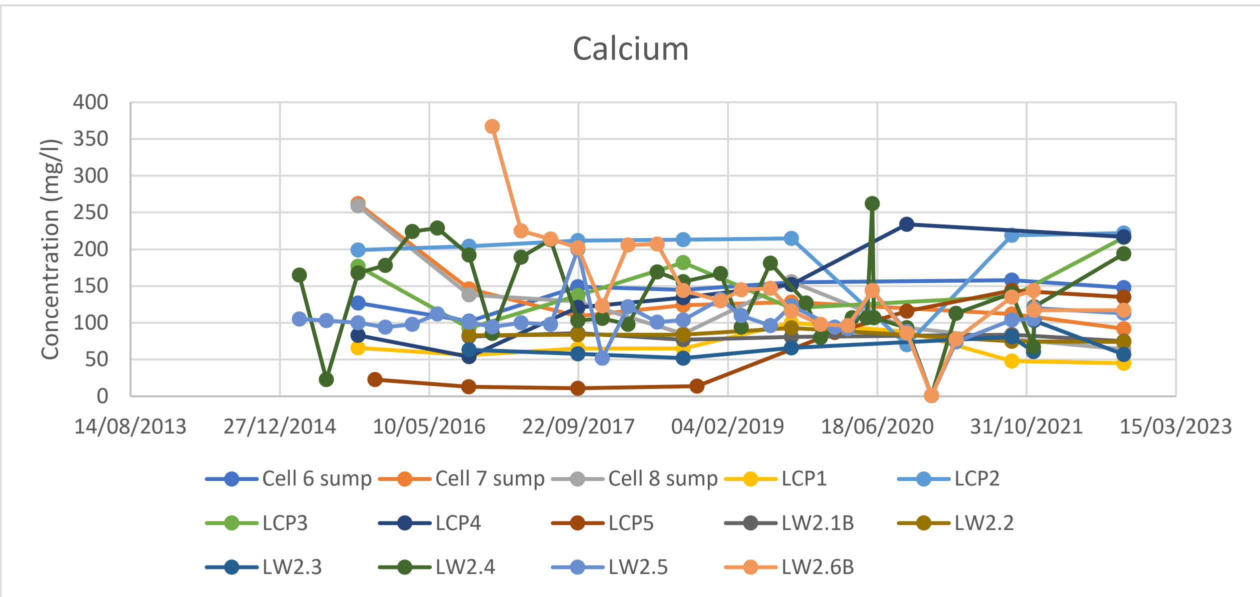

Mecoprop
Concentration (ug/l)
800
700
600
500
400
300
200
100
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
Cell 6 sump
Cell 7 sump
Cell 8 sump
LCP1
LCP2
LCP3
LCP4
LCP5
LW2.1B
LW2.2
LW2.3
LW2.4
LW2.5
LW2.6B

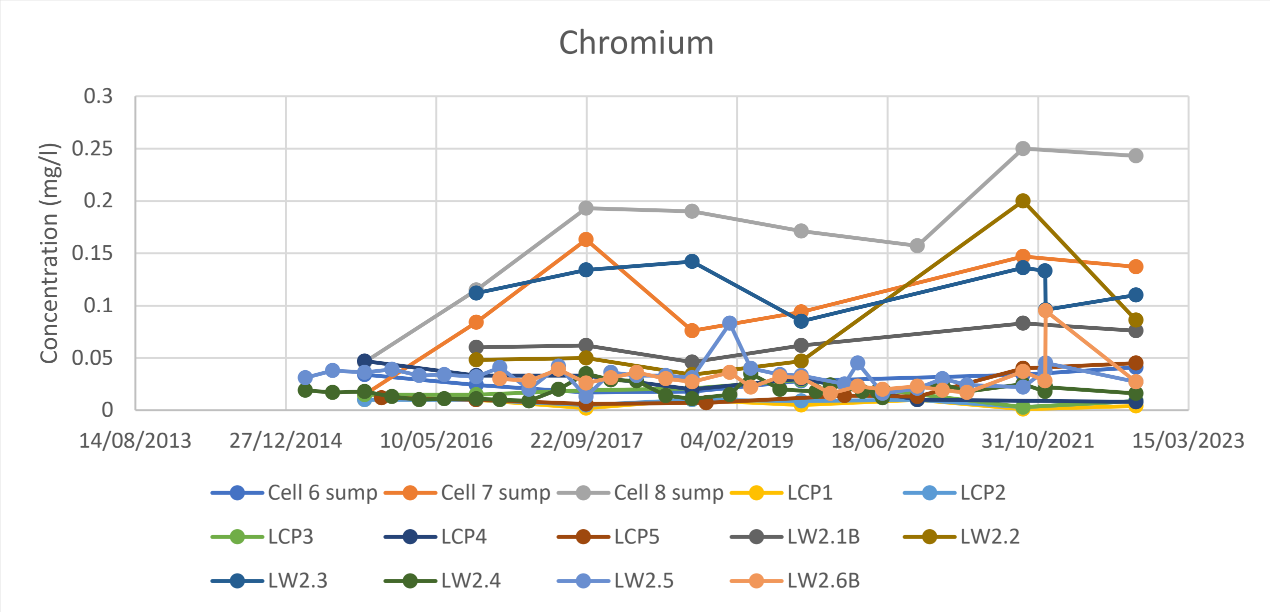

Cadmium
Concentration (mg/l)
0.0016
0.0014
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
Cell 6 sump
Cell 7 sump
Cell 8 sump
LCP1
LCP2
LCP3
LCP4
LCP5
LW2.1B
LW2.2
LW2.3
LW2.4
LW2.5
LW2.6B

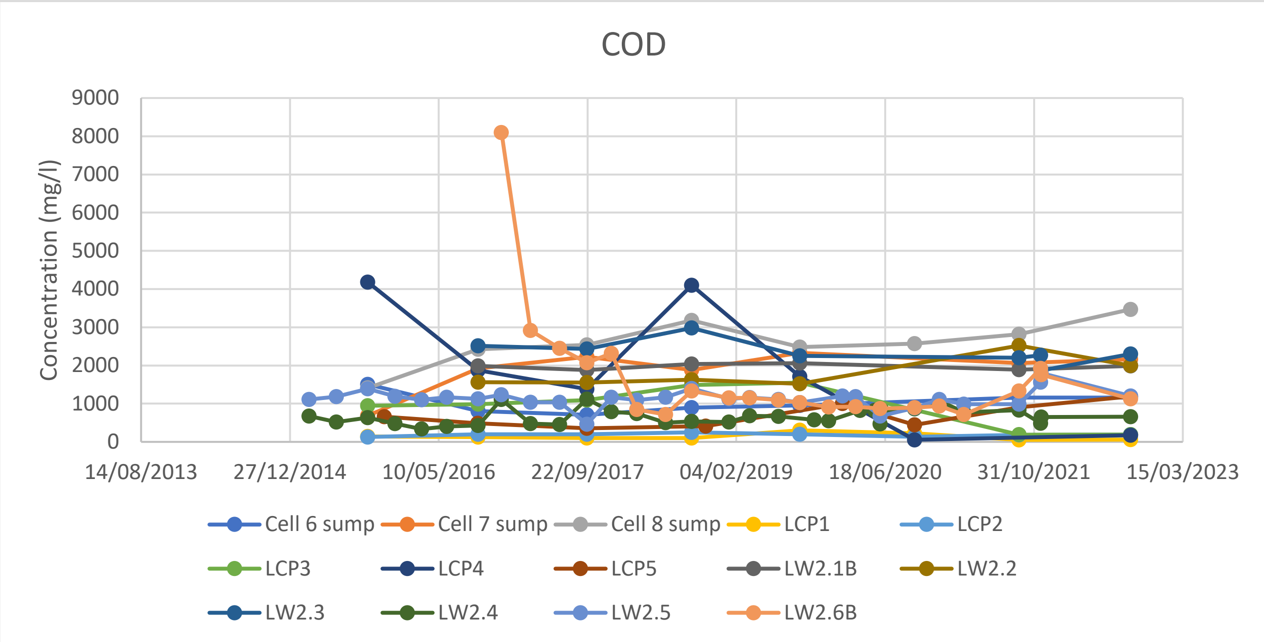

Alkalinity
Concentration (mg/l)
14000
12000
10000
8000
6000
4000
2000
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
Cell 6 sump
Cell 7 sump
Cell 8 sump
LCP1
LCP2
LCP3
LCP4
LCP5
LW2.1B
LW2.2
LW2.3
LW2.4
LW2.5
LW2.6B

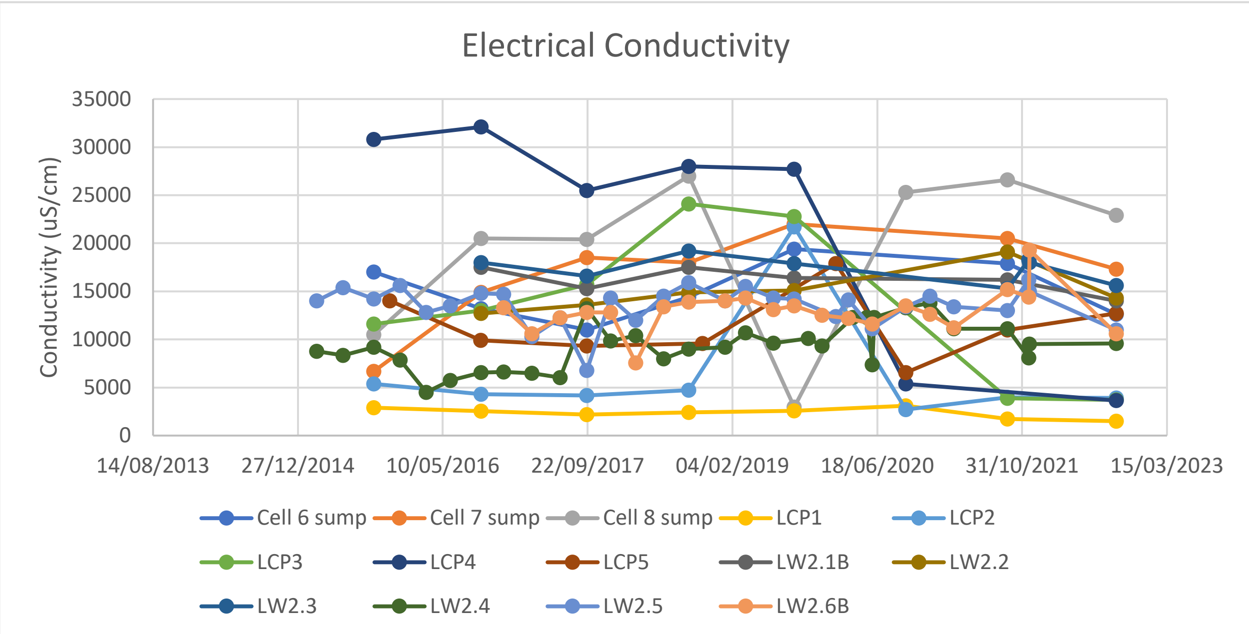

Arsenic
Concentration (mg/l)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
Cell 6 sump
Cell 7 sump
Cell 8 sump
LCP1
LCP2
LCP3
LCP4
LCP5
LW2.1B
LW2.2
LW2.3
LW2.4
LW2.5
LW2.6B

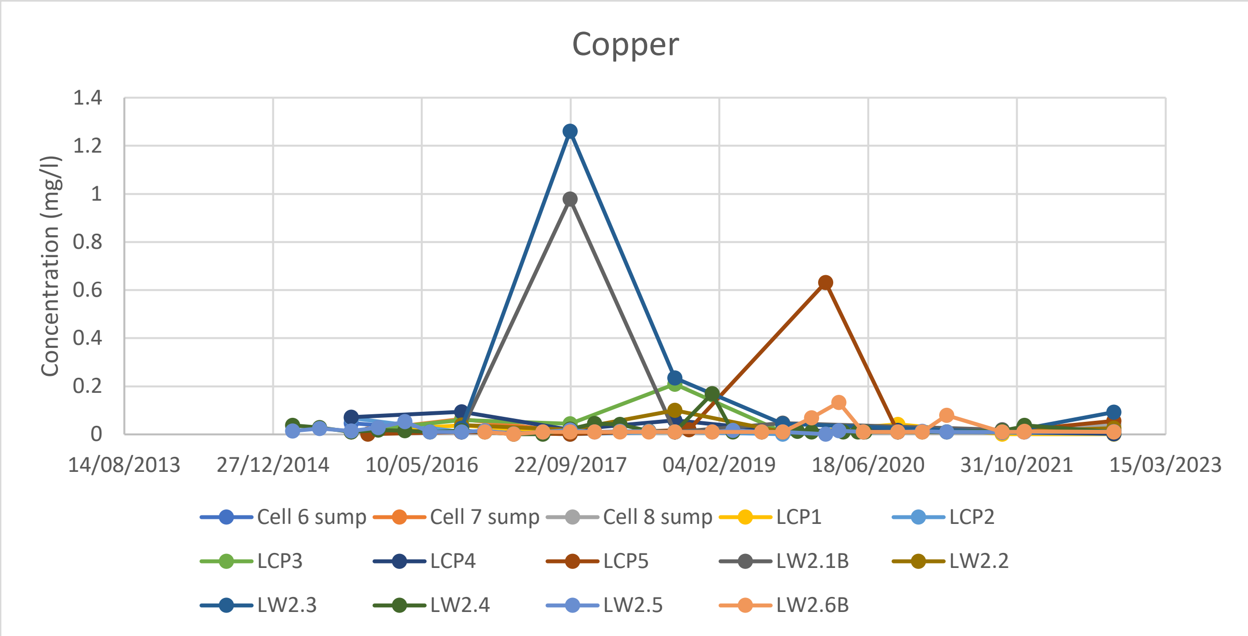

BOD
Concentration (mg/l)
3000
2500
2000
1500
1000
500
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
Cell 6 sump
Cell 7 sump
Cell 8 sump
LCP1
LCP2
LCP3
LCP4
LCP5
LW2.1B
LW2.2
LW2.3
LW2.4
LW2.5
LW2.6B

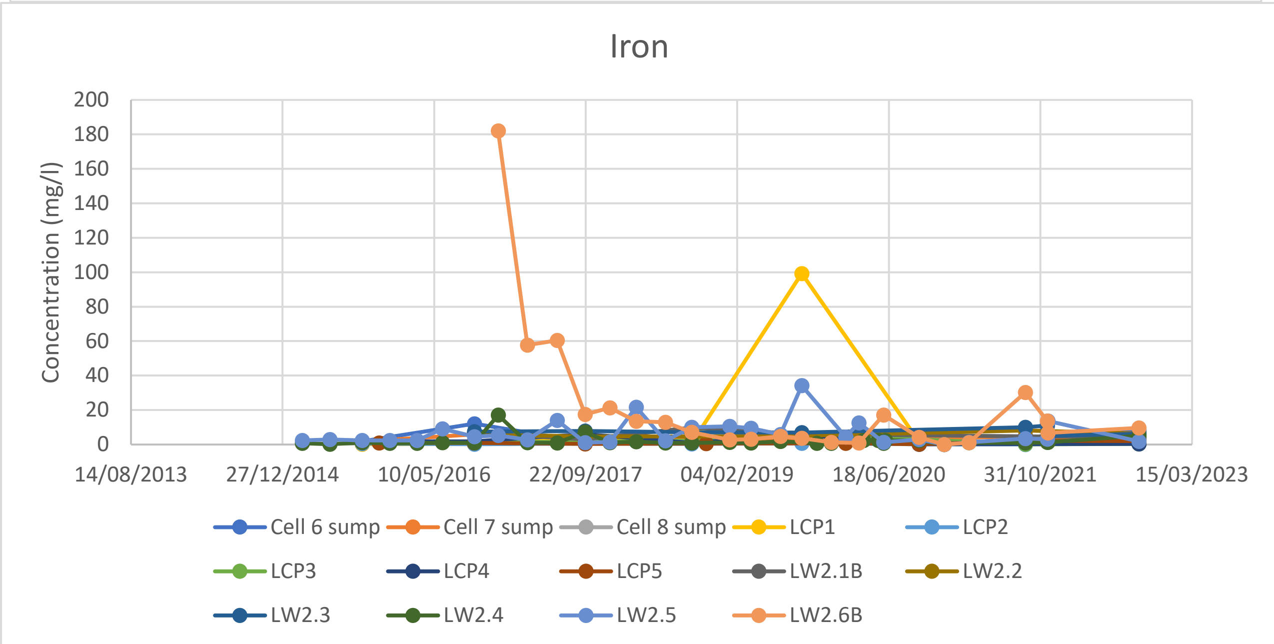

Calcium
Concentration (mg/l)
400
350
300
250
200
150
100
50
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
Cell 6 sump
Cell 7 sump
Cell 8 sump
LCP1
LCP2
LCP3
LCP4
LCP5
LW2.1B
LW2.2
LW2.3
LW2.4
LW2.5
LW2.6B

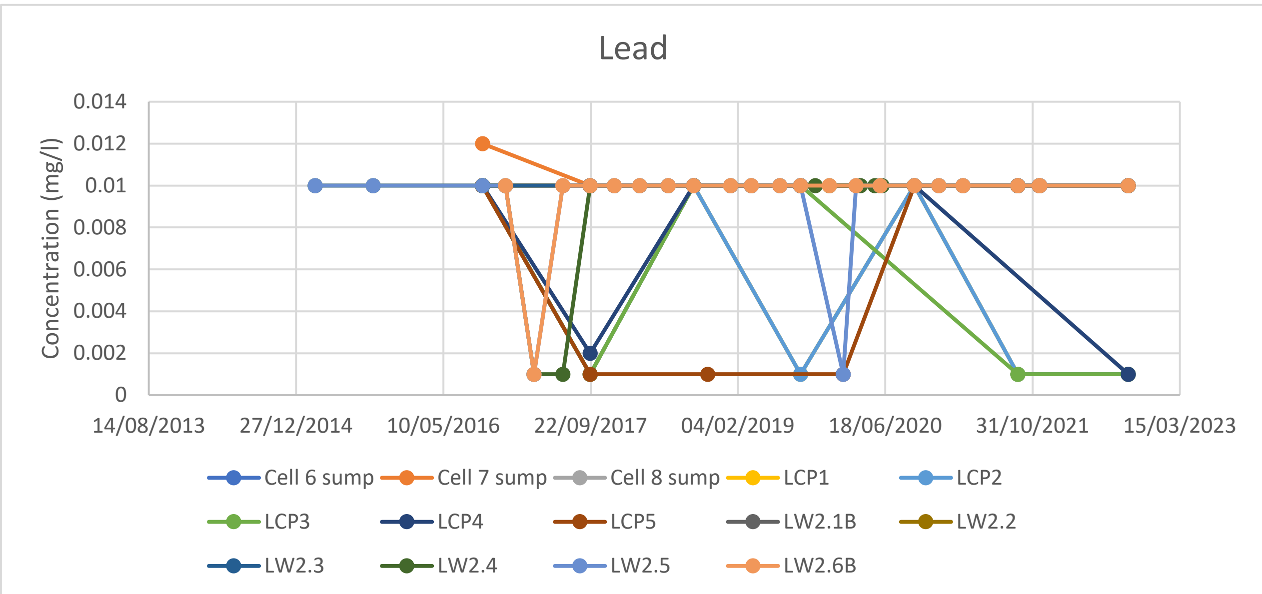

Chromium
Concentration (mg/l)
0
0.05
0.1
0.15
0.2
0.25
0.3
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
Cell 6 sump
Cell 7 sump
Cell 8 sump
LCP1
LCP2
LCP3
LCP4
LCP5
LW2.1B
LW2.2
LW2.3
LW2.4
LW2.5
LW2.6B

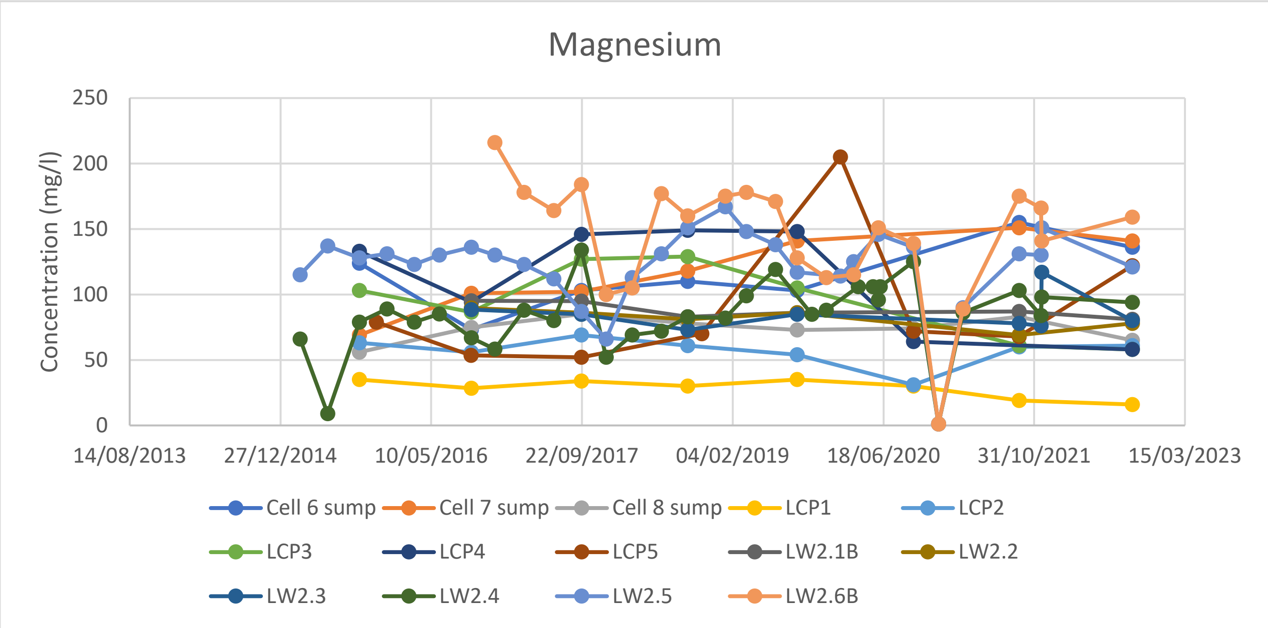

COD
Concentration (mg/l)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
Cell 6 sump
Cell 7 sump
Cell 8 sump
LCP1
LCP2
LCP3
LCP4
LCP5
LW2.1B
LW2.2
LW2.3
LW2.4
LW2.5
LW2.6B

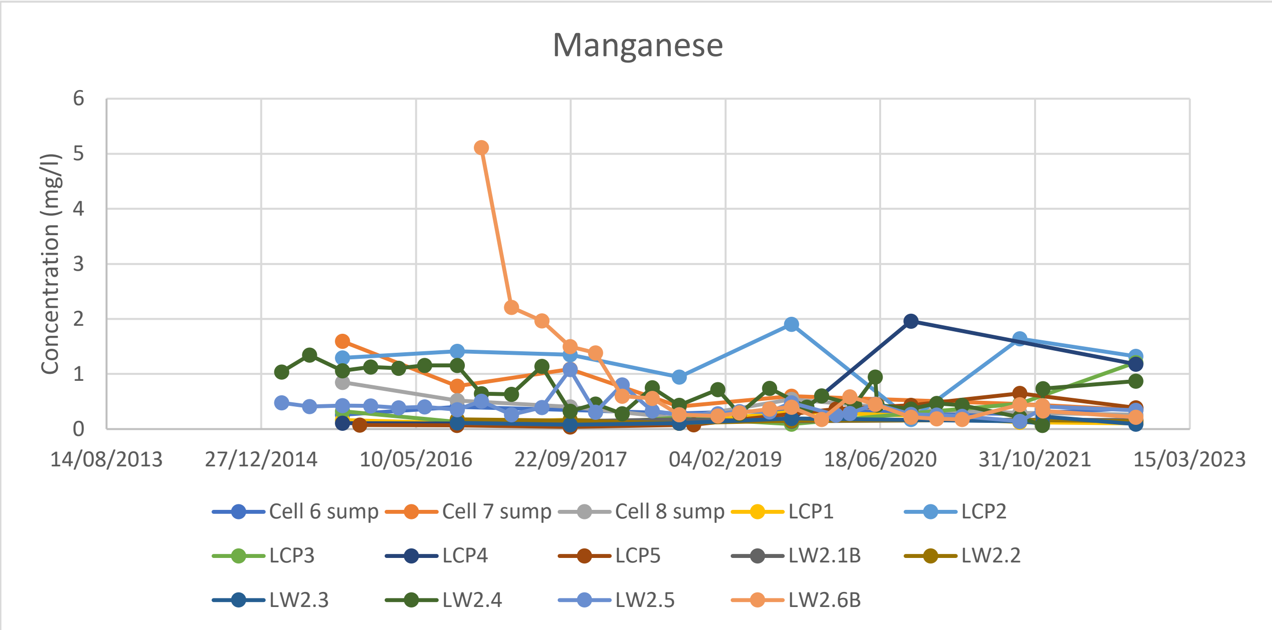

Electrical Conductivity
Conductivity (uS/cm)
0
5000
10000
15000
20000
25000
30000
35000
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
Cell 6 sump
Cell 7 sump
Cell 8 sump
LCP1
LCP2
LCP3
LCP4
LCP5
LW2.1B
LW2.2
LW2.3
LW2.4
LW2.5
LW2.6B

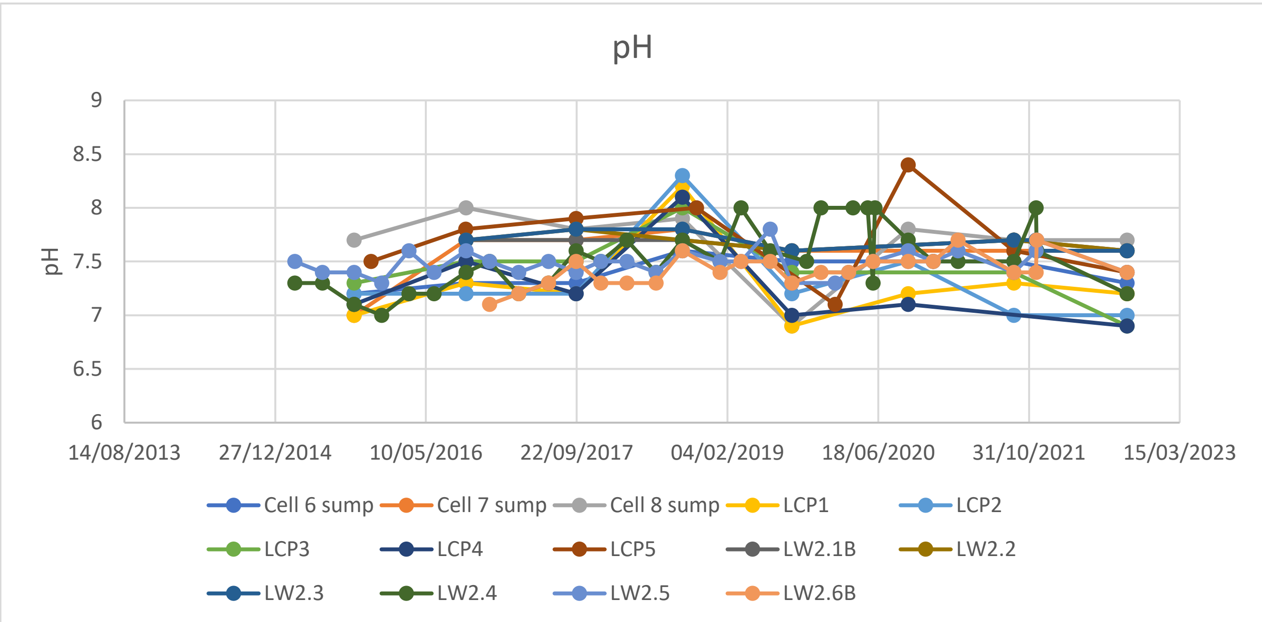

Copper
Concentration (mg/l)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
Cell 6 sump
Cell 7 sump
Cell 8 sump
LCP1
LCP2
LCP3
LCP4
LCP5
LW2.1B
LW2.2
LW2.3
LW2.4
LW2.5
LW2.6B

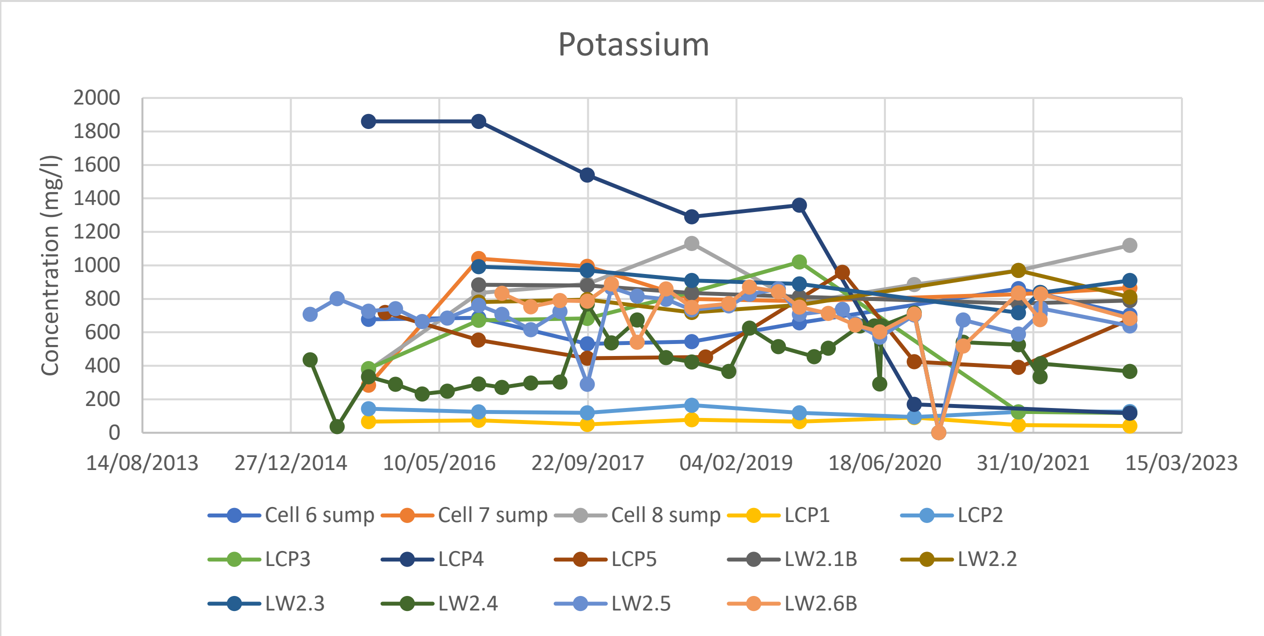

Iron
Concentration (mg/l)
200
180
160
140
120
100
80
60
40
20
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
Cell 6 sump
Cell 7 sump
Cell 8 sump
LCP1
LCP2
LCP3
LCP4
LCP5
LW2.1B
LW2.2
LW2.3
LW2.4
LW2.5
LW2.6B

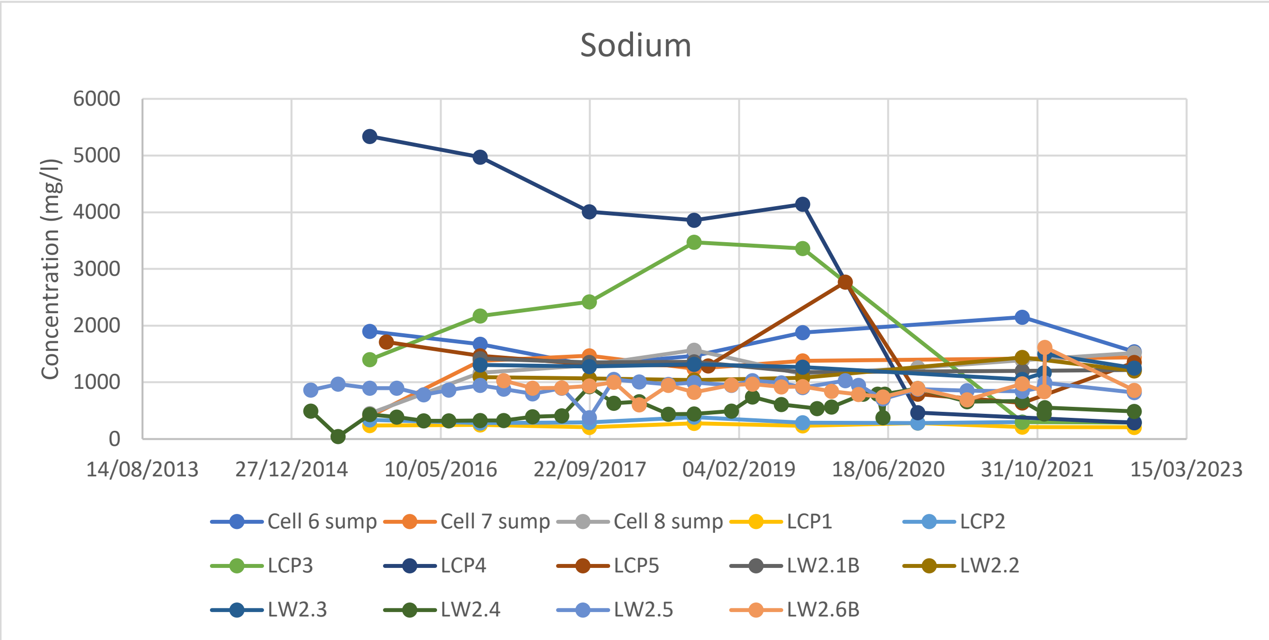

Lead
Concentration (mg/l)
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
Cell 6 sump
Cell 7 sump
Cell 8 sump
LCP1
LCP2
LCP3
LCP4
LCP5
LW2.1B
LW2.2
LW2.3
LW2.4
LW2.5
LW2.6B

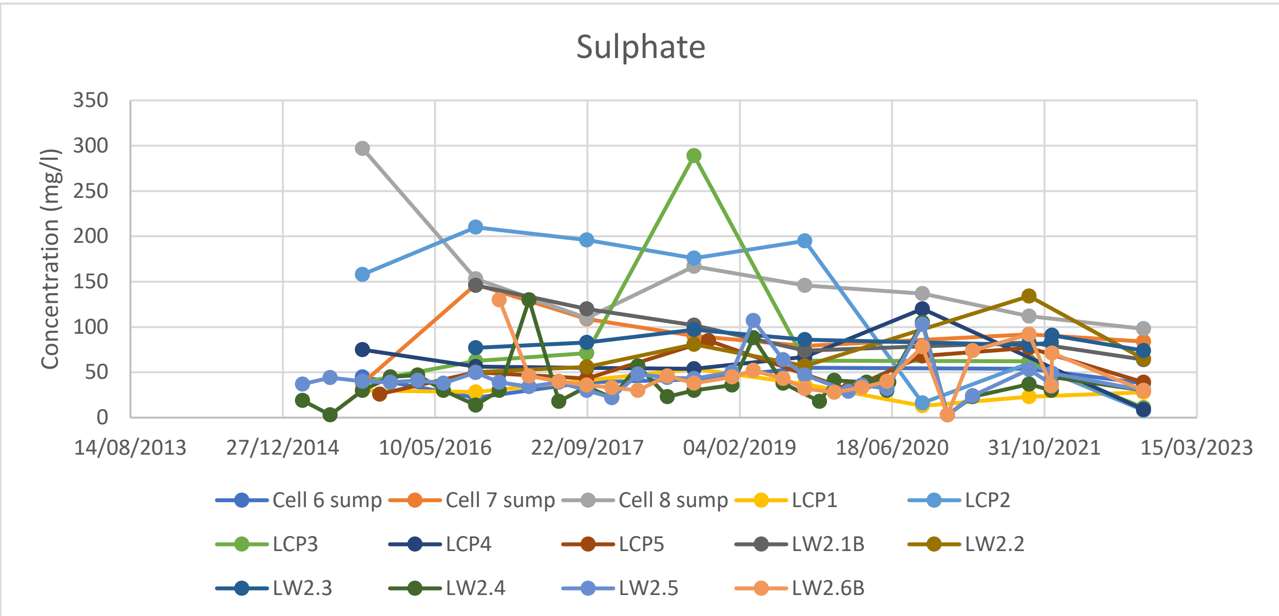

Magnesium
Concentration (mg/l)
250
200
150
100
50
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
Cell 6 sump
Cell 7 sump
Cell 8 sump
LCP1
LCP2
LCP3
LCP4
LCP5
LW2.1B
LW2.2
LW2.3
LW2.4
LW2.5
LW2.6B

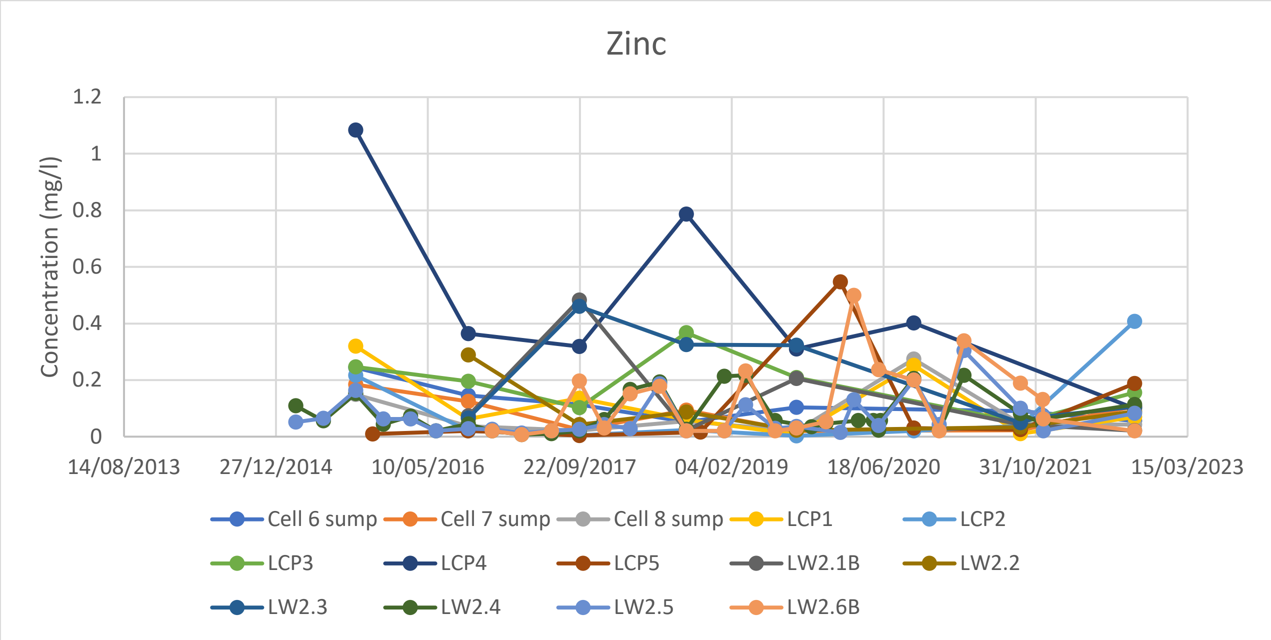

Manganese
Concentration (mg/l)
6
5
4
3
2
1
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
Cell 6 sump
Cell 7 sump
Cell 8 sump
LCP1
LCP2
LCP3
LCP4
LCP5
LW2.1B
LW2.2
LW2.3
LW2.4
LW2.5
LW2.6B


pH
pH
9
8.5
8
7.5
7
6.5
6
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
Cell 6 sump
Cell 7 sump
Cell 8 sump
LCP1
LCP2
LCP3
LCP4
LCP5
LW2.1B
LW2.2
LW2.3
LW2.4
LW2.5
LW2.6B


Potassium
Concentration (mg/l)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
Cell 6 sump
Cell 7 sump
Cell 8 sump
LCP1
LCP2
LCP3
LCP4
LCP5
LW2.1B
LW2.2
LW2.3
LW2.4
LW2.5
LW2.6B

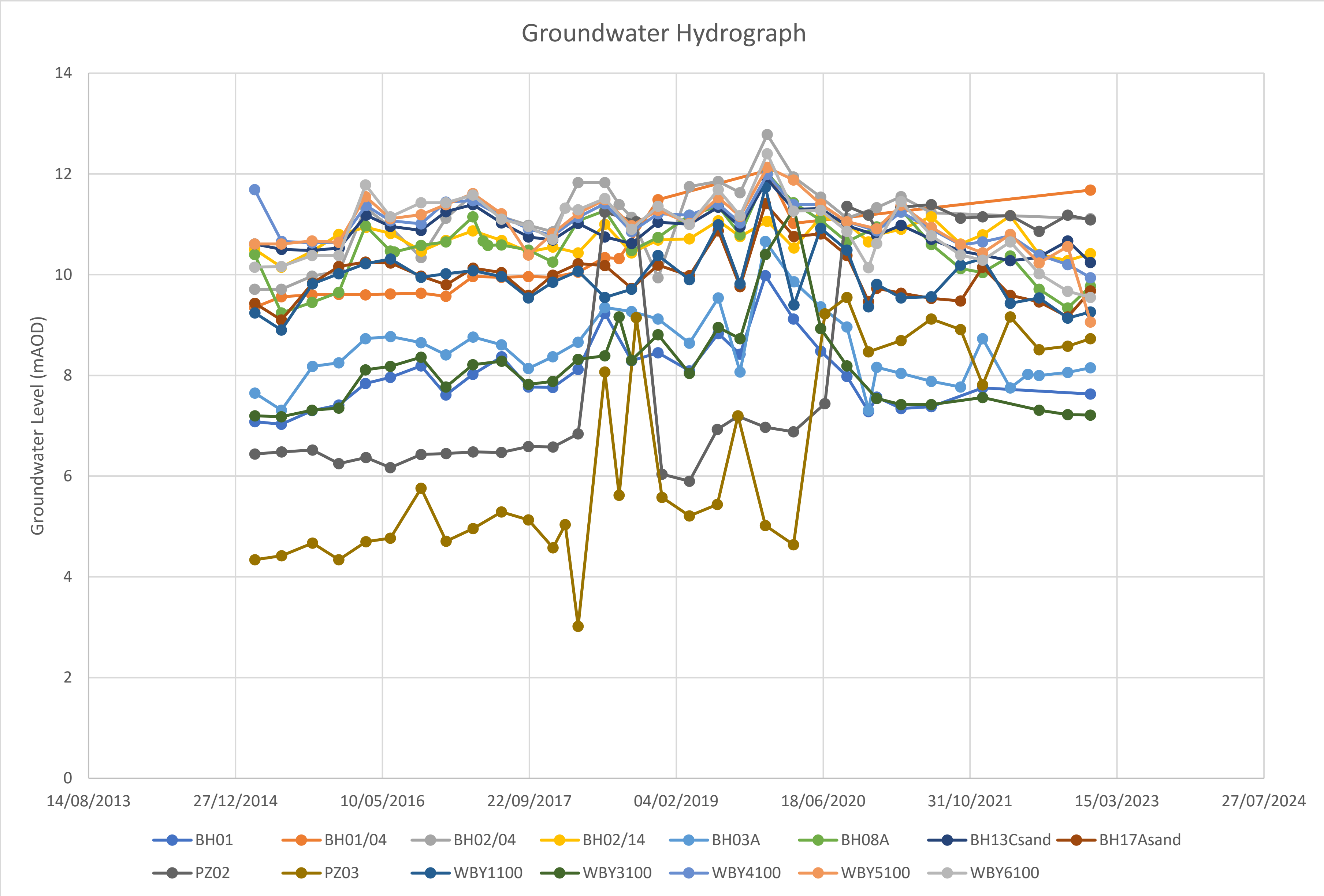

Sodium
Concentration (mg/l)
6000
5000
4000
3000
2000
1000
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
Cell 6 sump
Cell 7 sump
Cell 8 sump
LCP1
LCP2
LCP3
LCP4
LCP5
LW2.1B
LW2.2
LW2.3
LW2.4
LW2.5
LW2.6B


Sulphate
Concentration (mg/l)
350
300
250
200
150
100
50
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
Cell 6 sump
Cell 7 sump
Cell 8 sump
LCP1
LCP2
LCP3
LCP4
LCP5
LW2.1B
LW2.2
LW2.3
LW2.4
LW2.5
LW2.6B


Zinc
Concentration (mg/l)
1.2
1
0.8
0.6
0.4
0.2
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
Cell 6 sump
Cell 7 sump
Cell 8 sump
LCP1
LCP2
LCP3
LCP4
LCP5
LW2.1B
LW2.2
LW2.3
LW2.4
LW2.5
LW2.6B

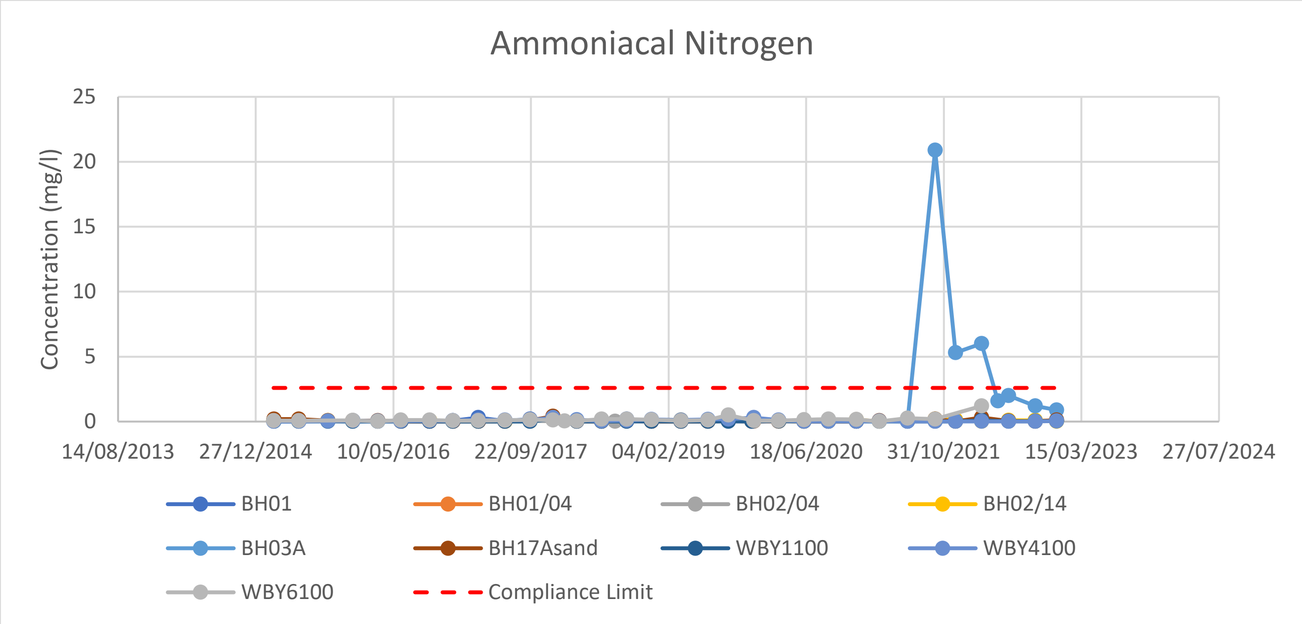
APPENDIX 3

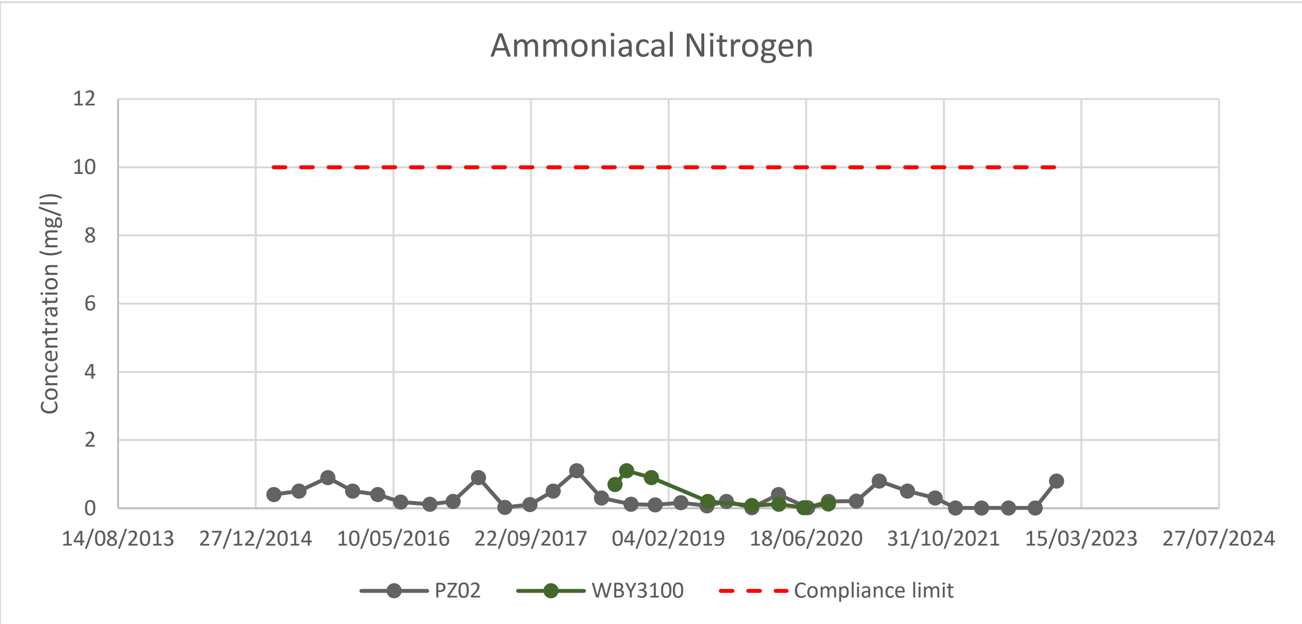
Groundwater Levels

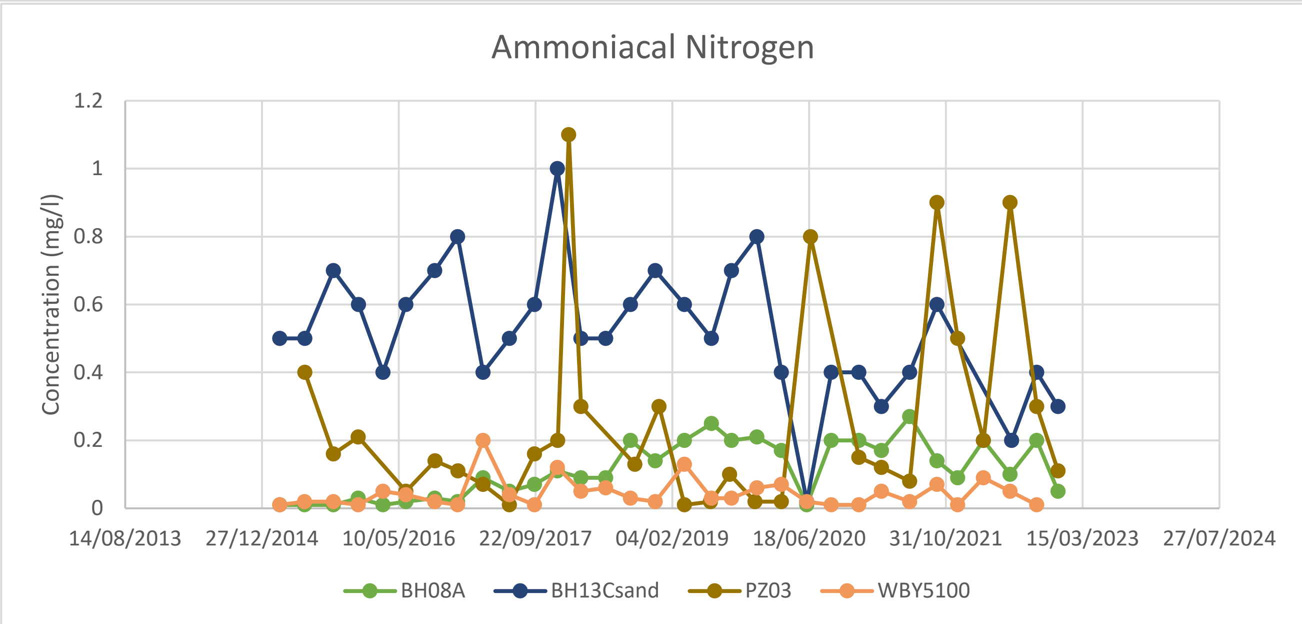

Groundwater Hydrograph
Groundwater Level (mAOD)
14
12
10
8
6
4
2
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
BH01
BH01/04
BH02/04
BH02/14
BH03A
BH08A
BH13Csand
BH17Asand
PZ02
PZ03
WBY1100
WBY3100
WBY4100
WBY5100
WBY6100

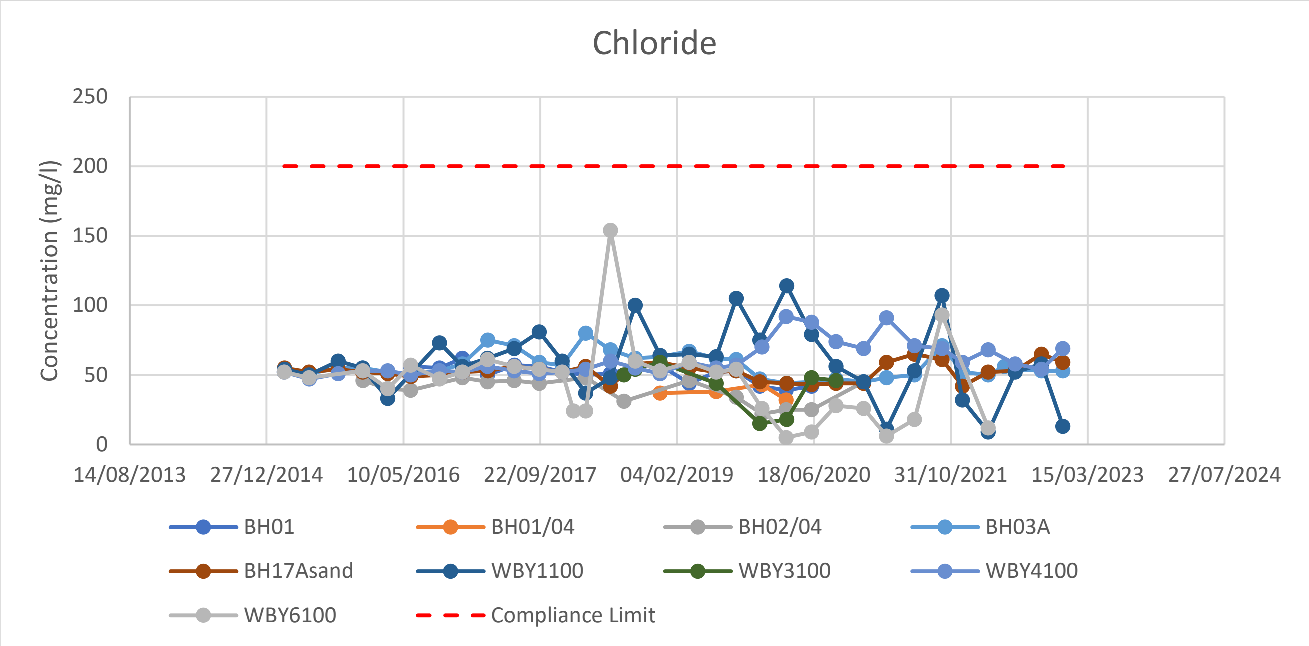
APPENDIX 4

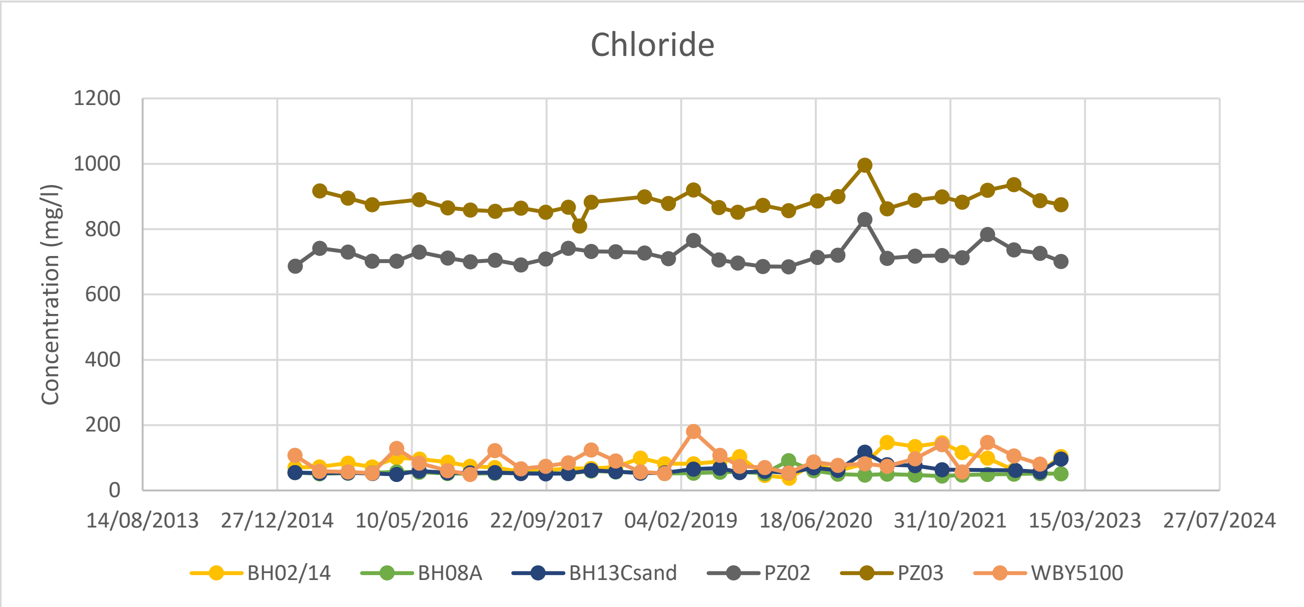
Groundwater Quality

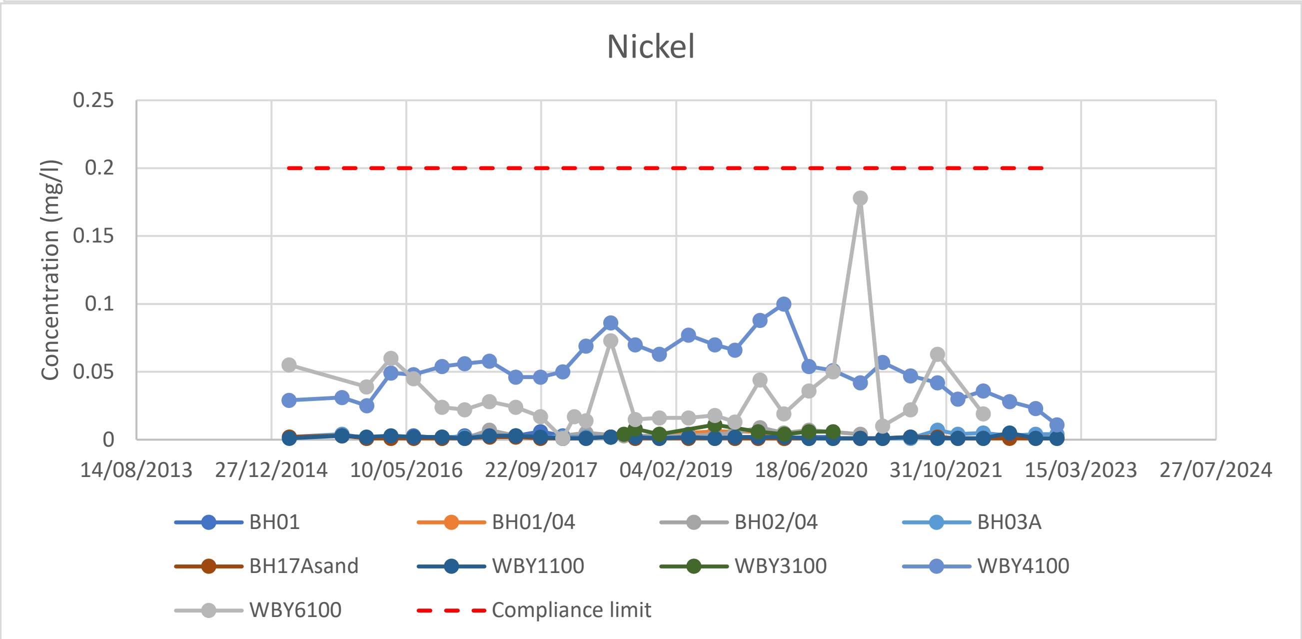

Ammoniacal Nitrogen
Concentration (mg/l)
25
20
15
10
5
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
BH01
BH01/04
BH02/04
BH02/14
BH03A
BH17Asand
WBY1100
WBY4100
WBY6100
Compliance Limit

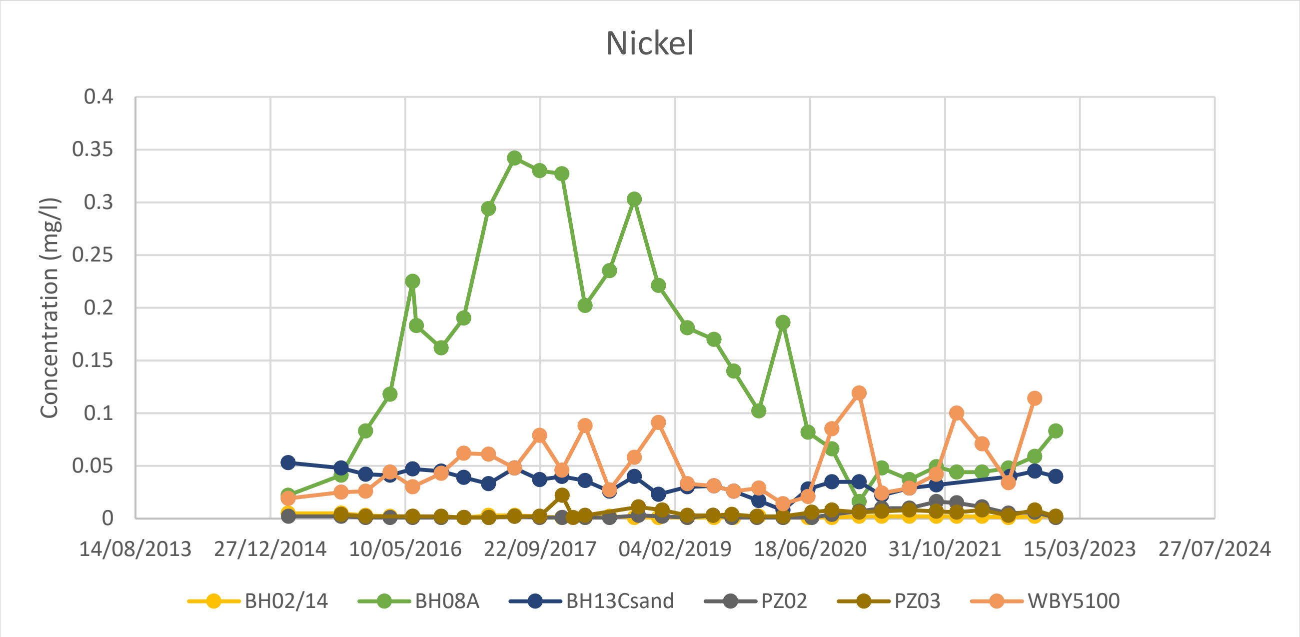

Ammoniacal Nitrogen
Concentration (mg/l)
12
10
8
6
4
2
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
PZ02
WBY3100
Compliance limit

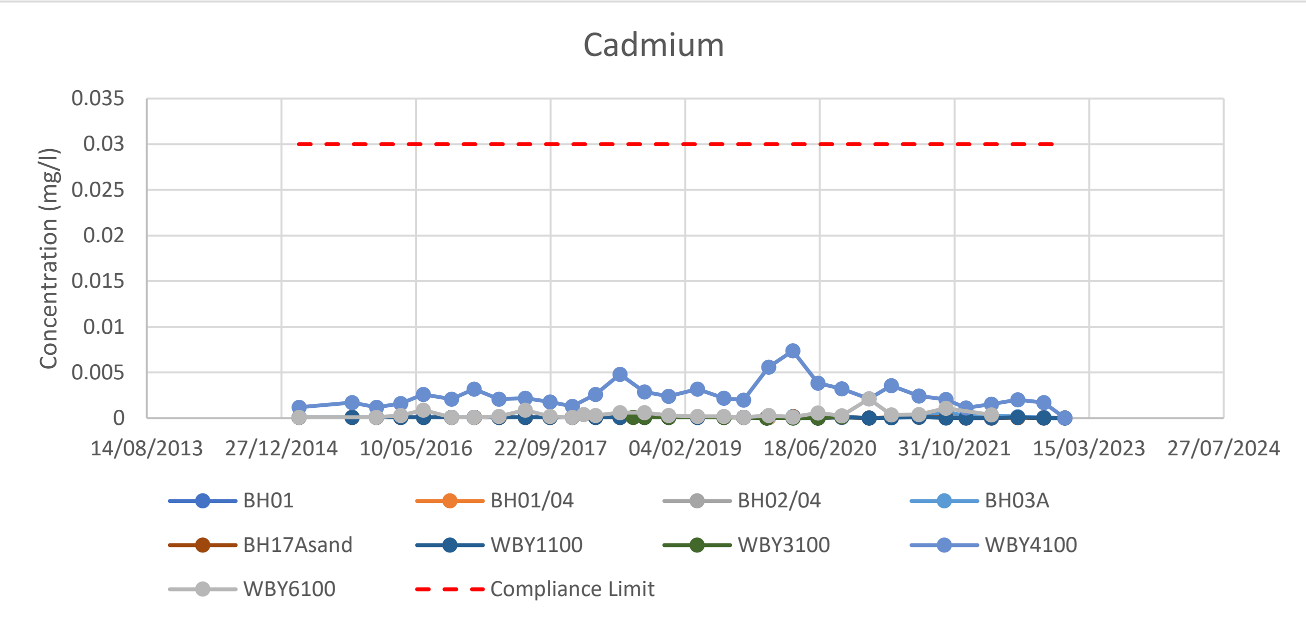

Ammoniacal Nitrogen
Concentration (mg/l)
1.2
1
0.8
0.6
0.4
0.2
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
BH08A
BH13Csand
PZ03
WBY5100

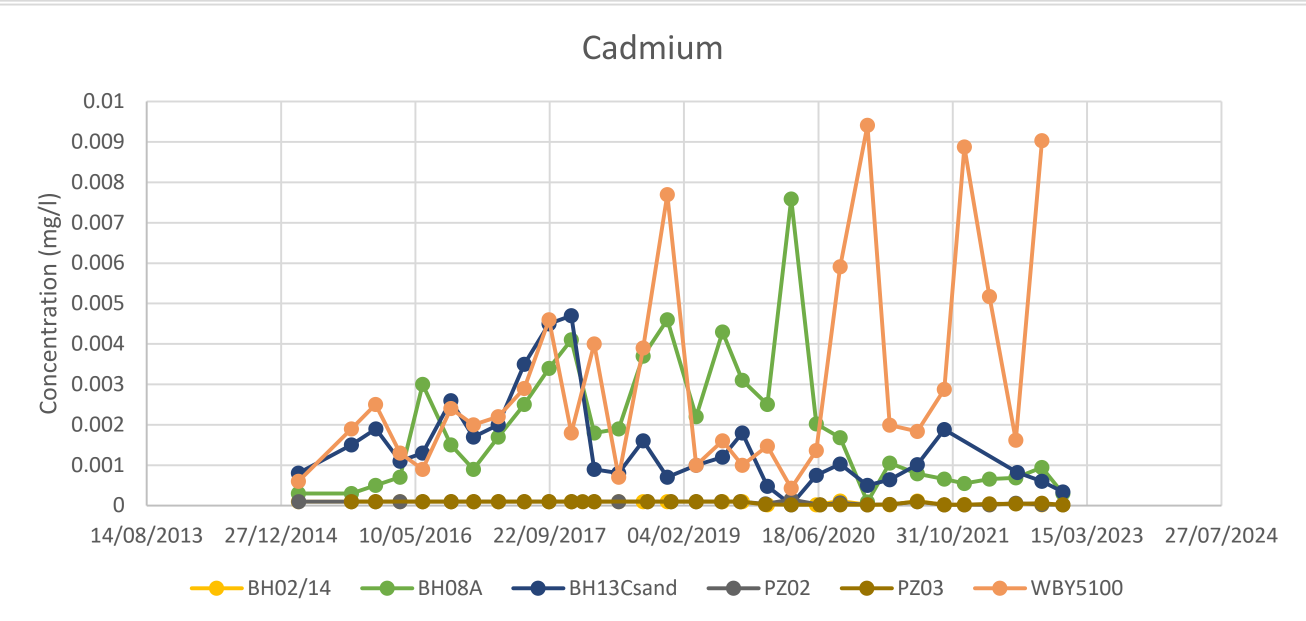

Chloride
Concentration (mg/l)
250
200
150
100
50
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
BH01
BH01/04
BH02/04
BH03A
BH17Asand
WBY1100
WBY3100
WBY4100
WBY6100
Compliance Limit

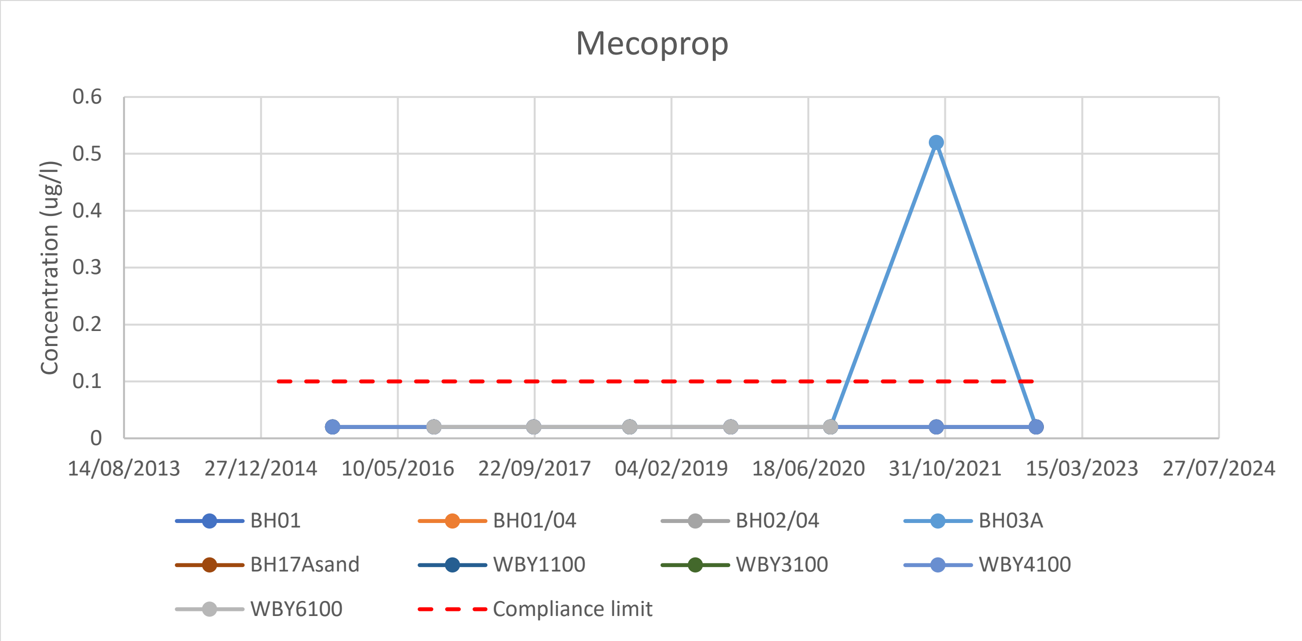

Chloride
Concentration (mg/l)
1200
1000
800
600
400
200
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
BH02/14
BH08A
BH13Csand
PZ02
PZ03
WBY5100

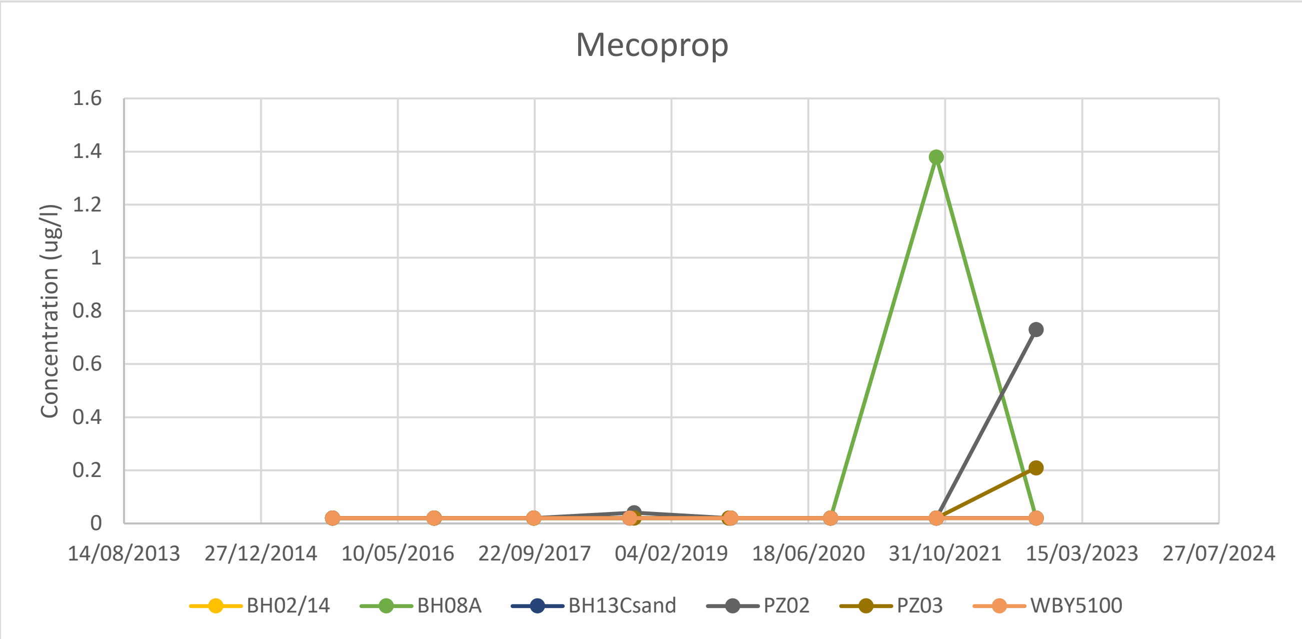

Nickel
Concentration (mg/l)
0.25
0.2
0.15
0.1
0.05
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
BH01
BH01/04
BH02/04
BH03A
BH17Asand
WBY1100
WBY3100
WBY4100
WBY6100
Compliance limit

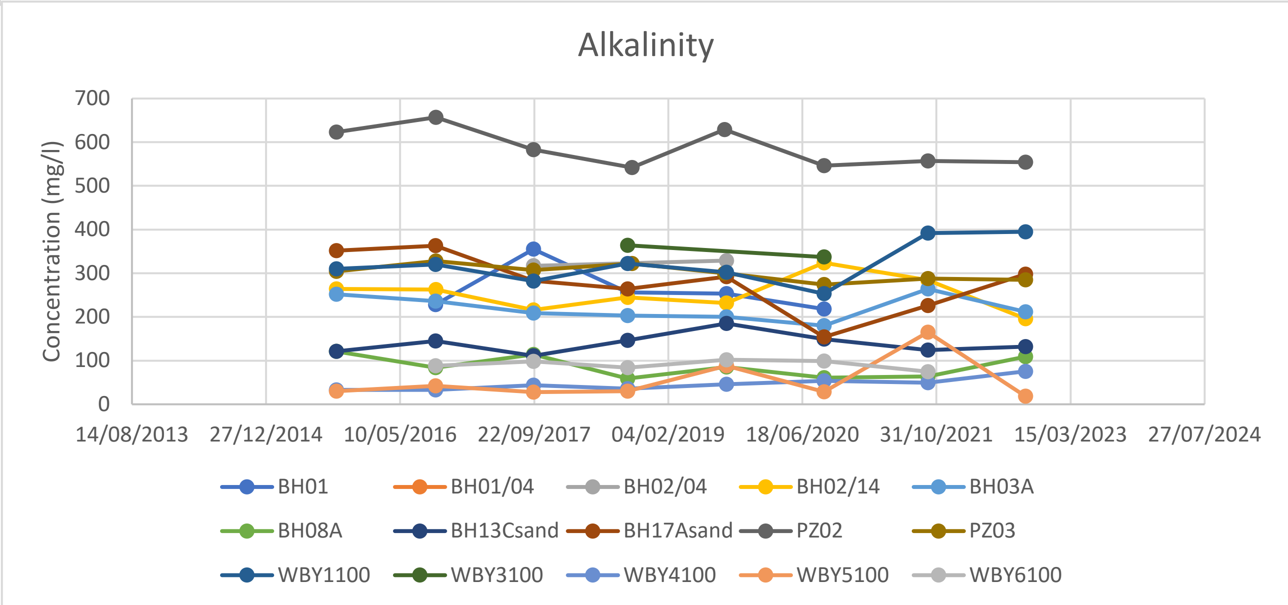

Nickel
Concentration (mg/l)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
BH02/14
BH08A
BH13Csand
PZ02
PZ03
WBY5100

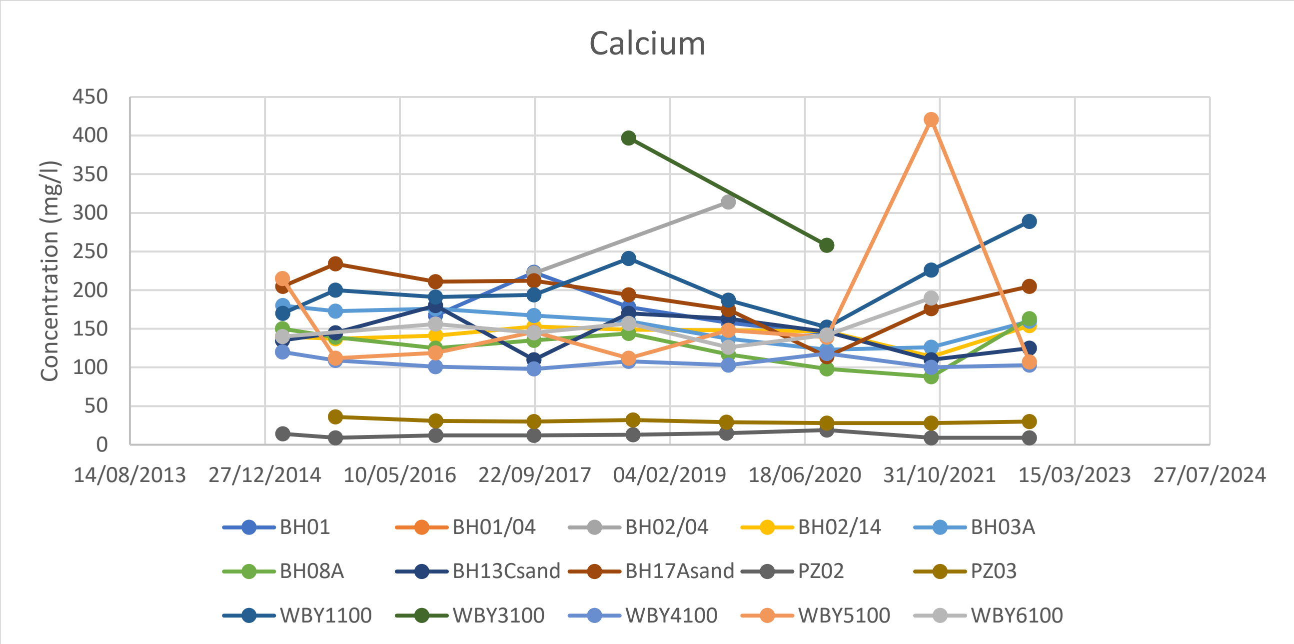

Cadmium
Concentration (mg/l)
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
BH01
BH01/04
BH02/04
BH03A
BH17Asand
WBY1100
WBY3100
WBY4100
WBY6100
Compliance Limit

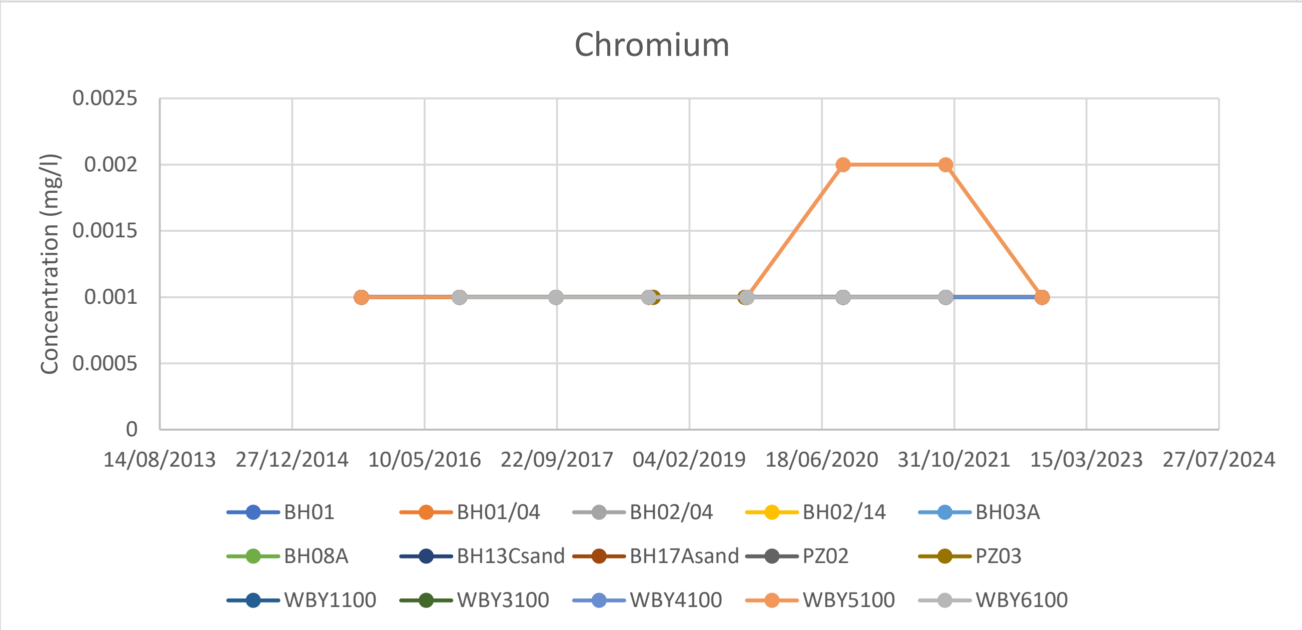

Cadmium
Concentration (mg/l)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
BH02/14
BH08A
BH13Csand
PZ02
PZ03
WBY5100

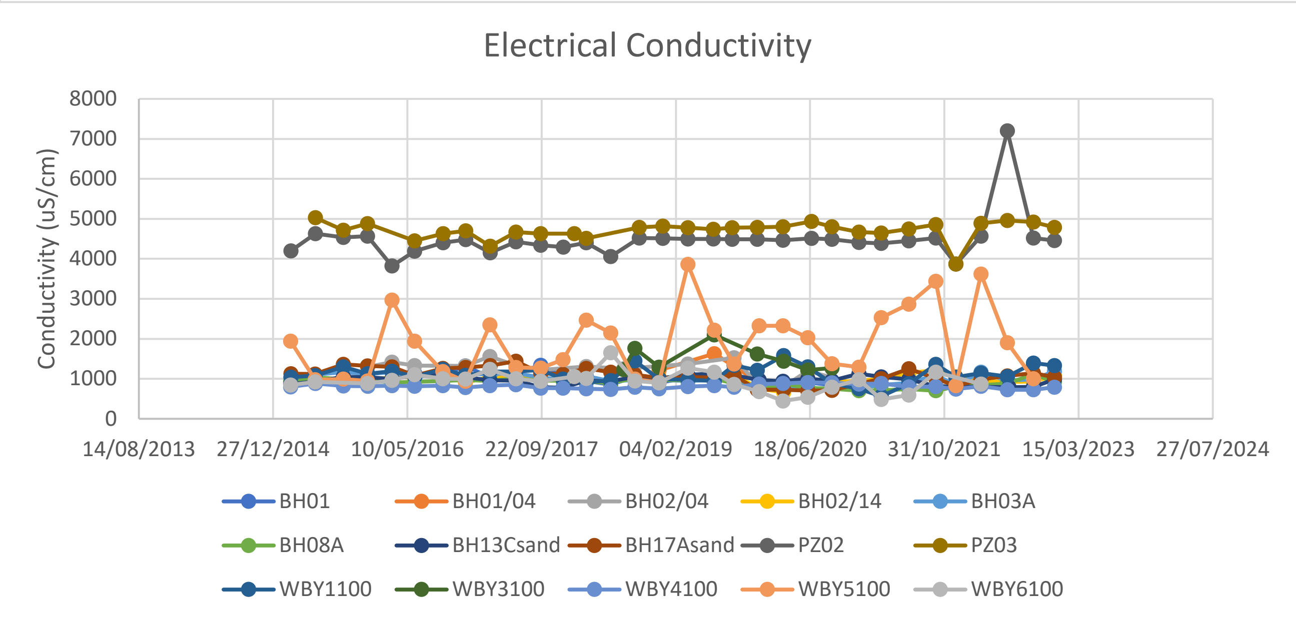

Mecoprop
Concentration (ug/l)
0.6
0.5
0.4
0.3
0.2
0.1
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
BH01
BH01/04
BH02/04
BH03A
BH17Asand
WBY1100
WBY3100
WBY4100
WBY6100
Compliance limit

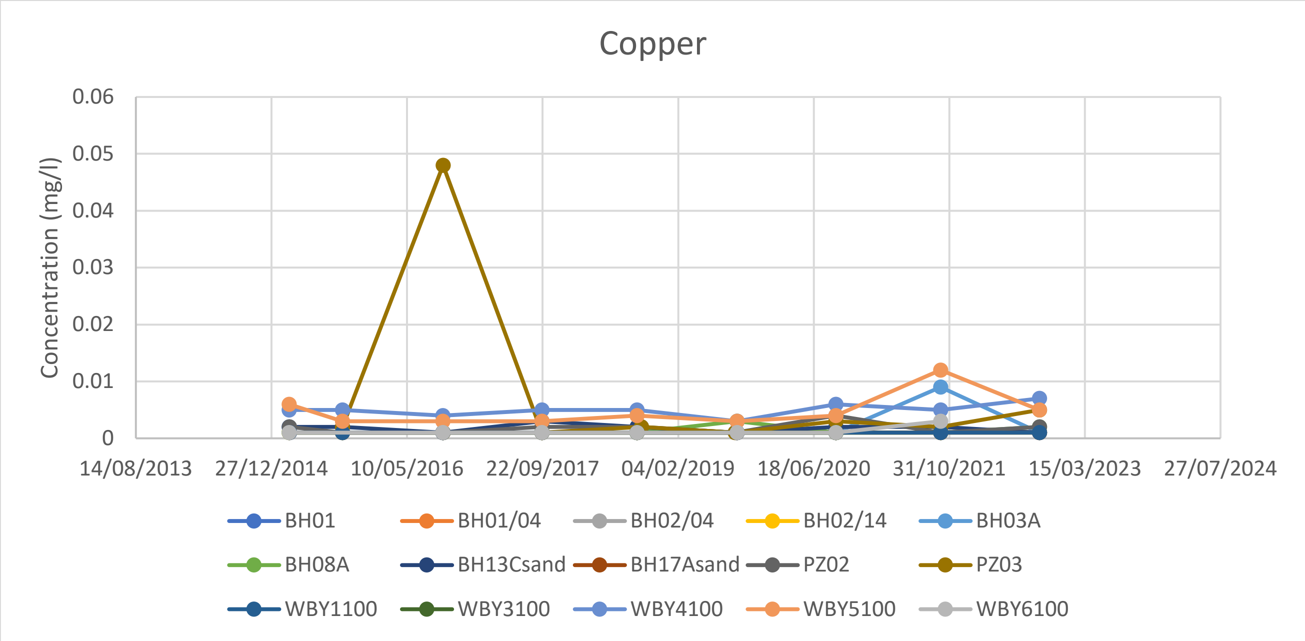

Mecoprop
Concentration (ug/l)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
BH02/14
BH08A
BH13Csand
PZ02
PZ03
WBY5100

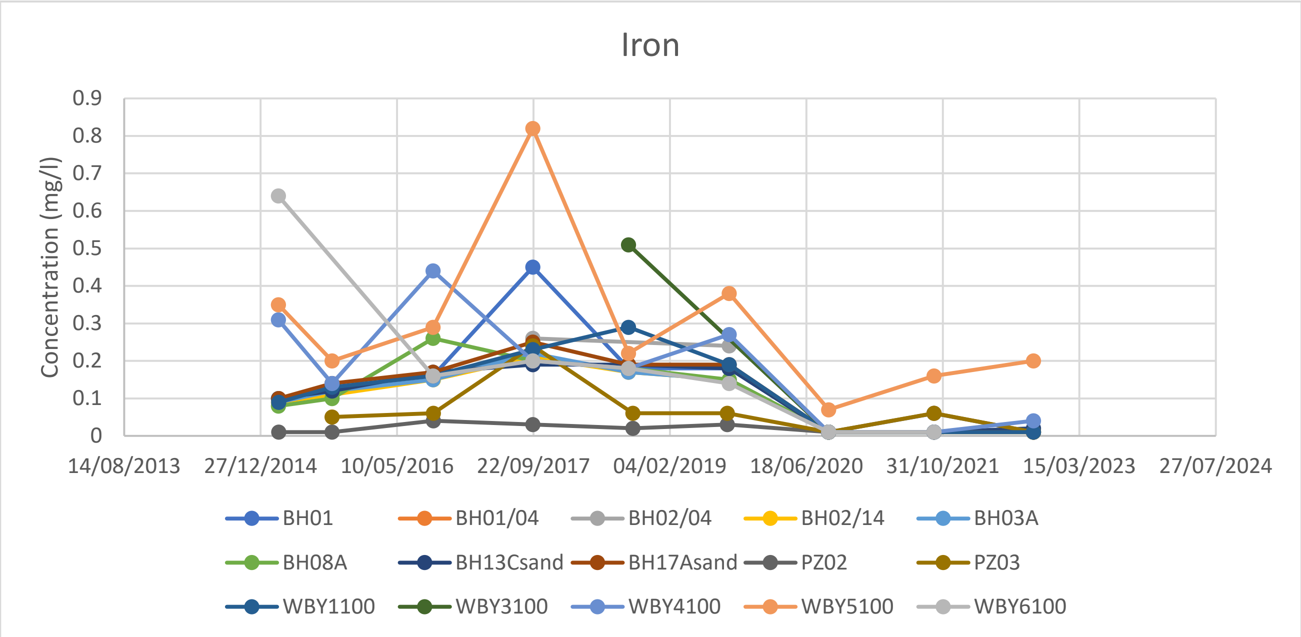

Alkalinity
Concentration (mg/l)
700
600
500
400
300
200
100
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
BH01
BH01/04
BH02/04
BH02/14
BH03A
BH08A
BH13Csand
BH17Asand
PZ02
PZ03
WBY1100
WBY3100
WBY4100
WBY5100
WBY6100

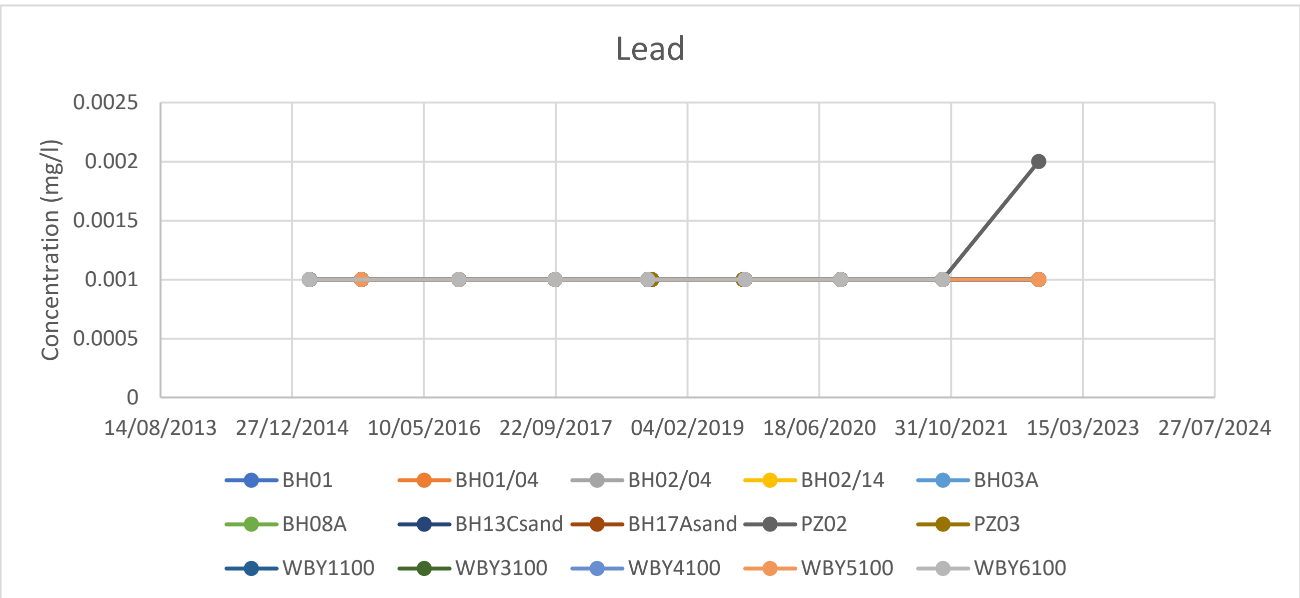

Calcium
Concentration (mg/l)
450
400
350
300
250
200
150
100
50
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
BH01
BH01/04
BH02/04
BH02/14
BH03A
BH08A
BH13Csand
BH17Asand
PZ02
PZ03
WBY1100
WBY3100
WBY4100
WBY5100
WBY6100

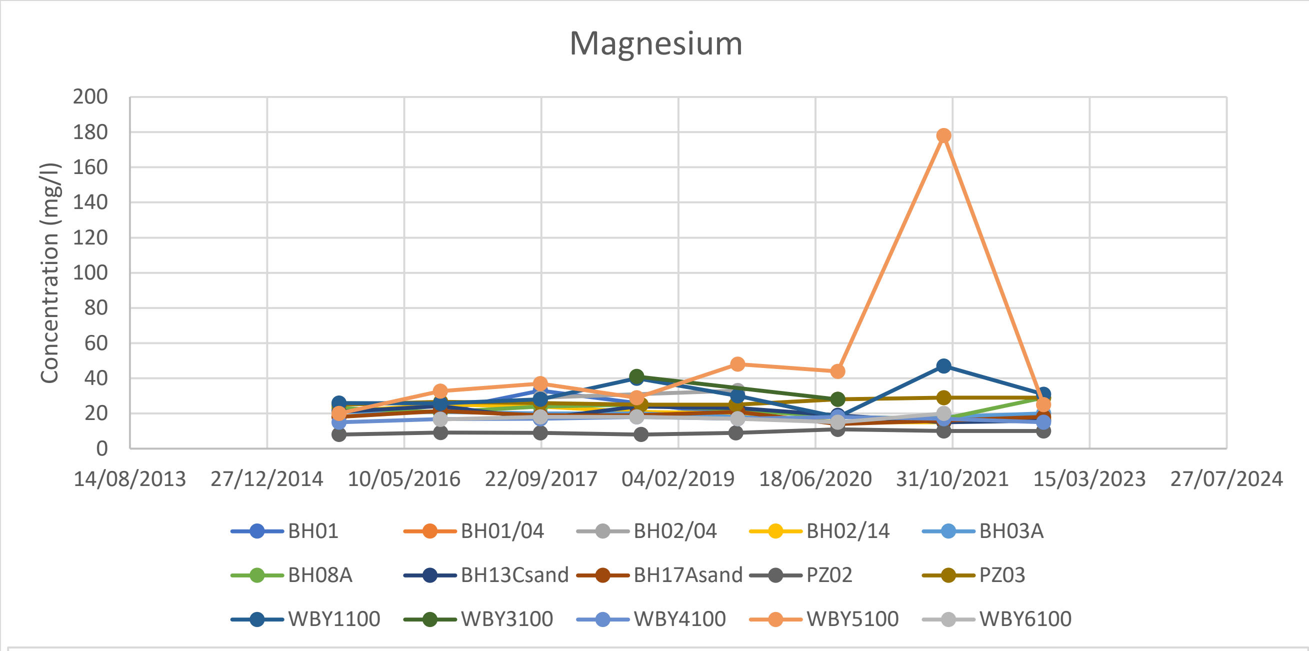

Chromium
Concentration (mg/l)
0.0025
0.002
0.0015
0.001
0.0005
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
BH01
BH01/04
BH02/04
BH02/14
BH03A
BH08A
BH13Csand
BH17Asand
PZ02
PZ03
WBY1100
WBY3100
WBY4100
WBY5100
WBY6100

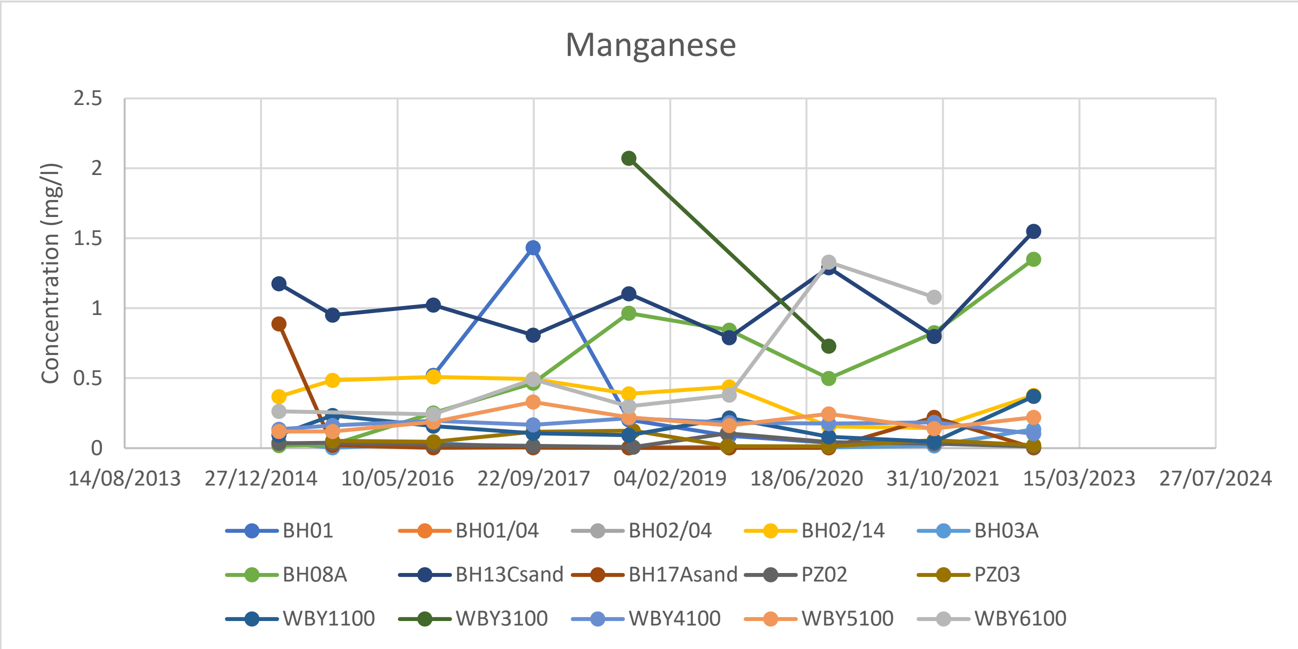

Electrical Conductivity
Conductivity (uS/cm)
8000
7000
6000
5000
4000
3000
2000
1000
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
BH01
BH01/04
BH02/04
BH02/14
BH03A
BH08A
BH13Csand
BH17Asand
PZ02
PZ03
WBY1100
WBY3100
WBY4100
WBY5100
WBY6100

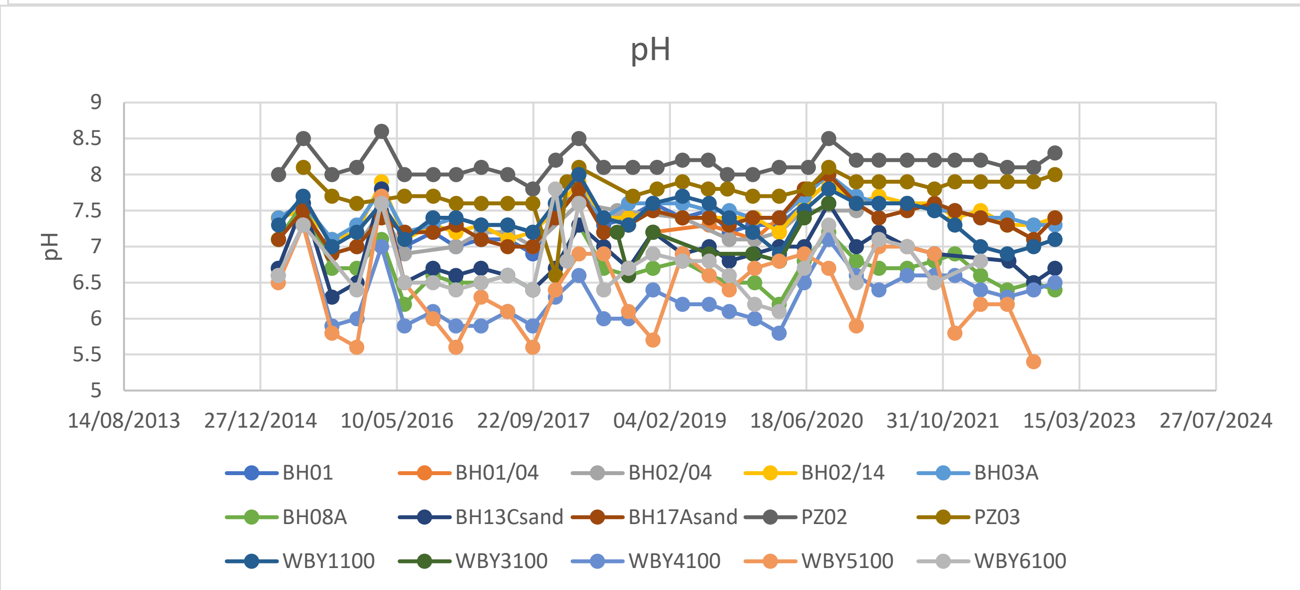

Copper
Concentration (mg/l)
0.06
0.05
0.04
0.03
0.02
0.01
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
BH01
BH01/04
BH02/04
BH02/14
BH03A
BH08A
BH13Csand
BH17Asand
PZ02
PZ03
WBY1100
WBY3100
WBY4100
WBY5100
WBY6100

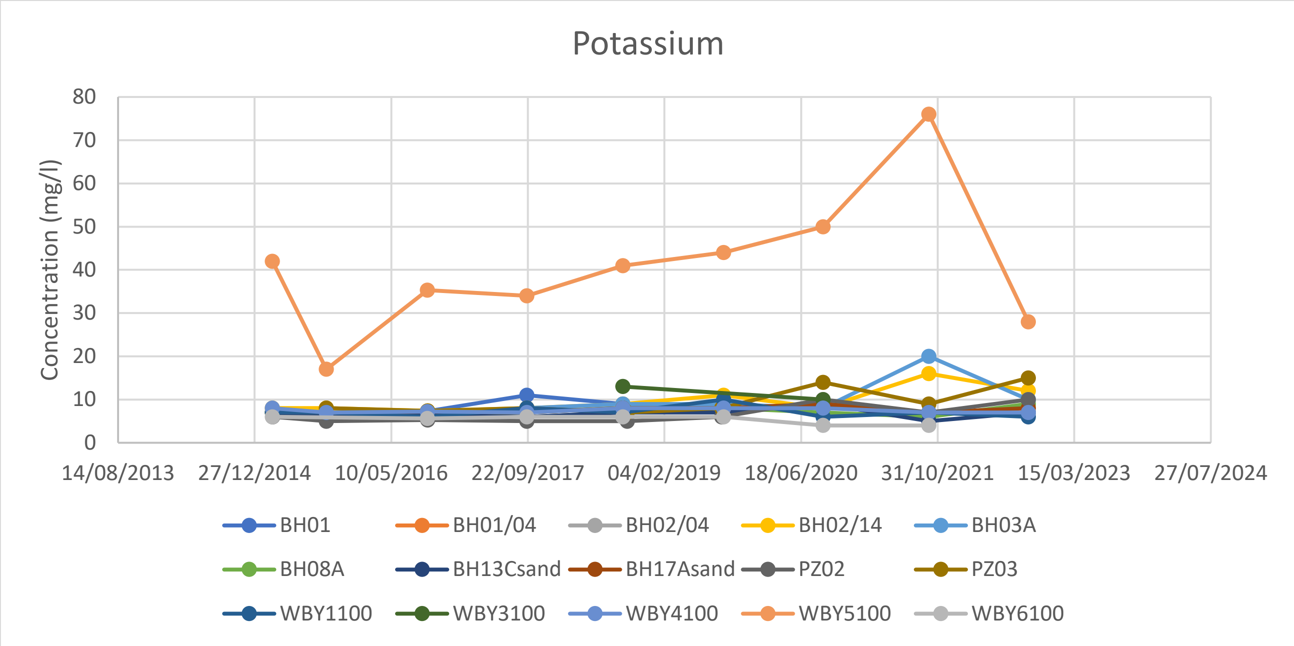

Iron
Concentration (mg/l)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
BH01
BH01/04
BH02/04
BH02/14
BH03A
BH08A
BH13Csand
BH17Asand
PZ02
PZ03
WBY1100
WBY3100
WBY4100
WBY5100
WBY6100

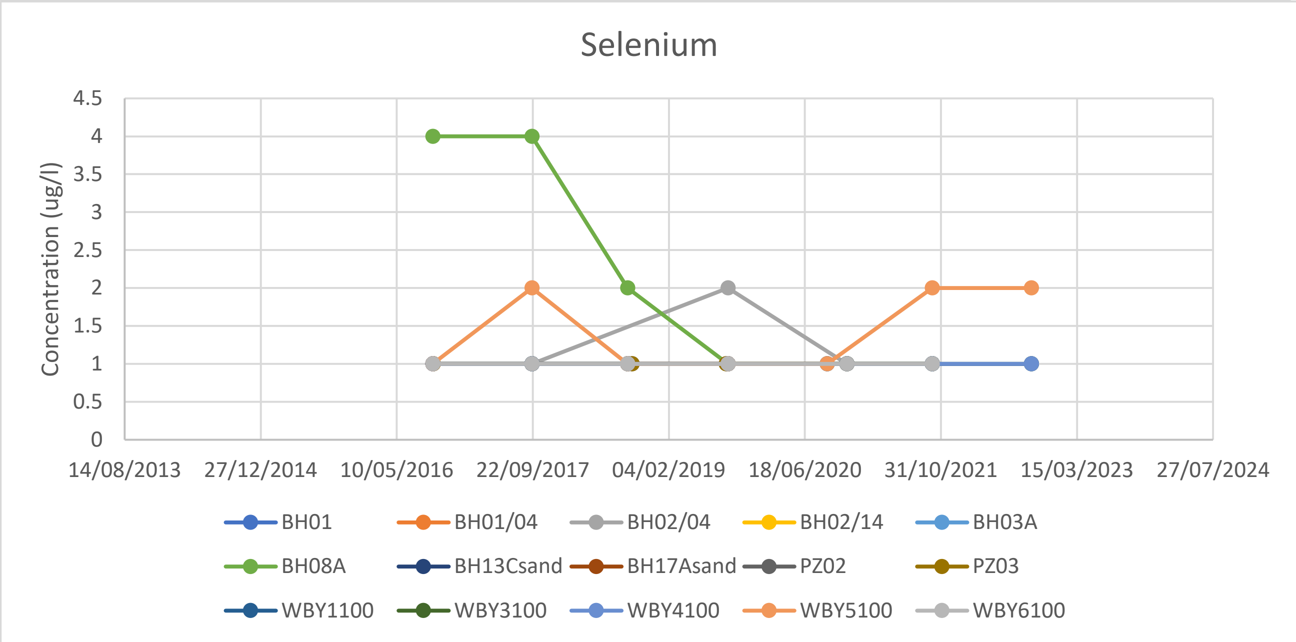

Lead
Concentration (mg/l)
0.0025
0.002
0.0015
0.001
0.0005
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
BH01
BH01/04
BH02/04
BH02/14
BH03A
BH08A
BH13Csand
BH17Asand
PZ02
PZ03
WBY1100
WBY3100
WBY4100
WBY5100
WBY6100

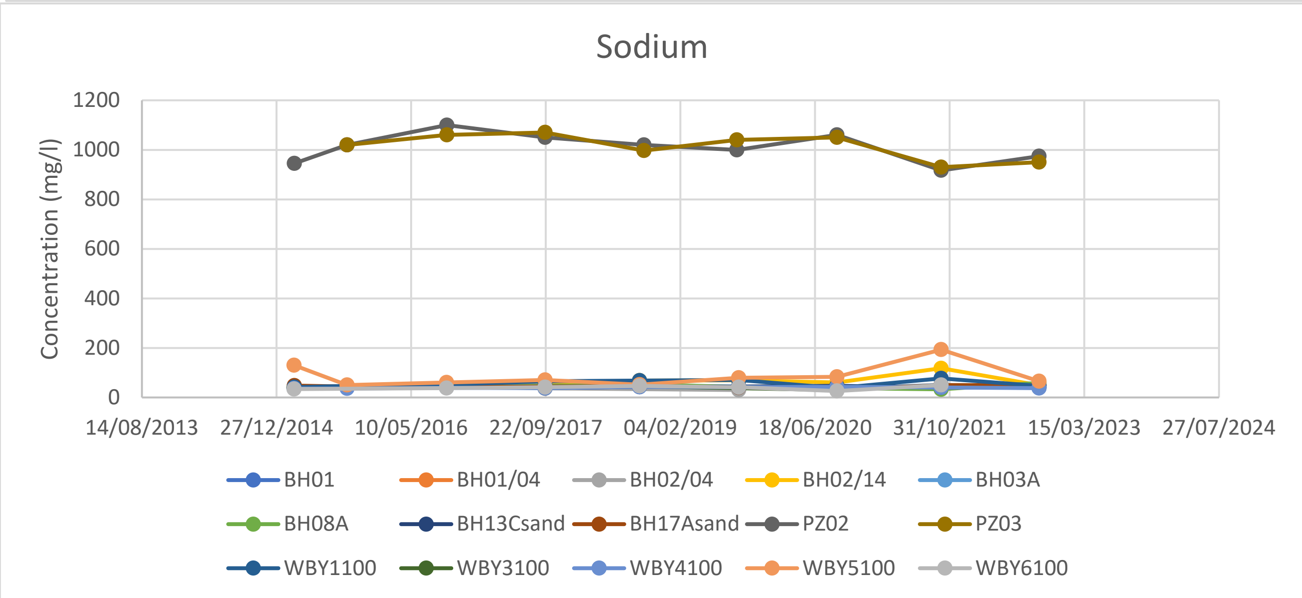

Magnesium
Concentration (mg/l)
200
180
160
140
120
100
80
60
40
20
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
BH01
BH01/04
BH02/04
BH02/14
BH03A
BH08A
BH13Csand
BH17Asand
PZ02
PZ03
WBY1100
WBY3100
WBY4100
WBY5100
WBY6100

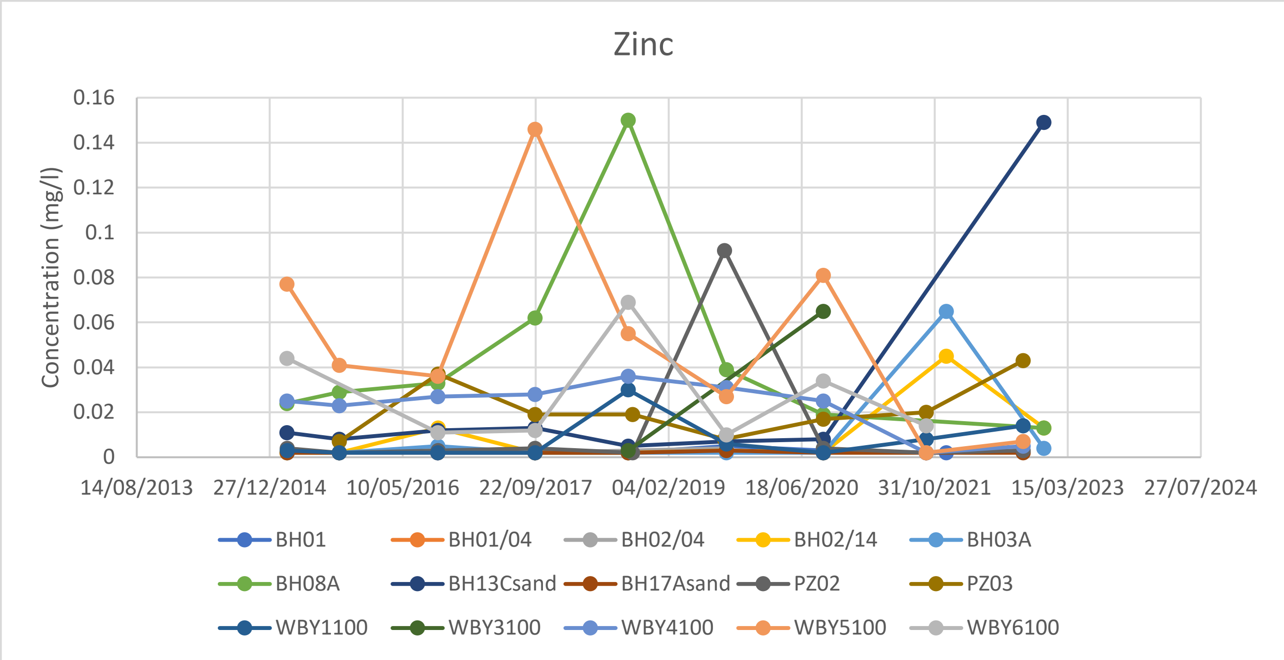

Manganese
Concentration (mg/l)
2.5
2
1.5
1
0.5
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
BH01
BH01/04
BH02/04
BH02/14
BH03A
BH08A
BH13Csand
BH17Asand
PZ02
PZ03
WBY1100
WBY3100
WBY4100
WBY5100
WBY6100


pH
pH
9
8.5
8
7.5
7
6.5
6
5.5
5
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
BH01
BH01/04
BH02/04
BH02/14
BH03A
BH08A
BH13Csand
BH17Asand
PZ02
PZ03
WBY1100
WBY3100
WBY4100
WBY5100
WBY6100


Potassium
Concentration (mg/l)
80
70
60
50
40
30
20
10
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
BH01
BH01/04
BH02/04
BH02/14
BH03A
BH08A
BH13Csand
BH17Asand
PZ02
PZ03
WBY1100
WBY3100
WBY4100
WBY5100
WBY6100

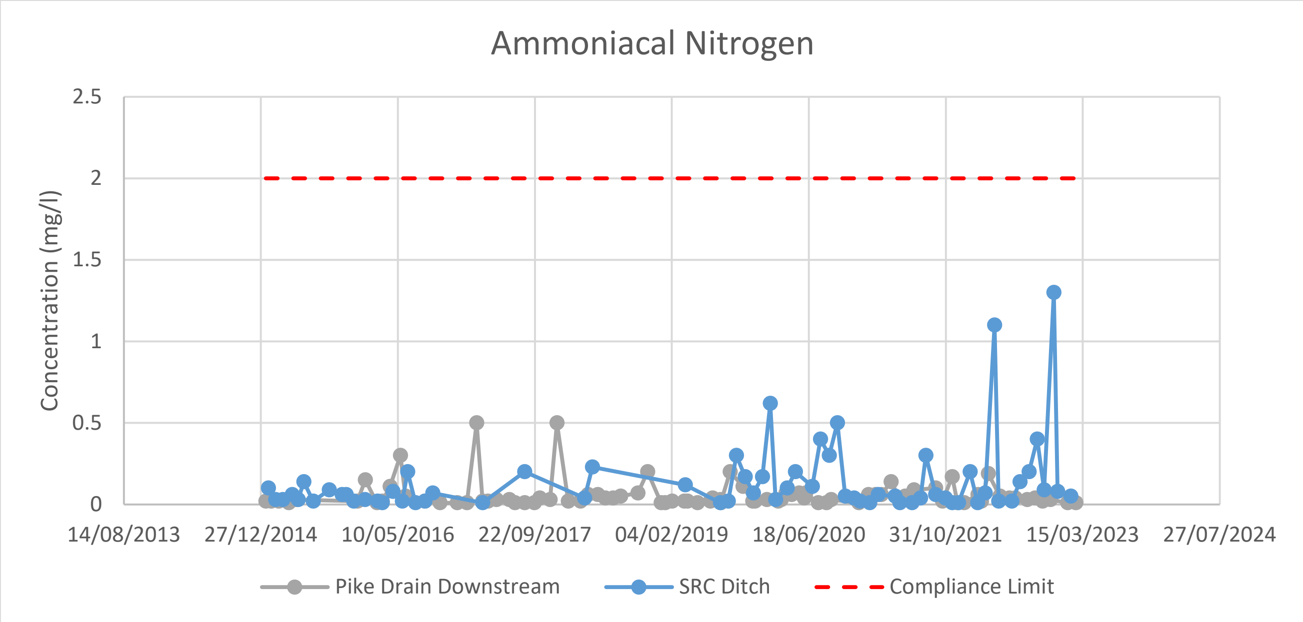

Selenium
Concentration (ug/l)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
BH01
BH01/04
BH02/04
BH02/14
BH03A
BH08A
BH13Csand
BH17Asand
PZ02
PZ03
WBY1100
WBY3100
WBY4100
WBY5100
WBY6100

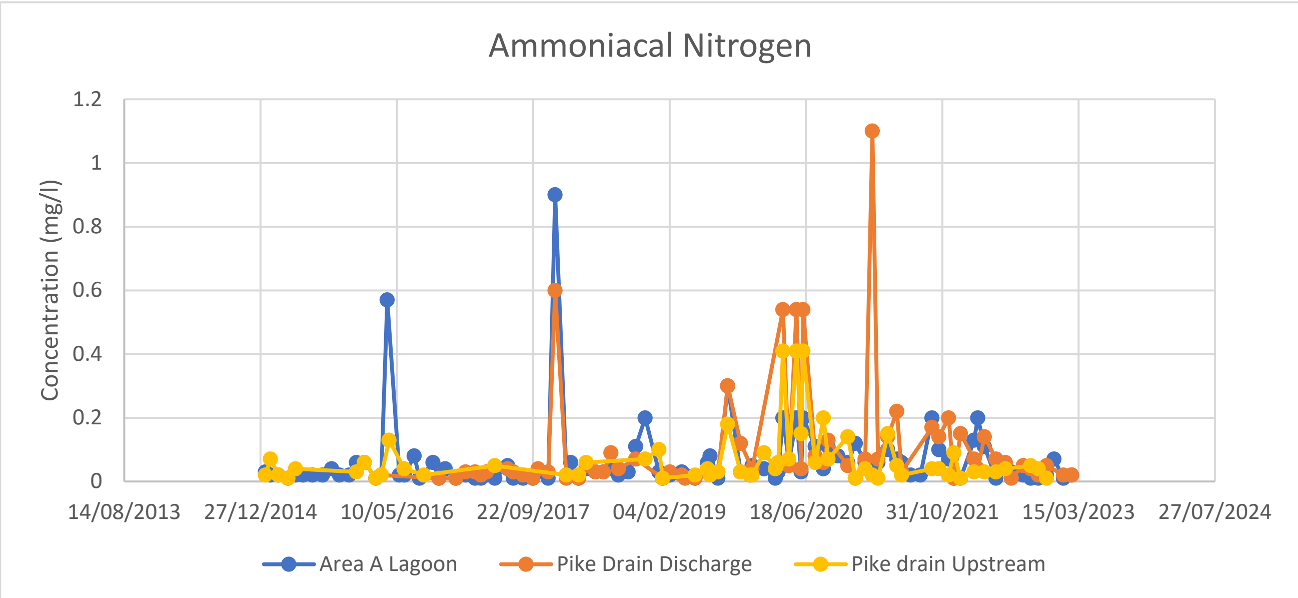

Sodium
Concentration (mg/l)
1200
1000
800
600
400
200
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
BH01
BH01/04
BH02/04
BH02/14
BH03A
BH08A
BH13Csand
BH17Asand
PZ02
PZ03
WBY1100
WBY3100
WBY4100
WBY5100
WBY6100

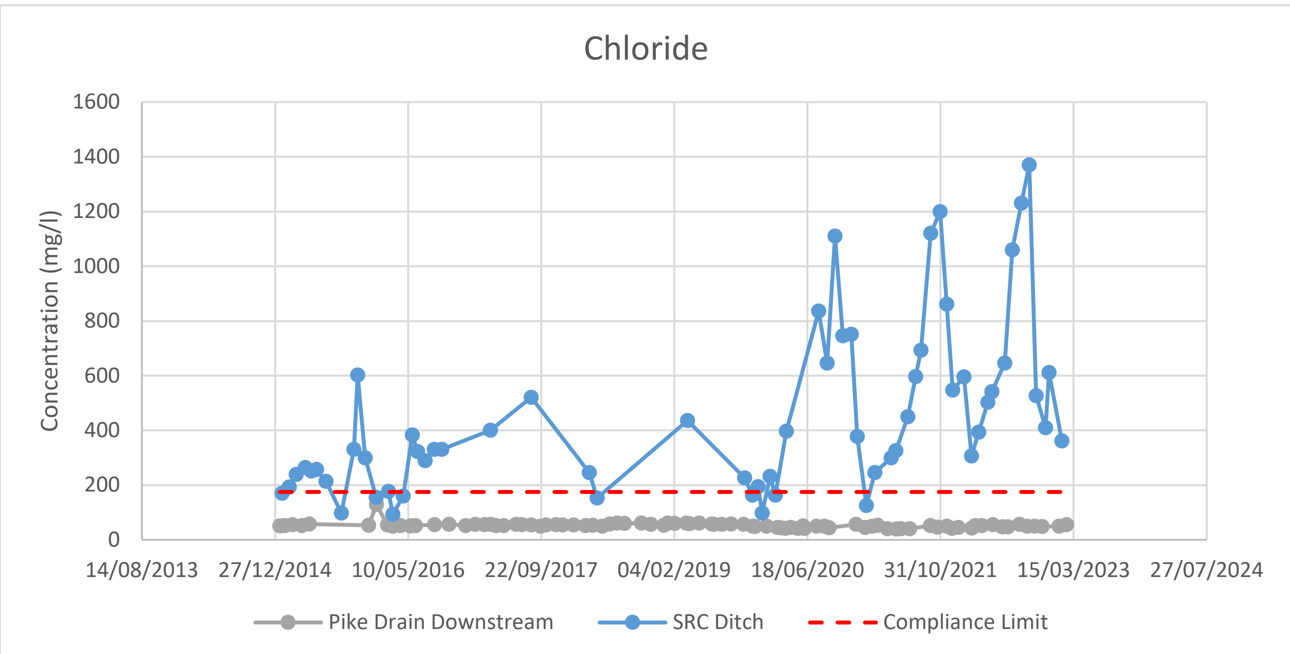

Zinc
Concentration (mg/l)
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
BH01
BH01/04
BH02/04
BH02/14
BH03A
BH08A
BH13Csand
BH17Asand
PZ02
PZ03
WBY1100
WBY3100
WBY4100
WBY5100
WBY6100

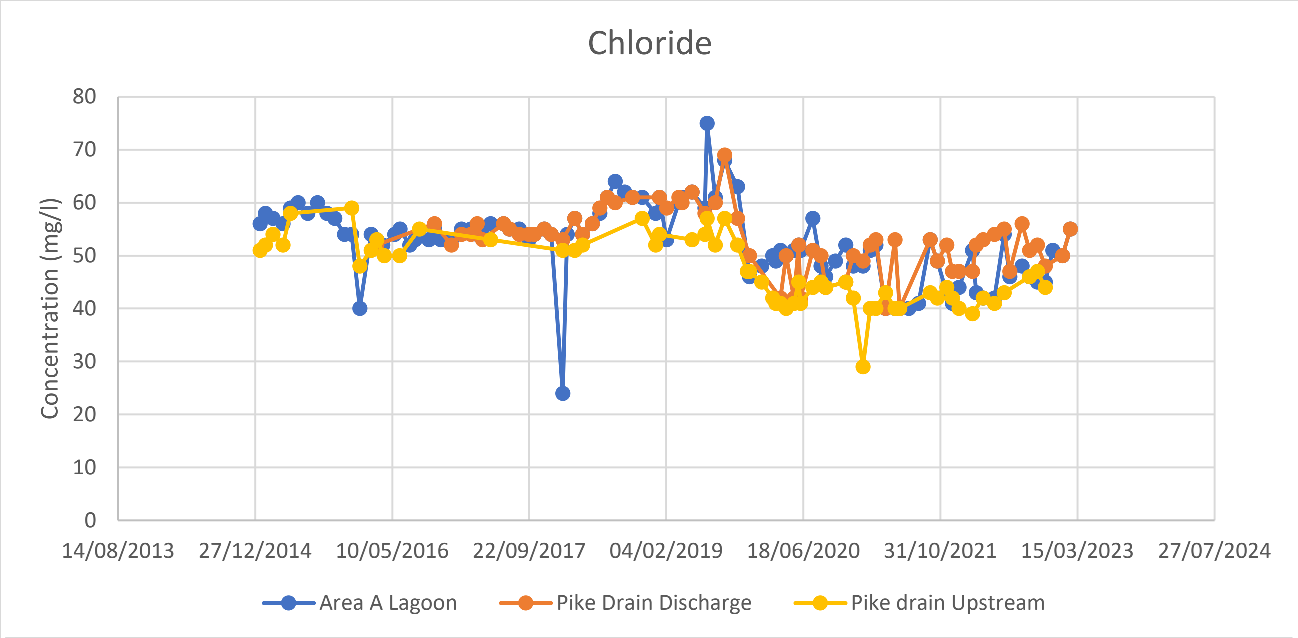
APPENDIX 5

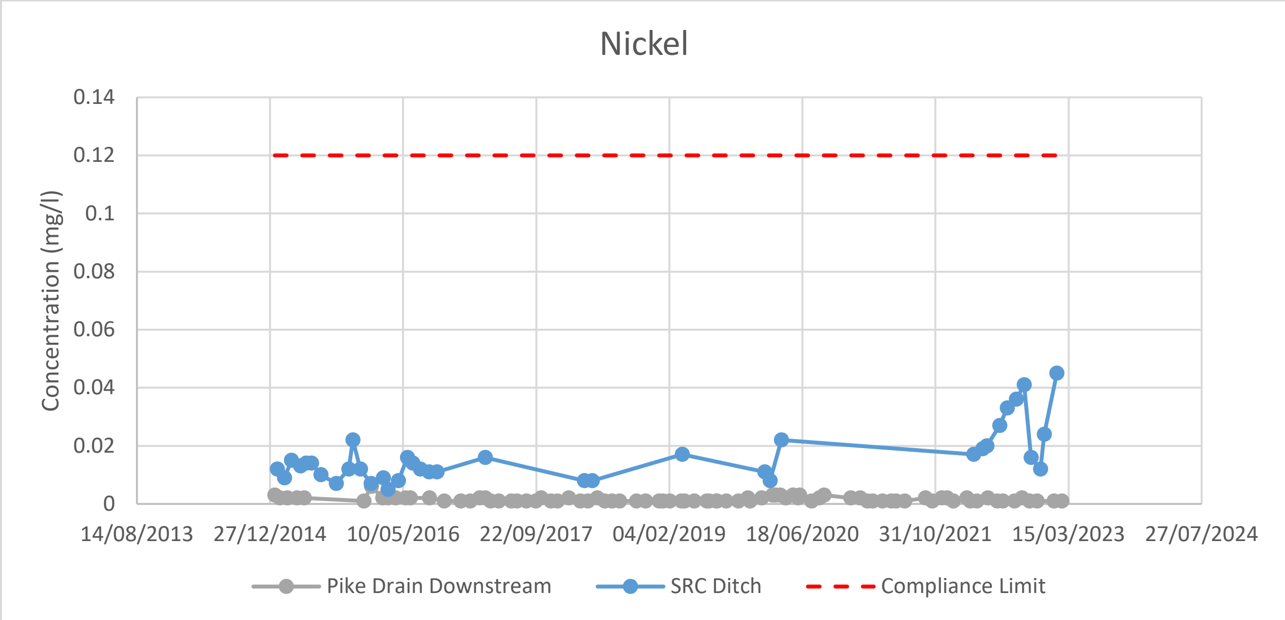
Surface Water Quality

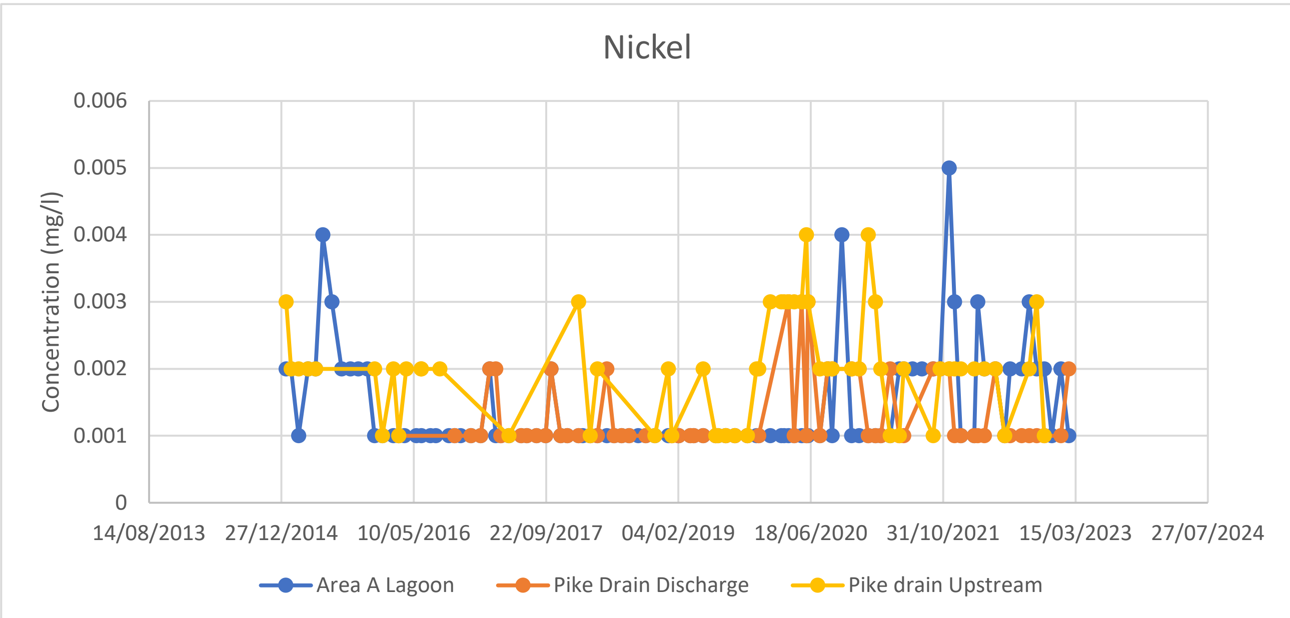

Ammoniacal Nitrogen
Concentration (mg/l)
2.5
2
1.5
1
0.5
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
Pike Drain Downstream
SRC Ditch
Compliance Limit

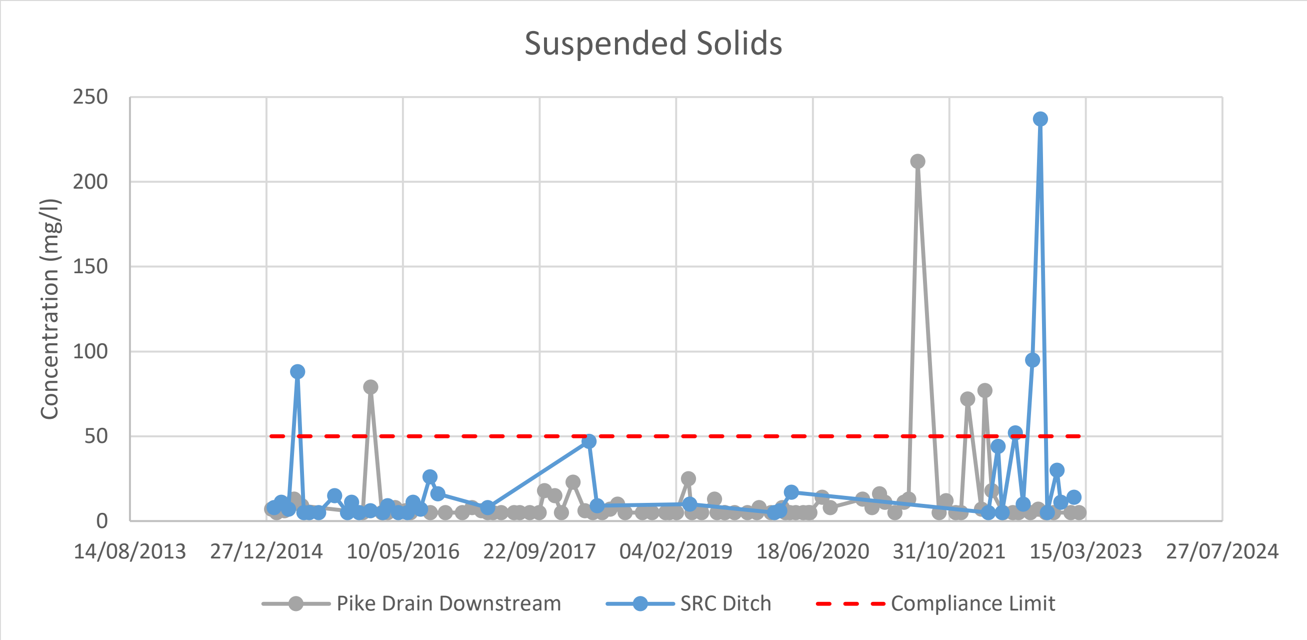

Ammoniacal Nitrogen
Concentration (mg/l)
1.2
1
0.8
0.6
0.4
0.2
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
Area A Lagoon
Pike Drain Discharge
Pike drain Upstream

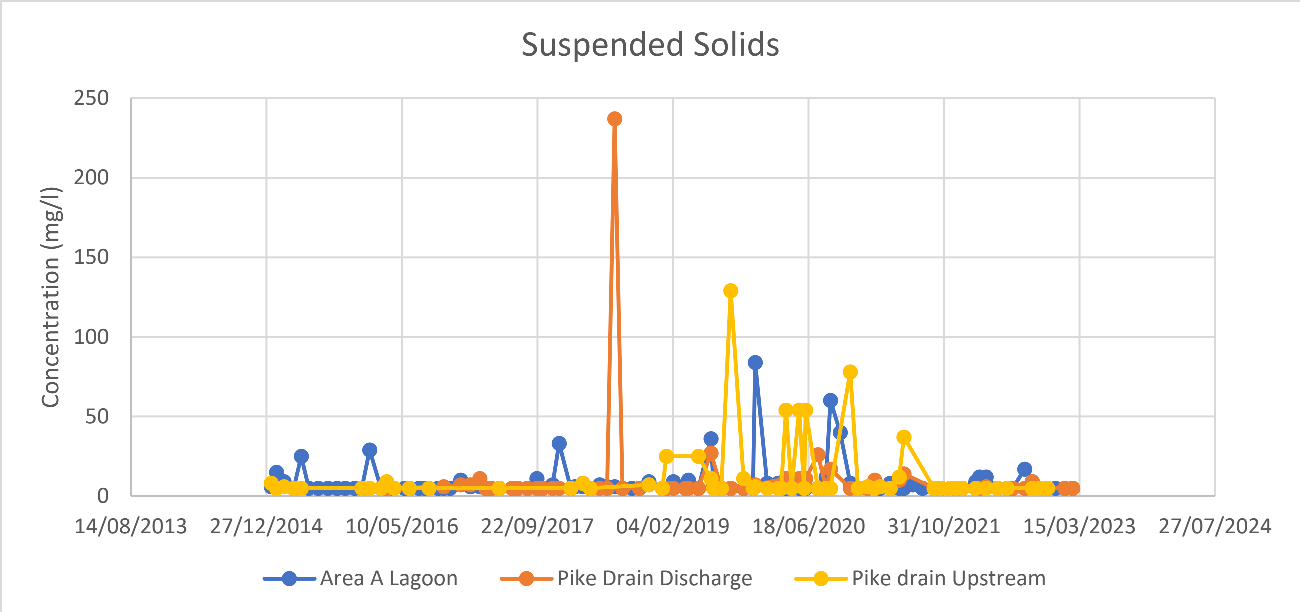

Chloride
Concentration (mg/l)
1600
1400
1200
1000
800
600
400
200
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
Pike Drain Downstream
SRC Ditch
Compliance Limit

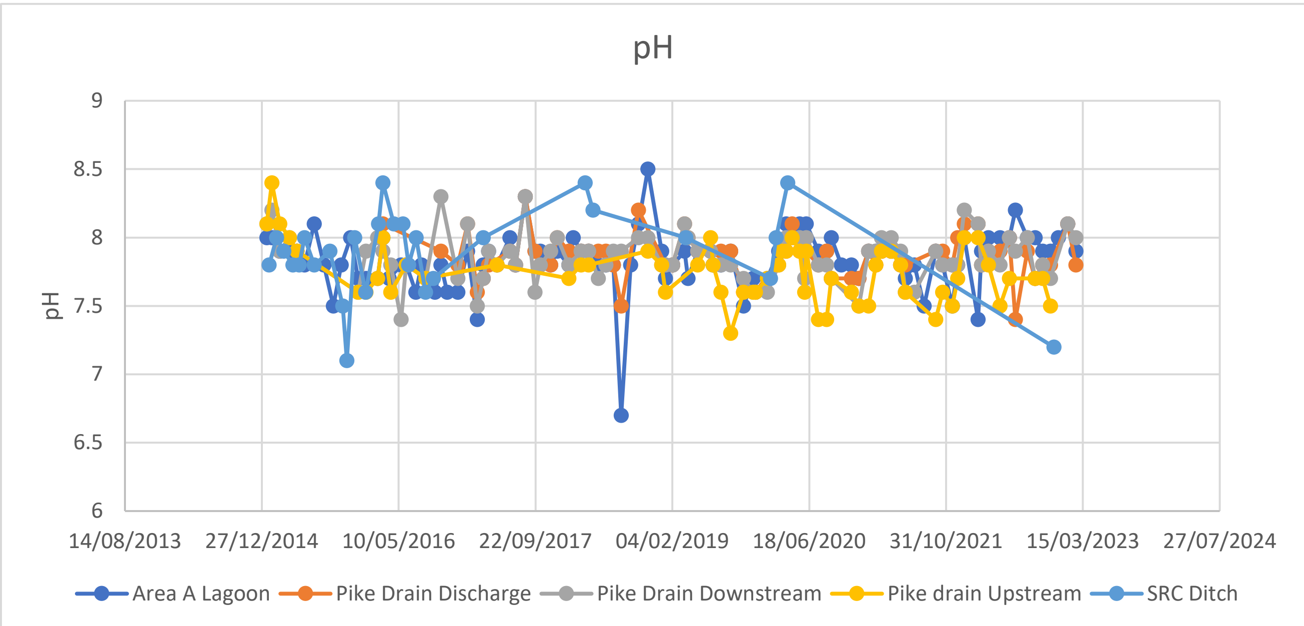

Chloride
Concentration (mg/l)
0
10
20
30
40
50
60
70
80
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
Area A Lagoon
Pike Drain Discharge
Pike drain Upstream

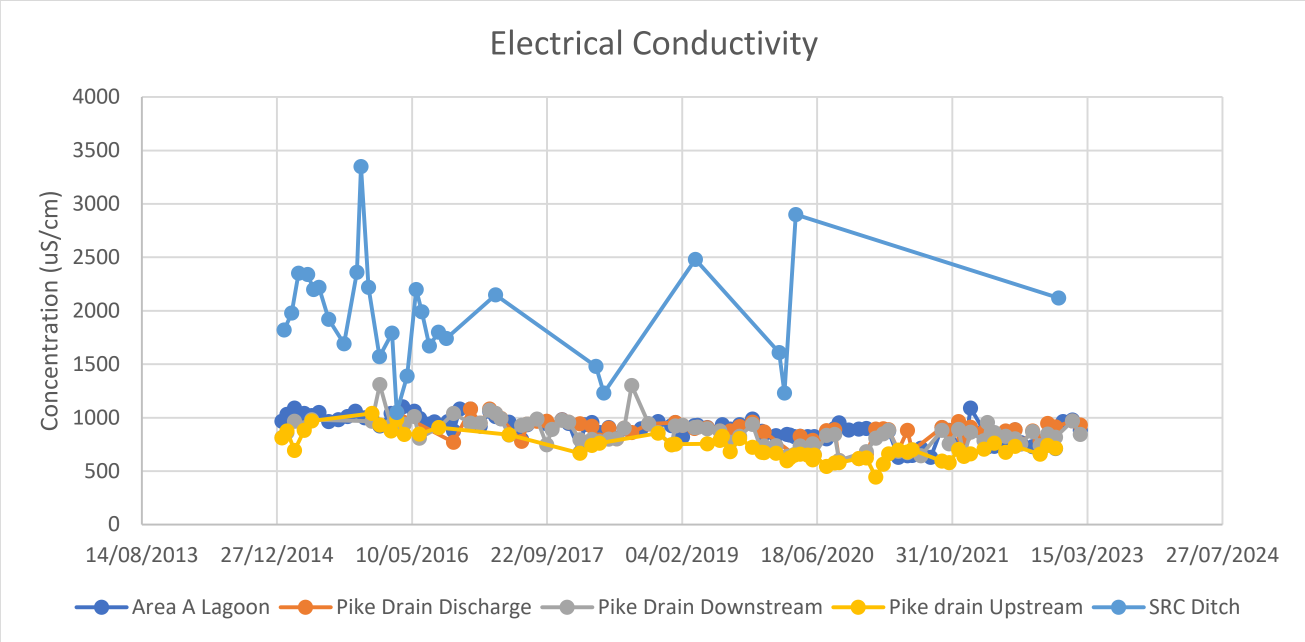

Nickel
Concentration (mg/l)
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
Pike Drain Downstream
SRC Ditch
Compliance Limit

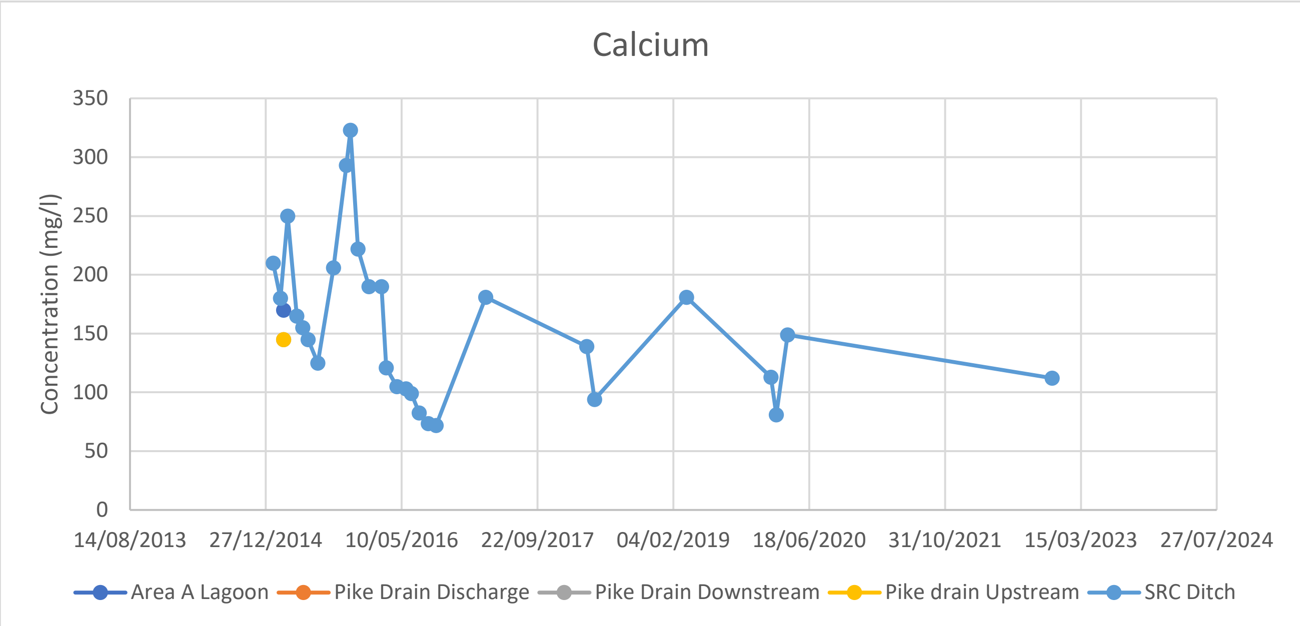

Nickel
Concentration (mg/l)
0
0.001
0.002
0.003
0.004
0.005
0.006
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
Area A Lagoon
Pike Drain Discharge
Pike drain Upstream

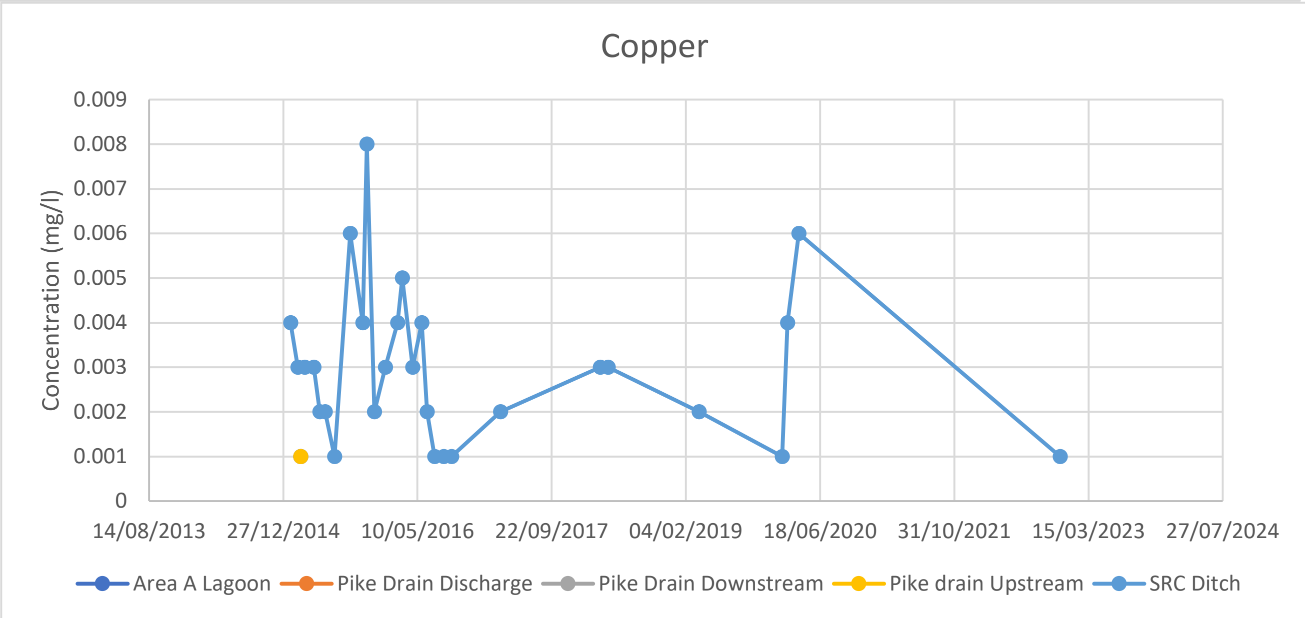

Suspended Solids
Concentration (mg/l)
250
200
150
100
50
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
Pike Drain Downstream
SRC Ditch
Compliance Limit

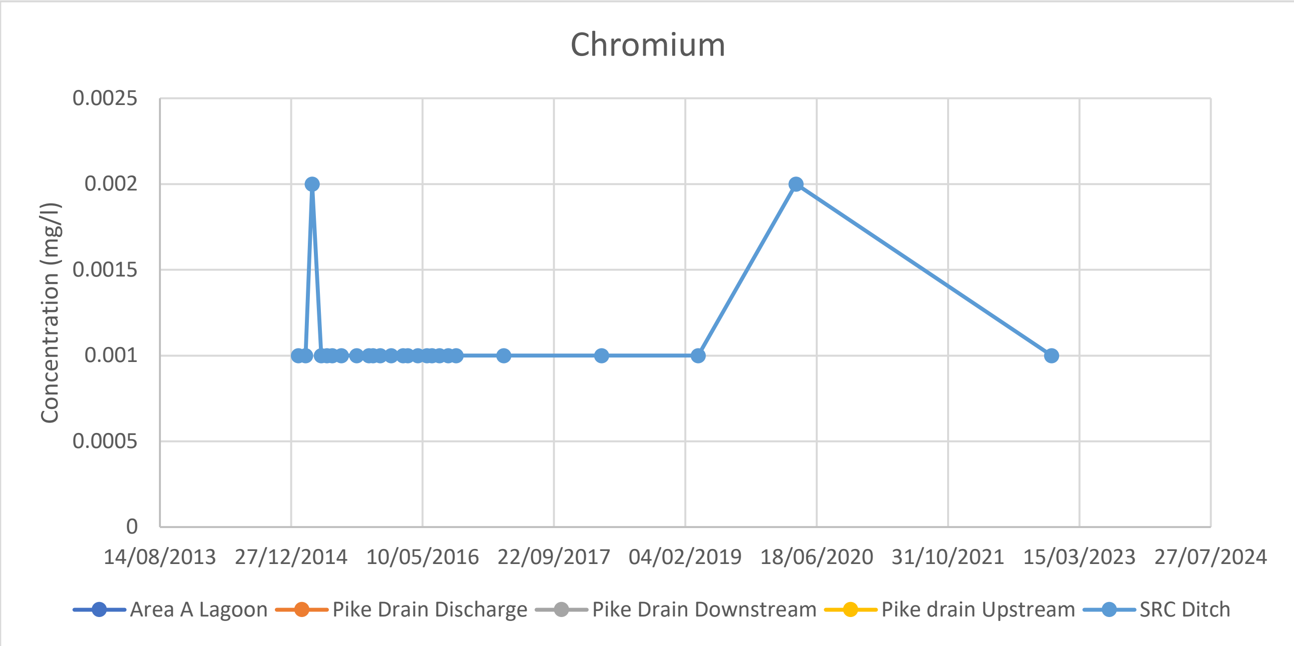

Suspended Solids
Concentration (mg/l)
250
200
150
100
50
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
Area A Lagoon
Pike Drain Discharge
Pike drain Upstream

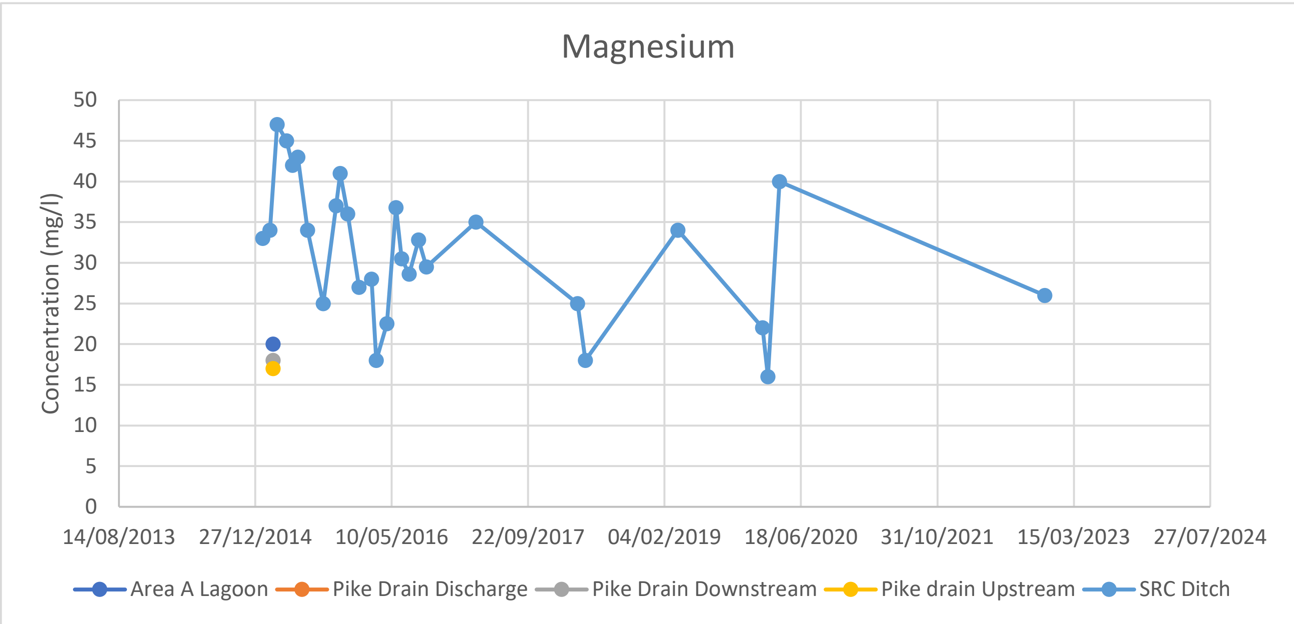

pH
pH
9
8.5
8
7.5
7
6.5
6
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
Area A Lagoon
Pike Drain Discharge
Pike Drain Downstream
Pike drain Upstream
SRC Ditch

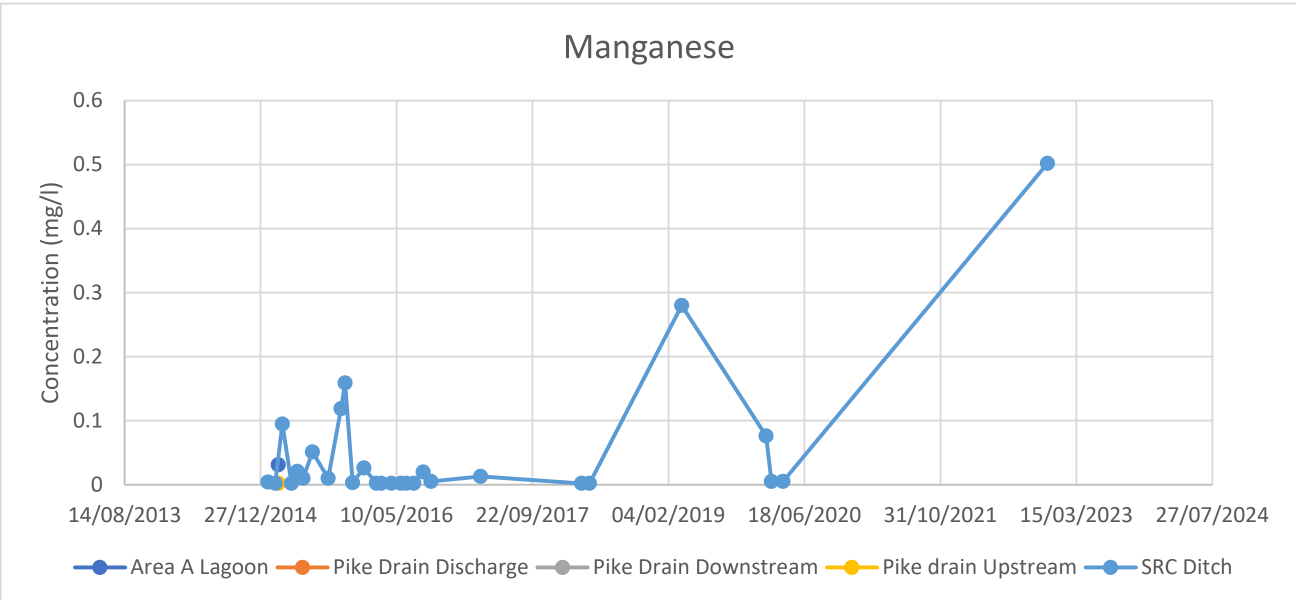

Electrical Conductivity
Concentration (uS/cm)
4000
3500
3000
2500
2000
1500
1000
500
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
Area A Lagoon
Pike Drain Discharge
Pike Drain Downstream
Pike drain Upstream
SRC Ditch

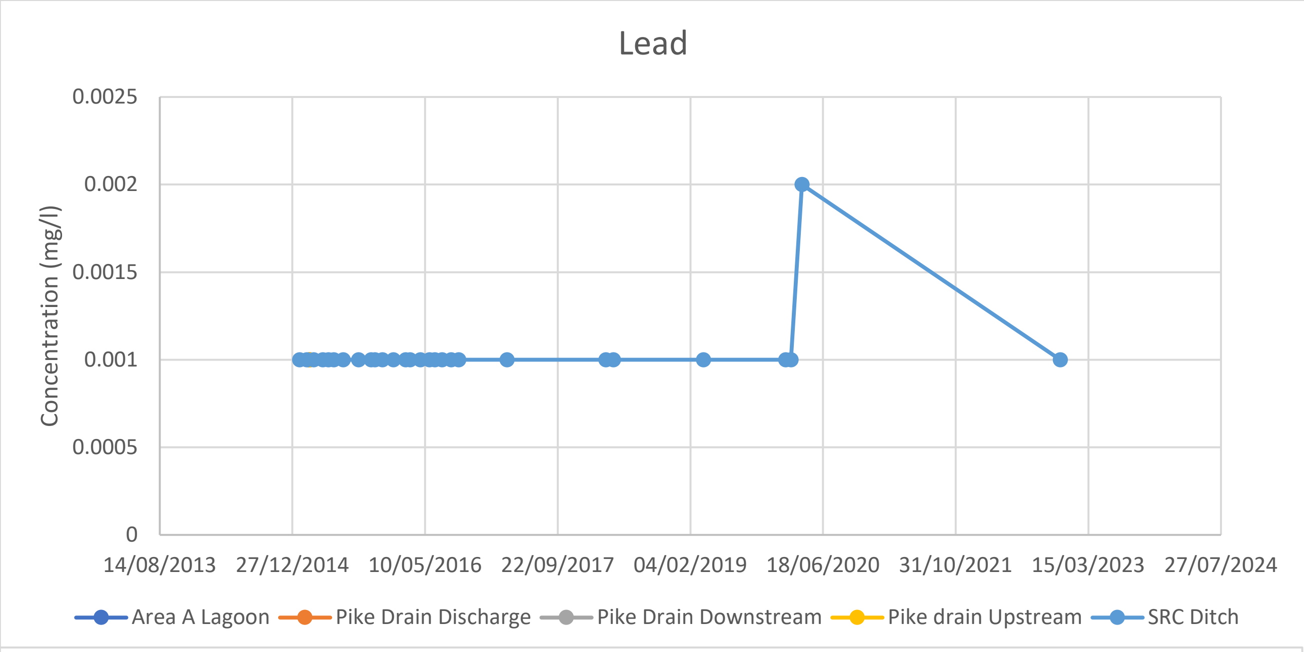

Calcium
Concentration (mg/l)
350
300
250
200
150
100
50
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
Area A Lagoon
Pike Drain Discharge
Pike Drain Downstream
Pike drain Upstream
SRC Ditch

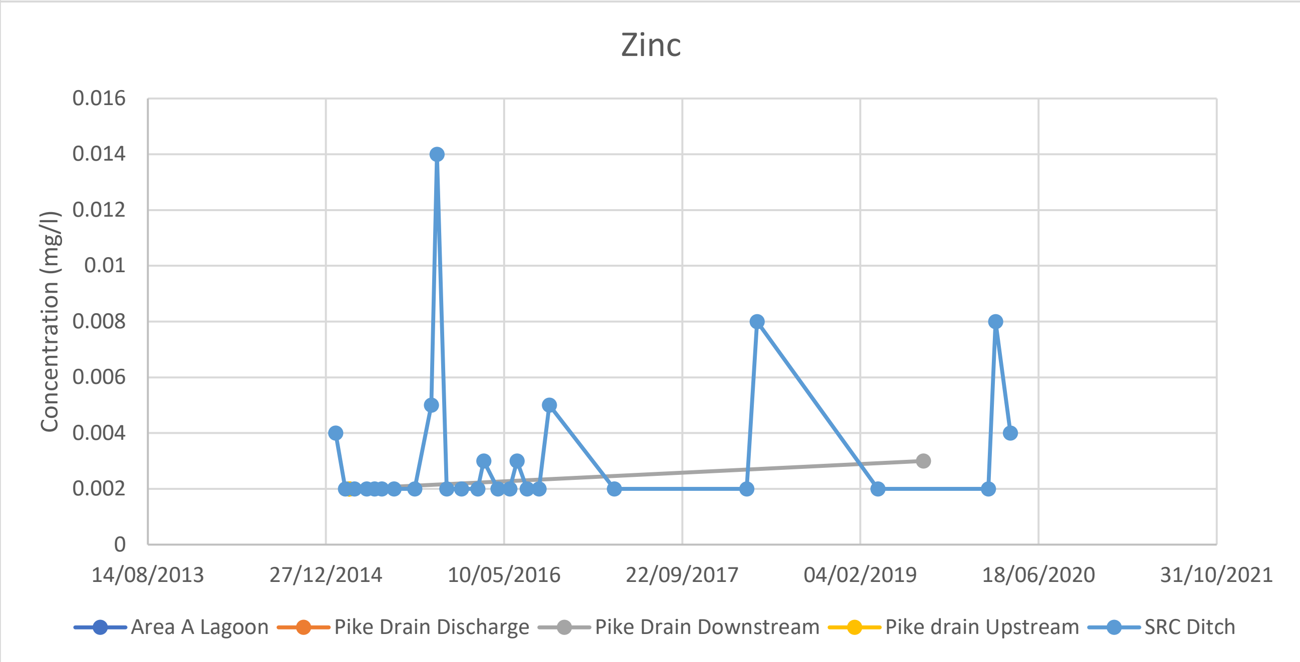

Copper
Concentration (mg/l)
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
Area A Lagoon
Pike Drain Discharge
Pike Drain Downstream
Pike drain Upstream
SRC Ditch


Chromium
Concentration (mg/l)
0.0025
0.002
0.0015
0.001
0.0005
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
Area A Lagoon
Pike Drain Discharge
Pike Drain Downstream
Pike drain Upstream
SRC Ditch


Magnesium
Concentration (mg/l)
50
45
40
35
30
25
20
15
10
5
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
Area A Lagoon
Pike Drain Discharge
Pike Drain Downstream
Pike drain Upstream
SRC Ditch


Manganese
Concentration (mg/l)
0.6
0.5
0.4
0.3
0.2
0.1
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
Area A Lagoon
Pike Drain Discharge
Pike Drain Downstream
Pike drain Upstream
SRC Ditch


Lead
Concentration (mg/l)
0.0025
0.002
0.0015
0.001
0.0005
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
Area A Lagoon
Pike Drain Discharge
Pike Drain Downstream
Pike drain Upstream
SRC Ditch


Zinc
Concentration (mg/l)
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
14/08/2013
27/12/2014
10/05/2016
22/09/2017
04/02/2019
18/06/2020
31/10/2021
Area A Lagoon
Pike Drain Discharge
Pike Drain Downstream
Pike drain Upstream
SRC Ditch

APPENDIX 6

Models and Results

Contaminant Fluxes from Hydraulic Containment Landfills Worksheet Version 1.0

Produced under Science Group: Air, Land & Water Project SC0310

Statement of Use

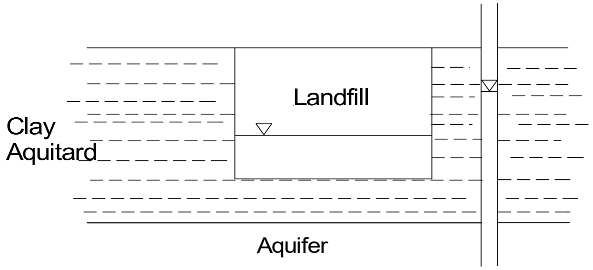
This worksheet has been prepared to help assessors quantify the contaminant flux from a hydraulic containment landfill constructed to the specifications in the Landfill Regulations (2002). It has been prepared to allow Agency staff to assess third party calculations of the diffusive contaminant flux from hydraulic containment landfills.

Data needs to be entered only in YELLOW cells. Assessors have to specify a preferred option from a pull-down menu in BLUE cells, interim calculation results are presented in GREY cells and final results in GREEN cells.
Only data in YELLOW or BLUE cells may be changed.

Site name
Whisby IBA Cells 1-4
Assessor's name
Alice Daly
Date
5th July 2023

SELECT LANDFILL CONSTRUCTION SCENARIO

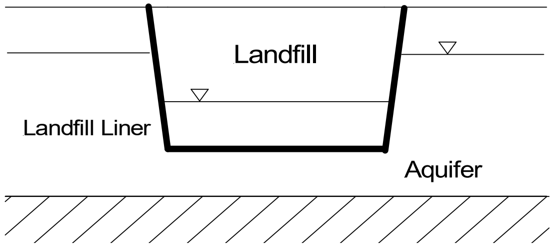
Scenario 1



The landfill is constructed in a clay pit, underlain by a confined aquifer. Water and contaminant fluxes occur across the bottom of the landfill only.

○ Select Scenario 1

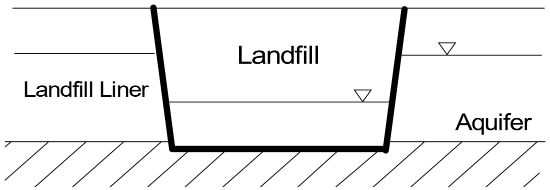
Scenario 2



The landfill is lined and located in a permeable formation a finite distance above an impermeable layer. The water and contaminant fluxes can occur through the base and sides of the landfill.

○ Select Scenario 2

Scenario 3



The landfill is lined and located in a permeable formation a finite distance below an impermeable layer. The water and contaminant fluxes can occur through the sides of the landfill only.

◉ Select Scenario 3

Whisby IBA Cells 1-4 — 5th July 2023

CONCEPTUAL MODEL AND LANDFILL CONSTRUCTION

Conceptual model of landfill construction	CM	3	-
Is a geomembrane present?	GM_opt	No	-
Basal width perpendicular to groundwater flow	Width_LF	210	m
Basal length parallel to groundwater flow	Length_LF	280	m
Basal area	Base_Area	58800	m2
Elevation of base of landfill	LFbase_elev	3	maOD
Elevation of base of aquifer	Aqbound_elev	6	maOD
Leachate head inside landfill	Head_inLF	7.5	maOD
Groundwater head outside landfill	Head_outLF	8.5	maOD
Area of liner below the water table	Area_contact	1470	m2

CONTAMINANT PARAMETERS

Contaminant name	Cont_Nme	Sulphate	-
Contaminant type	Cont_Type	Inorganic	-
Contaminant classification	Cont_Class	List II	-
Concentration in landfill leachate	Conc_LF	2141	mg/l
Free water diffusion coefficient	Dw_cl	5.00E-09	m2/s
Partition coefficient in clay	Kd_cl	0	l/kg
Retardation factor in clay	R_cl	1	-
Half life in clay (0 for no decay)	thalf_cl		days
Decay in sorbed phase?	Decay_sorb	No	-
Decay constant in clay	Decay_cl	0	1/s

MINERAL BARRIER / LINER

Thickness of mineral liner	thick_clbr	1	m
Hydraulic conductivity	k_cl	1.00E-09	m/s
Average pore radius	pore_radius	1.00E-05	m
Effective porosity	n	0.162	-
Dry bulk density	rho	1750	kg/m3
Tortuosity	tau_cl	5	-

Sulphate

STEADY STATE DILUTION

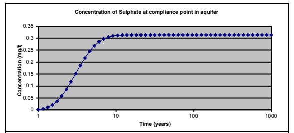
Hydraulic gradient in the aquifer	aq_I	0.004	-
Hydraulic conductivity of the aquifer	k_aq	1.00E-05	m/s
Downgradient distance of compliance point from landfill	dist_cp	100	m
Mixing width	Mix_W	210	m
Mixing depth	Mix_D	2.5	m
Dilution flow in aquifer downstream to the landfill	aq_Q	0.000021	m3/s

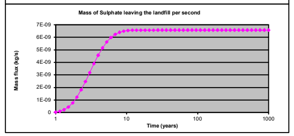
CONTAMINANT AND WATER FLUXES

Groundwater flux into landfill		0.00000294	m3/s
Maximum contaminant concentration at compliance point at tmax	C_comp	0.31319985	mg/l

CHART PARAMETERS

Minimum axis display	tmin	1	years
Maximum axis display	tmax	1.00E+03	years





Concentration c Mass of Sulphate leaving the landfill per second

Time years	Concentration	Mass flux (kg/s)
1	0.001664015	3.49443E-11
1.148153621	0.004583901	9.62619E-11
1.318256739	0.010532966	2.21192E-10
1.513561248	0.020868659	4.38242E-10
1.737800829	0.0366959	7.70614E-10
1.995262315	0.05850426	1.22859E-09
2.290867653	0.085918255	1.80428E-09
2.630267992	0.117656436	2.47079E-09
3.01995172	0.151722491	3.18617E-09
3.467368505	0.185772439	3.90122E-09
3.981071706	0.21754887	4.56853E-09
4.570881896	0.245263075	5.15052E-09
5.248074602	0.267835682	5.62455E-09
6.025595861	0.284958557	5.98413E-09
6.918309709	0.296994029	6.23687E-09
7.943282347	0.30476582	6.40008E-09
9.120108394	0.309311771	6.49555E-09
10.47128548	0.311662301	6.54491E-09
12.02264435	0.312686721	6.56642E-09
13.80384265	0.313021437	6.57345E-09
15.84893192	0.313069209	6.57445E-09
18.19700859	0.313043866	6.57392E-09
20.89296131	0.313032168	6.57368E-09
23.98832919	0.313051078	6.57407E-09
27.54228703	0.313089183	6.57487E-09
31.6227766	0.31313043	6.57574E-09
36.30780548	0.313164	6.57644E-09
41.68693835	0.313185868	6.5769E-09
47.86300923	0.31319682	6.57713E-09
54.95408739	0.31319985	6.5772E-09
63.09573445	0.313198249	6.57716E-09
72.44359601	0.313194636	6.57709E-09
83.17637711	0.313190692	6.577E-09
95.4992586	0.313187284	6.57693E-09
109.6478196	0.313184719	6.57688E-09
125.8925412	0.313182983	6.57684E-09
144.5439771	0.313181922	6.57682E-09
165.9586907	0.313181347	6.57681E-09
190.5460718	0.313181092	6.5768E-09
218.7761624	0.313181026	6.5768E-09
251.1886432	0.31318106	6.5768E-09
288.4031503	0.31318114	6.5768E-09
331.1311215	0.313181231	6.57681E-09
380.1893963	0.313181317	6.57681E-09
436.5158322	0.31318139	6.57681E-09
501.1872336	0.313181449	6.57681E-09
575.4399373	0.313181495	6.57681E-09
660.693448	0.313181529	6.57681E-09
758.577575	0.313181554	6.57681E-09
870.96359	0.313181573	6.57681E-09
1000	0.313181586	6.57681E-09

Yes	Inorganic	Good cont	Yes	s_per_year
	List I			s_per_day
	List II			86400
				tlarge
				1.00E+40
				tscale
				1.148154

CALCULATIONS START HERE...

Type of solution to use (determines flows and areas to use)	Solution_type	a	
Coefficient of mechanical dispersion	D_mech	0	-
Longitudinal mechanical dispersion in the clay	Dl_cl	0	m2/s

Calculated concentrations and hydraulic conductivities

Concentration at top of clay barrier	Conc_def	2141	mg/l

1.26478E-08

2.29247E-12

1.23686E-08

5.83209E-12

Fluxes into the landfill

Inward Darcy flow in absence of geomembrane	Q_darcy	0.00000147	m3/s
Inward flux into the landfill	Q	0.00000147	m3/s

Velocities

Velocity through the clay	vel_cl	-6.17284E-09	m/s
Maximum velocity through centre of a pore in mineral liner	umax	-1.5E-09	m/s

Summary of parameters for mass calculations

Leachate concentration	C_LF	2141	mg/l
Concentration at edge of barrier	C_bar	0.31319985	mg/l
Diffusion coefficient	D_used	1E-09	m2/s
Distance	x_used	1	m
Outward flux area	Area_flux	1470	m2
Inward flow area	Area_flow	1470	m2

WARNING: Concentrations at the compliance point are predicted to exceed 10% of the leachate concentration. The boundary conditions used are only valid for low concentrations, and results may be unreliable above 10% of the leachate concentration.
WARNING: This spreadsheet has expired! Please contact the Environment Agency for an updated version.

Area_delam_check	1
Area_defect_check	1
Aquifer base check	3
Head base check	4.5
Head out base check	5.5
Head check	1
CM3 check	1
Area check	1
elev check	9

WARNING: The delaminated area should be less than or equal to the area of the landfill!
WARNING: The base of the landfill should be higher than the base of the aquifer!
WARNING: The leachate head should be higher than the base of the landfill!
WARNING: The groundwater head should be higher than the base of the landfill!
WARNING: The leachate head should be lower than the groundwater head!
WARNING: The base of the landfill should be lower than the top of the aquifer!
WARNING: The leachate head should be greater than the elevation of the base of the aquifer
WARNING: The area over which the geomembrane is delaminated must be greater than zero and not greater than the area of the liner below the water table.
WARNING: The dimensions of the defects should not be set to zero! Set the density of the required defect to zero to indicate the defect is not present.

Whisby IBA Cells 1-4 **5th July 2023**
Alice Daly

CONCEPTUAL MODEL AND LANDFILL CONSTRUCTION				Justification / Reference / Notes
Scenario		3		
Is a geomembrane present?		No		
Basal width perpendicular to groundwater flow	Width_LF	210	m	Width of IBA Cells 1-4
Basal length parallel to groundwater flow	Length_LF	280	m	Length of IBA Cells 1-4
Elevation of base of landfill	LFbase_elev	3	maOD	Construction/design
Elevation of base of aquifer	Aqbound_elev	6	maOD	Base of Sand and Gravel Aquifer
Leachate head inside landfill	Head_inLF	7.5	maOD	1m below minimum rest groundwater level
Groundwater head outside landfill	Head_outLF	8.5	maOD	Minimum rest groundwater level interpolated from adjacent groundwater boreholes

CONTAMINANT PARAMETERS				
Contaminant name	Cont_Nme	Sulphate	-	
Contaminant type	Cont_Type	Inorganic	-	
Contaminant classification	Cont_Class	List II	-	
Concentration in landfill leachate	Conc_LF	2141	mg/l	Source term value
Free water diffusion coefficient	Dw_cl	0.000000005	m2/s	Default value
Partition coefficient in clay	Kd_cl	0	l/kg	Conservative tracer
Half life in clay (0 for no decay)	thalf_cl	0	days	
Decay in sorbed phase?	Decay_sorb	No	-	

MINERAL BARRIER / LINER				
Thickness of mineral liner	thick_clbr	1	m	Design spec
Hydraulic conductivity	k_cl	0.000000001	m/s	Design spec
Average pore radius	pore_radius	0.00001	m	Default value
Effective porosity	n	0.162	-	Default value
Dry bulk density	rho	1750	kg/m3	Typical clay values
Tortuosity	tau_cl	5	-	Default value

STEADY STATE DILUTION				
Hydraulic gradient in the aquifer	aq_I	0.004	-	Calculated from GW levels
Hydraulic conductivity of the aquifer	k_aq	0.00001	m/s	Expected for Sand and Gravel Aquifer
Downgradient distance of compliance point from landfill	dist_cp	100	m	
Dilution flow in aquifer downstream to the landfill	aq_Q	0.000021	m3/s	

Contaminant Fluxes from Hydraulic Containment Landfills Worksheet Version 1.0

ENVIRONMENT AGENCY

Produced under Science Group: Air, Land & Water Project SC0310

Statement of Use

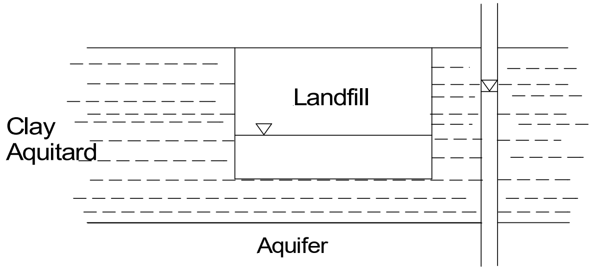
This worksheet has been prepared to help assessors quantify the contaminant flux from a hydraulic containment landfill constructed to the specifications in the Landfill Regulations (2002). It has been prepared to allow Agency staff to assess third party calculations of the diffusive contaminant flux from hydraulic containment landfills.

Data needs to be entered only in YELLOW cells. Assessors have to specify a preferred option from a pull-down menu in BLUE cells, interim calculation results are presented in GREY cells and final results in GREEN cells.
Only data in YELLOW or BLUE cells may be changed.

Site name
Whisby IBA Cells 1-4
Assessor's name
Alice Daly
Date
5th July 2023

SELECT LANDFILL CONSTRUCTION SCENARIO

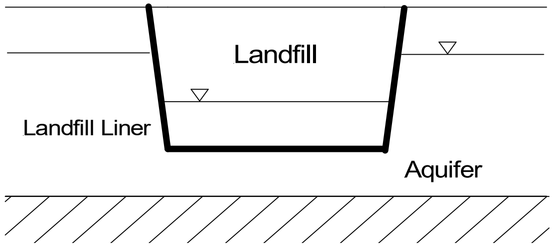
Scenario 1



The landfill is constructed in a clay pit, underlain by a confined aquifer. Water and contaminant fluxes occur across the bottom of the landfill only.

○ Select Scenario 1

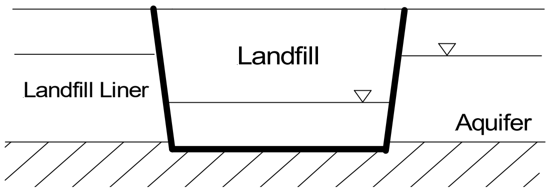
Scenario 2



The landfill is lined and located in a permeable formation a finite distance above an impermeable layer. The water and contaminant fluxes can occur through the base and sides of the landfill.

○ Select Scenario 2

Scenario 3



The landfill is lined and located in a permeable formation a finite distance below an impermeable layer. The water and contaminant fluxes can occur through the sides of the landfill only.

◉ Select Scenario 3

Whisby IBA Cells 1-4 5th July 2023

CONCEPTUAL MODEL AND LANDFILL CONSTRUCTION

Conceptual model of landfill construction	CM	3	-
Is a geomembrane present?	GM_opt	No	-
Basal width perpendicular to groundwater flow	Width_LF	210	m
Basal length parallel to groundwater flow	Length_LF	280	m
Basal area	Base_Area	58800	m2
Elevation of base of landfill	LFbase_elev	3	maOD
Elevation of base of aquifer	Aqbound_elev	6	maOD
Leachate head inside landfill	Head_inLF	7.5	maOD
Groundwater head outside landfill	Head_outLF	8.5	maOD
Area of liner below the water table	Area_contact	1470	m2

CONTAMINANT PARAMETERS

Contaminant name	Cont_Nme	Copper	-
Contaminant type	Cont_Type	Inorganic	-
Contaminant classification	Cont_Class	List II	-
Concentration in landfill leachate	Conc_LF	1.7	mg/l
Free water diffusion coefficient	Dw_cl	5.00E-09	m2/s
Partition coefficient in clay	Kd_cl	100	l/kg
Retardation factor in clay	R_cl	1081.246914	-
Half life in clay (0 for no decay)	thalf_cl		days
Decay in sorbed phase?	Decay_sorb	No	-
Decay constant in clay	Decay_cl	0	1/s

MINERAL BARRIER / LINER

Thickness of mineral liner	thick_clbr	1	m
Hydraulic conductivity	k_cl	1.00E-09	m/s
Average pore radius	pore_radius	1.00E-05	m
Effective porosity	n	0.162	-
Dry bulk density	rho	1750	kg/m3
Tortuosity	tau_cl	5	-

Copper

STEADY STATE DILUTION

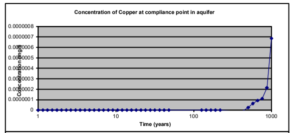
Hydraulic gradient in the aquifer	aq_I	0.004	-
Hydraulic conductivity of the aquifer	k_aq	1.00E-05	m/s
Downgradient distance of compliance point from landfill	dist_cp	100	m
Mixing width	Mix_W	210	m
Mixing depth	Mix_D	2.5	m
Dilution flow in aquifer downstream to the landfill	aq_Q	0.000021	m3/s

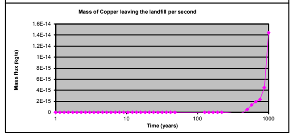
CONTAMINANT AND WATER FLUXES

Groundwater flux into landfill		0.00000294	m3/s
Maximum contaminant concentration at compliance point at tmax	C_comp	6.86205E-07	mg/l

CHART PARAMETERS

Minimum axis display	tmin	1	years
Maximum axis display	tmax	1.00E+03	years





Concentration o Mass of Copper leaving the landfill per second

Time years	Concentration	Mass flux (kg/s)
1	-4.91253E-70	-1.03163E-77
1.148153621	-1.34599E-65	-2.82657E-73
1.318256739	-1.85543E-61	-3.8964E-69
1.513561248	-1.34716E-57	-2.82904E-65
1.737800829	-5.377E-54	-1.12917E-61
1.995262315	-1.22784E-50	-2.57845E-58
2.290867653	-1.66493E-47	-3.49635E-55
2.630267992	-1.38804E-44	-2.91489E-52
3.01995172	-7.34935E-42	-1.54336E-49
3.467368505	-2.5473E-39	-5.34933E-47
3.981071706	-5.94517E-37	-1.24848E-44
4.570881896	-9.59289E-35	-2.01451E-42
5.248074602	-1.09678E-32	-2.30324E-40
6.025595861	-9.09165E-31	-1.90925E-38
6.918309709	-5.58241E-29	-1.17231E-36
7.943282347	-2.59023E-27	-5.43948E-35
9.120108394	-9.25316E-26	-1.94316E-33
10.47128548	-2.58962E-24	-5.43821E-32
12.02264435	-5.77071E-23	-1.21185E-30
13.80384265	-1.03954E-21	-2.18304E-29
15.84893192	-1.53536E-20	-3.22425E-28
18.19700859	-1.88378E-19	-3.95594E-27
20.89296131	-1.94352E-18	-4.08138E-26
23.98832919	-1.70504E-17	-3.58057E-25
27.54228703	-1.2848E-16	-2.69807E-24
31.6227766	-8.38843E-16	-1.76157E-23
36.30780548	-4.77882E-15	-1.00355E-22
41.68693835	-2.38674E-14	-5.01216E-22
47.86300923	-1.04671E-13	-2.1981E-21
54.95408739	-4.01948E-13	-8.44091E-21
63.09573445	-1.33892E-12	-2.81174E-20
72.44359601	-3.78966E-12	-7.95828E-20
83.17637711	-8.70924E-12	-1.82894E-19
95.4992586	-1.43403E-11	-3.01146E-19
109.6478196	-7.66577E-12	-1.60981E-19
125.8925412	5.04826E-11	1.06013E-18
144.5439771	2.30893E-10	4.84876E-18
165.9586907	5.82754E-10	1.22378E-17
190.5460718	9.56489E-10	2.00863E-17
218.7761624	7.34459E-10	1.54236E-17
251.1886432	-1.21449E-09	-2.55042E-17
288.4031503	-5.75368E-09	-1.20827E-16
331.1311215	-1.15708E-08	-2.42986E-16
380.1893963	-1.32704E-08	-2.78679E-16
436.5158322	-2.43171E-09	-5.10659E-17
501.1872336	2.58201E-08	5.42221E-16
575.4399373	6.37347E-08	1.33843E-15
660.693448	9.21286E-08	1.9347E-15
758.577575	1.11197E-07	2.33513E-15
870.96359	2.13357E-07	4.4805E-15
1000	6.86205E-07	1.44103E-14

Yes	Inorganic	Good cont	Yes	**s_per_year**
	List I			**s_per_day**
	List II			86400
				tlarge
				1.00E+40
				tscale
				1.148154

CALCULATIONS START HERE...

Type of solution to use (determines flows and areas to use)	Solution_type	a	
Coefficient of mechanical dispersion	D_mech	0	-
Longitudinal mechanical dispersion in the clay	Dl_cl	0	m2/s

Calculated concentrations and hydraulic conductivities

Concentration at top of clay barrier	Conc_def	1.7	mg/l

1.26478E-08

2.29247E-12

1.23686E-08

5.83209E-12

Fluxes into the landfill

Inward Darcy flow in absence of geomembrane	Q_darcy	0.00000147	m3/s
Inward flux into the landfill	Q	0.00000147	m3/s

Velocities

Velocity through the clay	vel_cl	-6.17284E-09	m/s
Maximum velocity through centre of a pore in mineral liner	umax	-1.5E-09	m/s

Summary of parameters for mass calculations

Leachate concentration	C_LF	1.7	mg/l
Concentration at edge of barrier	C_bar	6.86205E-07	mg/l
Diffusion coefficient	D_used	1E-09	m2/s
Distance	x_used	1	m
Outward flux area	Area_flux	1470	m2
Inward flow area	Area_flow	1470	m2

WARNING: Concentrations at the compliance point are predicted to exceed 10% of the leachate concentration. The boundary conditions used are only valid for low concentrations, and results may be unreliable above 10% of the leachate concentration.
WARNING: This spreadsheet has expired! Please contact the Environment Agency for an updated version.

Area_delam_check	1
Area_defect_check	1
Aquifer base check	3
Head base check	4.5
Head out base check	5.5
Head check	1
CM3 check	1
Area check	1
elev check	9

WARNING: The delaminated area should be less than or equal to the area of the landfill!
WARNING: The base of the landfill should be higher than the base of the aquifer!
WARNING: The leachate head should be higher than the base of the landfill!
WARNING: The groundwater head should be higher than the base of the landfill!
WARNING: The leachate head should be lower than the groundwater head!
WARNING: The base of the landfill should be lower than the top of the aquifer!
WARNING: The leachate head should be greater than the elevation of the base of the aquifer
WARNING: The area over which the geomembrane is delaminated must be greater than zero and not greater than the area of the liner below the water table.
WARNING: The dimensions of the defects should not be set to zero! Set the density of the required defect to zero to indicate the defect is not present.

Whisby IBA Cells 1-4		**5th July 2023**		
Alice Daly				

CONCEPTUAL MODEL AND LANDFILL CONSTRUCTION | **Justification / Reference / Notes**

				Justification / Reference / Notes
Scenario		3		
Is a geomembrane present?		No		
Basal width perpendicular to groundwater flow	Width_LF	210	m	Width of IBA Cells 1-4
Basal length parallel to groundwater flow	Length_LF	280	m	Length of IBA Cells 1-4
Elevation of base of landfill	LFbase_elev	3	maOD	Construction/design
Elevation of base of aquifer	Aqbound_elev	6	maOD	Base of Sand and Gravel Aquifer
Leachate head inside landfill	Head_inLF	7.5	maOD	1m below minimum rest groundwater level
Groundwater head outside landfill	Head_outLF	8.5	maOD	Minimum rest groundwater level interpolated from adjacent groundwater boreholes

CONTAMINANT PARAMETERS

				Justification / Reference / Notes
Contaminant name	Cont_Nme	Copper	-	
Contaminant type	Cont_Type	Inorganic	-	
Contaminant classification	Cont_Class	List II	-	
Concentration in landfill leachate	Conc_LF	1.7	mg/l	Source term value
Free water diffusion coefficient	Dw_cl	0.000000005	m2/s	Default value
Partition coefficient in clay	Kd_cl	100	l/kg	Conservative tracer
Half life in clay (0 for no decay)	thalf_cl	0	days	
Decay in sorbed phase?	Decay_sorb	No	-	

MINERAL BARRIER / LINER

				Justification / Reference / Notes
Thickness of mineral liner	thick_clbr	1	m	Design spec
Hydraulic conductivity	k_cl	0.000000001	m/s	Design spec
Average pore radius	pore_radius	0.00001	m	Default value
Effective porosity	n	0.162	-	Default value
Dry bulk density	rho	1750	kg/m3	Typical clay values
Tortuosity	tau_cl	5	-	Default value

STEADY STATE DILUTION

				Justification / Reference / Notes
Hydraulic gradient in the aquifer	aq_I	0.004	-	Calculated from GW levels
Hydraulic conductivity of the aquifer	k_aq	0.00001	m/s	Expected for Sand and Gravel Aquifer
Downgradient distance of compliance point from landfill	dist_cp	100	m	
Dilution flow in aquifer downstream to the landfill	aq_Q	0.000021	m3/s	

Contaminant Fluxes from Hydraulic Containment Landfills Worksheet Version 1.0

ENVIRONMENT AGENCY

Produced under Science Group: Air, Land & Water Project SC0310

Statement of Use

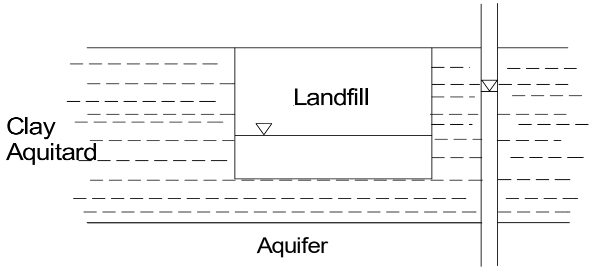
This worksheet has been prepared to help assessors quantify the contaminant flux from a hydraulic containment landfill constructed to the specifications in the Landfill Regulations (2002). It has been prepared to allow Agency staff to assess third party calculations of the diffusive contaminant flux from hydraulic containment landfills.

Data needs to be entered only in YELLOW cells. Assessors have to specify a preferred option from a pull-down menu in BLUE cells, interim calculation results are presented in GREY cells and final results in GREEN cells.
Only data in YELLOW or BLUE cells may be changed.

Site name
Whisby IBA Cells 1-4
Assessor's name
Alice Daly
Date
5th July 2023

SELECT LANDFILL CONSTRUCTION SCENARIO

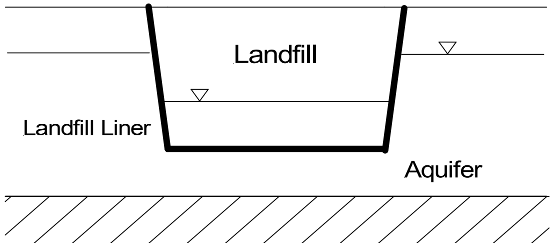
Scenario 1



The landfill is constructed in a clay pit, underlain by a confined aquifer. Water and contaminant fluxes occur across the bottom of the landfill only.

○ Select Scenario 1

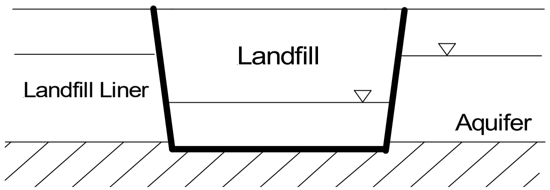
Scenario 2



The landfill is lined and located in a permeable formation a finite distance above an impermeable layer. The water and contaminant fluxes can occur through the base and sides of the landfill.

○ Select Scenario 2

Scenario 3



The landfill is lined and located in a permeable formation a finite distance below an impermeable layer. The water and contaminant fluxes can occur through the sides of the landfill only.

◉ Select Scenario 3

Whisby IBA Cells 1-4		5th July 2023	

CONCEPTUAL MODEL AND LANDFILL CONSTRUCTION

Conceptual model of landfill construction	CM	3	-
Is a geomembrane present?	GM_opt	No	-
Basal width perpendicular to groundwater flow	Width_LF	210	m
Basal length parallel to groundwater flow	Length_LF	280	m
Basal area	Base_Area	58800	m2
Elevation of base of landfill	LFbase_elev	3	maOD
Elevation of base of aquifer	Aqbound_elev	6	maOD
Leachate head inside landfill	Head_inLF	7.5	maOD
Groundwater head outside landfill	Head_outLF	8.5	maOD
Area of liner below the water table	Area_contact	1470	m2

CONTAMINANT PARAMETERS

Contaminant name	Cont_Nme	Lead	-
Contaminant type	Cont_Type	Inorganic	-
Contaminant classification	Cont_Class	List II	-
Concentration in landfill leachate	Conc_LF	5	mg/l
Free water diffusion coefficient	Dw_cl	5.00E-09	m2/s
Partition coefficient in clay	Kd_cl	27	l/kg
Retardation factor in clay	R_cl	292.6666667	-
Half life in clay (0 for no decay)	thalf_cl		days
Decay in sorbed phase?	Decay_sorb	No	-
Decay constant in clay	Decay_cl	0	1/s

MINERAL BARRIER / LINER

Thickness of mineral liner	thick_clbr	1	m
Hydraulic conductivity	k_cl	1.00E-09	m/s
Average pore radius	pore_radius	1.00E-05	m
Effective porosity	n	0.162	-
Dry bulk density	rho	1750	kg/m3
Tortuosity	tau_cl	5	-

Lead

STEADY STATE DILUTION

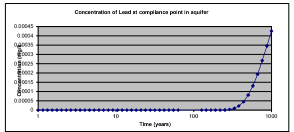
Hydraulic gradient in the aquifer	aq_I	0.004	-
Hydraulic conductivity of the aquifer	k_aq	1.00E-05	m/s
Downgradient distance of compliance point from landfill	dist_cp	100	m
Mixing width	Mix_W	210	m
Mixing depth	Mix_D	2.5	m
Dilution flow in aquifer downstream to the landfill	aq_Q	0.000021	m3/s

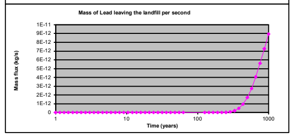
CONTAMINANT AND WATER FLUXES

Groundwater flux into landfill		0.00000294	m3/s
Maximum contaminant concentration at compliance point at tmax	C_comp	0.000425565	mg/l

CHART PARAMETERS

Minimum axis display	tmin	1	years
Maximum axis display	tmax	1.00E+03	years





Concentration Mass of Lead leaving the landfill per second

Time years	Concentration	Mass flux (kg/s)
1	-9.60784E-38	-2.01765E-45
1.148153621	-1.88681E-35	-3.9623E-43
1.318256739	-2.59136E-33	-5.44186E-41
1.513561248	-2.54904E-31	-5.35298E-39
1.737800829	-1.83624E-29	-3.85611E-37
1.995262315	-9.8901E-28	-2.07692E-35
2.290867653	-4.06066E-26	-8.52739E-34
2.630267992	-1.29409E-24	-2.71759E-32
3.01995172	-3.25557E-23	-6.83669E-31
3.467368505	-6.56765E-22	-1.37921E-29
3.981071706	-1.07816E-20	-2.26414E-28
4.570881896	-1.4601E-19	-3.06621E-27
5.248074602	-1.65201E-18	-3.46922E-26
6.025595861	-1.58002E-17	-3.31804E-25
6.918309709	-1.29113E-16	-2.71138E-24
7.943282347	-9.10026E-16	-1.91106E-23
9.120108394	-5.57683E-15	-1.17114E-22
10.47128548	-2.98951E-14	-6.27796E-22
12.02264435	-1.4066E-13	-2.95386E-21
13.80384265	-5.80766E-13	-1.21961E-20
15.84893192	-2.09276E-12	-4.39479E-20
18.19700859	-6.49187E-12	-1.36329E-19
20.89296131	-1.68354E-11	-3.53542E-19
23.98832919	-3.40622E-11	-7.15305E-19
27.54228703	-4.22827E-11	-8.87937E-19
31.6227766	2.63214E-11	5.52748E-19
36.30780548	3.33432E-10	7.00207E-18
41.68693835	1.09586E-09	2.3013E-17
47.86300923	2.27999E-09	4.78799E-17
54.95408739	2.90659E-09	6.10383E-17
63.09573445	3.80154E-10	7.98323E-18
72.44359601	-8.76047E-09	-1.8397E-16
83.17637711	-2.49589E-08	-5.24136E-16
95.4992586	-3.92567E-08	-8.24391E-16
109.6478196	-3.04066E-08	-6.38539E-16
125.8925412	2.49213E-08	5.23348E-16
144.5439771	1.26722E-07	2.66115E-15
165.9586907	2.32408E-07	4.88057E-15
190.5460718	2.93267E-07	6.15861E-15
218.7761624	4.00569E-07	8.41194E-15
251.1886432	1.05058E-06	2.20622E-14
288.4031503	3.45001E-06	7.24503E-14
331.1311215	9.70082E-06	2.03717E-13
380.1893963	2.26899E-05	4.76488E-13
436.5158322	4.55991E-05	9.57581E-13
501.1872336	8.11134E-05	1.70338E-12
575.4399373	0.000130564	2.74183E-12
660.693448	0.000193301	4.05933E-12
758.577575	0.000266547	5.59748E-12
870.96359	0.00034578	7.26138E-12
1000	0.000425565	8.93686E-12

Yes	Inorganic	Good cont	Yes	**s_per_year**
	List I			**s_per_day**
	List II			86400
				tlarge
				1.00E+40
				tscale
				1.148154

CALCULATIONS START HERE...

Type of solution to use (determines flows and areas to use)	Solution_type	a	
Coefficient of mechanical dispersion	D_mech	0	-
Longitudinal mechanical dispersion in the clay	Dl_cl	0	m2/s

Calculated concentrations and hydraulic conductivities

Concentration at top of clay barrier	Conc_def	5	mg/l
		1.26478E-08	
		2.29247E-12	
		1.23686E-08	
		5.83209E-12	

Fluxes into the landfill

Inward Darcy flow in absence of geomembrane	Q_darcy	0.00000147	m3/s
Inward flux into the landfill	Q	0.00000147	m3/s

Velocities

Velocity through the clay	vel_cl	-6.17284E-09	m/s
Maximum velocity through centre of a pore in mineral liner	umax	-1.5E-09	m/s

Summary of parameters for mass calculations

Leachate concentration	C_LF	5	mg/l
Concentration at edge of barrier	C_bar	0.000425565	mg/l
Diffusion coefficient	D_used	1E-09	m2/s
Distance	x_used	1	m
Outward flux area	Area_flux	1470	m2
Inward flow area	Area_flow	1470	m2

WARNING: Concentrations at the compliance point are predicted to exceed 10% of the leachate concentration. The boundary conditions used are only valid for low concentrations, and results may be unreliable above 10% of the leachate concentration.
WARNING: This spreadsheet has expired! Please contact the Environment Agency for an updated version.

Area_delam_check	1
Area_defect_check	1
Aquifer base check	3
Head base check	4.5
Head out base check	5.5
Head check	1
CM3 check	1
Area check	1
elev check	9

WARNING: The delaminated area should be less than or equal to the area of the landfill!
WARNING: The base of the landfill should be higher than the base of the aquifer!
WARNING: The leachate head should be higher than the base of the landfill!
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WARNING: The dimensions of the defects should not be set to zero! Set the density of the required defect to zero to indicate the defect is not present.

Whisby IBA Cells 1-4 **5th July 2023**
Alice Daly

CONCEPTUAL MODEL AND LANDFILL CONSTRUCTION				Justification / Reference / Notes
Scenario		3		
Is a geomembrane present?		No		
Basal width perpendicular to groundwater flow	Width_LF	210	m	Width of IBA Cells 1-4
Basal length parallel to groundwater flow	Length_LF	280	m	Length of IBA Cells 1-4
Elevation of base of landfill	LFbase_elev	3	maOD	Construction/design
Elevation of base of aquifer	Aqbound_elev	6	maOD	Base of Sand and Gravel Aquifer
Leachate head inside landfill	Head_inLF	7.5	maOD	1m below minimum rest groundwater level
Groundwater head outside landfill	Head_outLF	8.5	maOD	Minimum rest groundwater level interpolated from adjacent groundwater boreholes

CONTAMINANT PARAMETERS				
Contaminant name	Cont_Nme	Lead	-	
Contaminant type	Cont_Type	Inorganic	-	
Contaminant classification	Cont_Class	List II	-	
Concentration in landfill leachate	Conc_LF	5	mg/l	Source term value
Free water diffusion coefficient	Dw_cl	0.000000005	m2/s	Default value
Partition coefficient in clay	Kd_cl	27	l/kg	LandSim default minimum value
Half life in clay (0 for no decay)	thalf_cl	0	days	
Decay in sorbed phase?	Decay_sorb	No	-	

MINERAL BARRIER / LINER				
Thickness of mineral liner	thick_clbr	1	m	Design spec
Hydraulic conductivity	k_cl	0.000000001	m/s	Design spec
Average pore radius	pore_radius	0.00001	m	Default value
Effective porosity	n	0.162	-	Default value
Dry bulk density	rho	1750	kg/m3	Typical clay values
Tortuosity	tau_cl	5	-	Default value

STEADY STATE DILUTION				
Hydraulic gradient in the aquifer	aq_I	0.004	-	Calculated from GW levels
Hydraulic conductivity of the aquifer	k_aq	0.00001	m/s	Expected for Sand and Gravel Aquifer
Downgradient distance of compliance point from landfill	dist_cp	100	m	
Dilution flow in aquifer downstream to the landfill	aq_Q	0.000021	m3/s	

Contaminant Fluxes from Hydraulic Containment Landfills Worksheet Version 1.0

ENVIRONMENT AGENCY

Produced under Science Group: Air, Land & Water Project SC0310

Statement of Use

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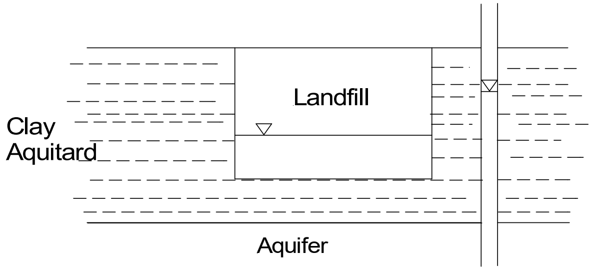
Site name
Whisby IBA Cells 1-4
Assessor's name
Alice Daly
Date
5th July 2023

SELECT LANDFILL CONSTRUCTION SCENARIO

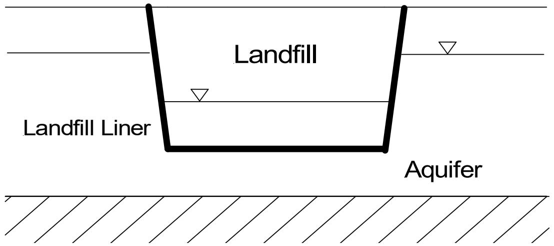
Scenario 1



The landfill is constructed in a clay pit, underlain by a confined aquifer. Water and contaminant fluxes occur across the bottom of the landfill only.

○ Select Scenario 1

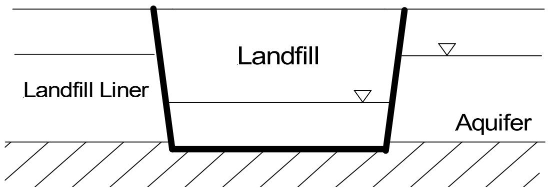
Scenario 2



The landfill is lined and located in a permeable formation a finite distance above an impermeable layer. The water and contaminant fluxes can occur through the base and sides of the landfill.

○ Select Scenario 2

Scenario 3



The landfill is lined and located in a permeable formation a finite distance below an impermeable layer. The water and contaminant fluxes can occur through the sides of the landfill only.

◉ Select Scenario 3

Whisby IBA Cells 1-4 — 5th July 2023

CONCEPTUAL MODEL AND LANDFILL CONSTRUCTION

Conceptual model of landfill construction	CM	3	-
Is a geomembrane present?	GM_opt	No	-
Basal width perpendicular to groundwater flow	Width_LF	210	m
Basal length parallel to groundwater flow	Length_LF	280	m
Basal area	Base_Area	58800	m2
Elevation of base of landfill	LFbase_elev	3	maOD
Elevation of base of aquifer	Aqbound_elev	6	maOD
Leachate head inside landfill	Head_inLF	7.5	maOD
Groundwater head outside landfill	Head_outLF	8.5	maOD
Area of liner below the water table	Area_contact	1470	m2

CONTAMINANT PARAMETERS

Contaminant name	Cont_Nme	Zinc	-
Contaminant type	Cont_Type	Inorganic	-
Contaminant classification	Cont_Class	List II	-
Concentration in landfill leachate	Conc_LF	1.3	mg/l
Free water diffusion coefficient	Dw_cl	5.00E-09	m2/s
Partition coefficient in clay	Kd_cl	38	l/kg
Retardation factor in clay	R_cl	411.4938272	-
Half life in clay (0 for no decay)	thalf_cl		days
Decay in sorbed phase?	Decay_sorb	No	-
Decay constant in clay	Decay_cl	0	1/s

MINERAL BARRIER / LINER

Thickness of mineral liner	thick_clbr	1	m
Hydraulic conductivity	k_cl	1.00E-09	m/s
Average pore radius	pore_radius	1.00E-05	m
Effective porosity	n	0.162	-
Dry bulk density	rho	1750	kg/m3
Tortuosity	tau_cl	5	-

Zinc

STEADY STATE DILUTION

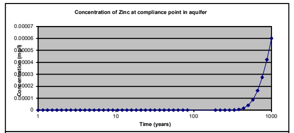
Hydraulic gradient in the aquifer	aq_I	0.004	-
Hydraulic conductivity of the aquifer	k_aq	1.00E-05	m/s
Downgradient distance of compliance point from landfill	dist_cp	100	m
Mixing width	Mix_W	210	m
Mixing depth	Mix_D	2.5	m
Dilution flow in aquifer downstream to the landfill	aq_Q	0.000021	m3/s

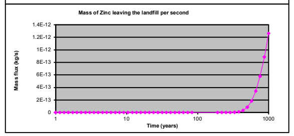
CONTAMINANT AND WATER FLUXES

Groundwater flux into landfill		0.00000294	m3/s
Maximum contaminant concentration at compliance point at tmax	C_comp	6.01446E-05	mg/l

CHART PARAMETERS

Minimum axis display	tmin	1	years
Maximum axis display	tmax	1.00E+03	years





Concentration of Zinc / Mass of Zinc leaving the landfill per second

Time years	Concentration	Mass flux (kg/s)
1	-1.01224E-44	-2.12571E-52
1.148153621	-5.37678E-42	-1.12912E-49
1.318256739	-1.86918E-39	-3.92529E-47
1.513561248	-4.3747E-37	-9.18688E-45
1.737800829	-7.07727E-35	-1.48623E-42
1.995262315	-8.11133E-33	-1.70338E-40
2.290867653	-6.73909E-31	-1.41521E-38
2.630267992	-4.14668E-29	-8.70803E-37
3.01995172	-1.92786E-27	-4.04851E-35
3.467368505	-6.8997E-26	-1.44894E-33
3.981071706	-1.93431E-24	-4.06204E-32
4.570881896	-4.31734E-23	-9.0664E-31
5.248074602	-7.78901E-22	-1.63569E-29
6.025595861	-1.15201E-20	-2.41923E-28
6.918309709	-1.4153E-19	-2.97212E-27
7.943282347	-1.46197E-18	-3.07013E-26
9.120108394	-1.28405E-17	-2.6965E-25
10.47128548	-9.68611E-17	-2.03408E-24
12.02264435	-6.33051E-16	-1.32941E-23
13.80384265	-3.60996E-15	-7.58091E-23
15.84893192	-1.80468E-14	-3.78983E-22
18.19700859	-7.92204E-14	-1.66363E-21
20.89296131	-3.04517E-13	-6.39485E-21
23.98832919	-1.01548E-12	-2.13252E-20
27.54228703	-2.87797E-12	-6.04373E-20
31.6227766	-6.62599E-12	-1.39146E-19
36.30780548	-1.09476E-11	-2.29899E-19
41.68693835	-5.98929E-12	-1.25775E-19
47.86300923	3.80154E-11	7.98323E-19
54.95408739	1.75082E-10	3.67673E-18
63.09573445	4.43302E-10	9.30933E-18
72.44359601	7.30141E-10	1.5333E-17
83.17637711	5.66491E-10	1.18963E-17
95.4992586	-9.10885E-10	-1.91286E-17
109.6478196	-4.36807E-09	-9.17295E-17
125.8925412	-8.82004E-09	-1.85221E-16
144.5439771	-1.01653E-08	-2.13471E-16
165.9586907	-1.96827E-09	-4.13337E-17
190.5460718	1.95454E-08	4.10453E-16
218.7761624	4.85345E-08	1.01922E-15
251.1886432	7.0344E-08	1.47722E-15
288.4031503	8.4852E-08	1.78189E-15
331.1311215	1.61944E-07	3.40082E-15
380.1893963	5.20167E-07	1.09235E-14
436.5158322	1.59543E-06	3.35041E-14
501.1872336	4.05292E-06	8.51113E-14
575.4399373	8.70599E-06	1.82826E-13
660.693448	1.63415E-05	3.43171E-13
758.577575	2.74954E-05	5.77403E-13
870.96359	4.22526E-05	8.87304E-13
1000	6.01446E-05	1.26304E-12

Yes	Inorganic	Good cont	Yes	s_per_year
	List I			s_per_day
	List II			86400
				tlarge
				1.00E+40
				tscale
				1.148154

CALCULATIONS START HERE...

Type of solution to use (determines flows and areas to use)	Solution_type	a	
Coefficient of mechanical dispersion	D_mech	0	-
Longitudinal mechanical dispersion in the clay	Dl_cl	0	m2/s

Calculated concentrations and hydraulic conductivities

Concentration at top of clay barrier	Conc_def	1.3	mg/l
		1.26478E-08	
		2.29247E-12	
		1.23686E-08	
		5.83209E-12	

Fluxes into the landfill

Inward Darcy flow in absence of geomembrane	Q_darcy	0.00000147	m3/s
Inward flux into the landfill	Q	0.00000147	m3/s

Velocities

Velocity through the clay	vel_cl	-6.17284E-09	m/s
Maximum velocity through centre of a pore in mineral liner	umax	-1.5E-09	m/s

Summary of parameters for mass calculations

Leachate concentration	C_LF	1.3	mg/l
Concentration at edge of barrier	C_bar	6.01446E-05	mg/l
Diffusion coefficient	D_used	1E-09	m2/s
Distance	x_used	1	m
Outward flux area	Area_flux	1470	m2
Inward flow area	Area_flow	1470	m2

WARNING: Concentrations at the compliance point are predicted to exceed 10% of the leachate concentration. The boundary conditions used are only valid for low concentrations, and results may be unreliable above 10% of the leachate concentration.
WARNING: This spreadsheet has expired! Please contact the Environment Agency for an updated version.

Area_delam_check	1
Area_defect_check	1
Aquifer base check	3
Head base check	4.5
Head out base check	5.5
Head check	1
CM3 check	1
Area check	1
elev check	9

WARNING: The delaminated area should be less than or equal to the area of the landfill!
WARNING: The base of the landfill should be higher than the base of the aquifer!
WARNING: The leachate head should be higher than the base of the landfill!
WARNING: The groundwater head should be higher than the base of the landfill!
WARNING: The leachate head should be lower than the groundwater head!
WARNING: The base of the landfill should be lower than the top of the aquifer!
WARNING: The leachate head should be greater than the elevation of the base of the aquifer
WARNING: The area over which the geomembrane is delaminated must be greater than zero and not greater than the area of the liner below the water table.
WARNING: The dimensions of the defects should not be set to zero! Set the density of the required defect to zero to indicate the defect is not present.

Whisby IBA Cells 1-4 **5th July 2023**
Alice Daly

CONCEPTUAL MODEL AND LANDFILL CONSTRUCTION				Justification / Reference / Notes
Scenario		3		
Is a geomembrane present?		No		
Basal width perpendicular to groundwater flow	Width_LF	210	m	Width of IBA Cells 1-4
Basal length parallel to groundwater flow	Length_LF	280	m	Length of IBA Cells 1-4
Elevation of base of landfill	LFbase_elev	3	maOD	Construction/design
Elevation of base of aquifer	Aqbound_elev	6	maOD	Base of Sand and Gravel Aquifer
Leachate head inside landfill	Head_inLF	7.5	maOD	1m below minimum rest groundwater level
Groundwater head outside landfill	Head_outLF	8.5	maOD	Minimum rest groundwater level interpolated from adjacent groundwater boreholes

CONTAMINANT PARAMETERS				
Contaminant name	Cont_Nme	Zinc	-	
Contaminant type	Cont_Type	Inorganic	-	
Contaminant classification	Cont_Class	List II	-	
Concentration in landfill leachate	Conc_LF	1.3	mg/l	Source term value
Free water diffusion coefficient	Dw_cl	0.000000005	m2/s	Default value
Partition coefficient in clay	Kd_cl	38	l/kg	LQM/CIEH
Half life in clay (0 for no decay)	thalf_cl	0	days	
Decay in sorbed phase?	Decay_sorb	No	-	

MINERAL BARRIER / LINER				
Thickness of mineral liner	thick_clbr	1	m	Design spec
Hydraulic conductivity	k_cl	0.000000001	m/s	Design spec
Average pore radius	pore_radius	0.00001	m	Default value
Effective porosity	n	0.162	-	Default value
Dry bulk density	rho	1750	kg/m3	Typical clay values
Tortuosity	tau_cl	5	-	Default value

STEADY STATE DILUTION				
Hydraulic gradient in the aquifer	aq_I	0.004	-	Calculated from GW levels
Hydraulic conductivity of the aquifer	k_aq	0.00001	m/s	Expected for Sand and Gravel Aquifer
Downgradient distance of compliance point from landfill	dist_cp	100	m	
Dilution flow in aquifer downstream to the landfill	aq_Q	0.000021	m3/s	

Contaminant Fluxes from Hydraulic Containment Landfills Worksheet Version 1.0

ENVIRONMENT AGENCY

Produced under Science Group: Air, Land & Water Project SC0310

Statement of Use

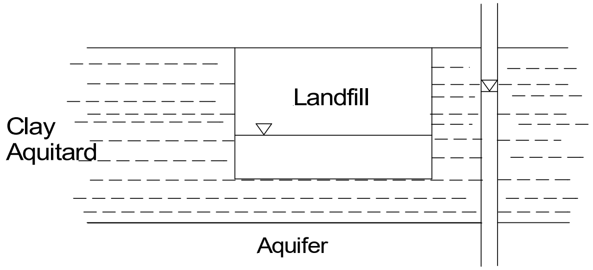
This worksheet has been prepared to help assessors quantify the contaminant flux from a hydraulic containment landfill constructed to the specifications in the Landfill Regulations (2002). It has been prepared to allow Agency staff to assess third party calculations of the diffusive contaminant flux from hydraulic containment landfills.

Data needs to be entered only in YELLOW cells. Assessors have to specify a preferred option from a pull-down menu in BLUE cells, interim calculation results are presented in GREY cells and final results in GREEN cells.
Only data in YELLOW or BLUE cells may be changed.

Site name
Whisby IBA Cells 1-4
Assessor's name
Alice Daly
Date
5th July 2023

SELECT LANDFILL CONSTRUCTION SCENARIO

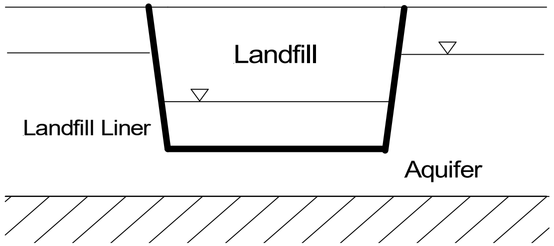
Scenario 1



The landfill is constructed in a clay pit, underlain by a confined aquifer.
Water and contaminant fluxes occur across the bottom of the landfill only.

○ Select Scenario 1

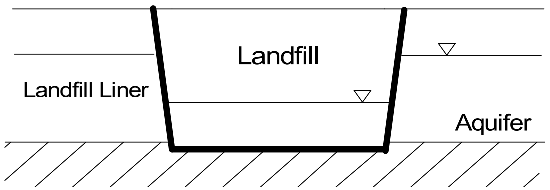
Scenario 2



The landfill is lined and located in a permeable formation a finite distance above an impermeable layer. The water and contaminant fluxes can occur through the base and sides of the landfill.

○ Select Scenario 2

Scenario 3



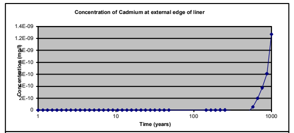
The landfill is lined and located in a permeable formation a finite distance below an impermeable layer. The water and contaminant fluxes can occur through the sides of the landfill only.

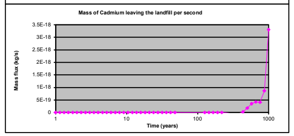
◉ Select Scenario 3

Whisby IBA Cells 1-4		5th July 2023	
CONCEPTUAL MODEL AND LANDFILL CONSTRUCTION			
Conceptual model of landfill construction	CM	3	-
Is a geomembrane present?	GM_opt	No	-
Basal width perpendicular to groundwater flow	Width_LF	210	m
Basal length parallel to groundwater flow	Length_LF	280	m
Basal area	Base_Area	58800	m2
Elevation of base of landfill	LFbase_elev	3	maOD
Elevation of base of aquifer	Aqbound_elev	6	maOD
Leachate head inside landfill	Head_inLF	7.5	maOD
Groundwater head outside landfill	Head_outLF	8.5	maOD
Area of liner below the water table	Area_contact	1470	m2
CONTAMINANT PARAMETERS			
Contaminant name	Cont_Nme	Cadmium	-
Contaminant type	Cont_Type	Inorganic	-
Contaminant classification	Cont_Class	List I	-
Concentration in landfill leachate	Conc_LF	0.001	mg/l
Free water diffusion coefficient	Dw_cl	5.00E-09	m2/s
Partition coefficient in clay	Kd_cl	100	l/kg
Retardation factor in clay	R_cl	1081.246914	-
Half life in clay (0 for no decay)	thalf_cl		days
Decay in sorbed phase?	Decay_sorb	No	-
Decay constant in clay	Decay_cl	0	1/s
MINERAL BARRIER / LINER			
Thickness of mineral liner	thick_clbr	1	m
Hydraulic conductivity	k_cl	1.00E-09	m/s
Average pore radius	pore_radius	1.00E-05	m
Effective porosity	n	0.162	-
Dry bulk density	rho	1750	kg/m3
Tortuosity	tau_cl	5	-

Cadmium

CONTAMINANT AND WATER FLUXES			
Groundwater flux into landfill		0.00000294	m3/s
Maximum contaminant concentration at compliance point at tmax	C_comp	1.27049E-09	mg/l
CHART PARAMETERS			
Minimum axis display	tmin	1	years
Maximum axis display	tmax	1.00E+03	years





Concentration of Cadmium at external edge of liner · Mass of Cadmium leaving the landfill per second

Time years	Concentration	Mass flux (kg/s)
1	-8.26331E-74	-2.97347E-81
1.148153621	-2.42592E-69	-8.13514E-77
1.318256739	-3.58316E-65	-1.11966E-72
1.513561248	-2.78756E-61	-8.11581E-69
1.737800829	-1.19213E-57	-3.23347E-65
1.995262315	-2.91677E-54	-7.36931E-62
2.290867653	-4.23772E-51	-9.97192E-59
2.630267992	-3.78539E-48	-8.29498E-56
3.01995172	-2.14745E-45	-4.38147E-53
3.467368505	-7.9747E-43	-1.51472E-50
3.981071706	-1.99413E-40	-3.52545E-48
4.570881896	-3.44737E-38	-5.67164E-46
5.248074602	-4.22279E-36	-6.46385E-44
6.025595861	-3.7502E-34	-5.33979E-42
6.918309709	-2.46693E-32	-3.26664E-40
7.943282347	-1.22626E-30	-1.50972E-38
9.120108394	-4.69282E-29	-5.37027E-37
10.47128548	-1.4069E-27	-1.49607E-35
12.02264435	-3.35832E-26	-3.31742E-34
13.80384265	-6.48014E-25	-5.94443E-33
15.84893192	-1.02513E-23	-8.72961E-32
18.19700859	-1.34715E-22	-1.06449E-30
20.89296131	-1.48864E-21	-1.09099E-29
23.98832919	-1.3989E-20	-9.50291E-29
27.54228703	-1.12941E-19	-7.10539E-28
31.6227766	-7.90544E-19	-4.60004E-27
36.30780548	-4.83441E-18	-2.59629E-26
41.68693835	-2.59804E-17	-1.28321E-25
47.86300923	-1.23125E-16	-5.56003E-25
54.95408739	-5.14745E-16	-2.10428E-24
63.09573445	-1.89079E-15	-6.8801E-24
72.44359601	-6.0389E-15	-1.89681E-23
83.17637711	-1.64098E-14	-4.17312E-23
95.4992586	-3.61934E-14	-6.19701E-23
109.6478196	-5.68036E-14	-5.5968E-24
125.8925412	-2.53981E-14	3.30472E-22
144.5439771	2.08174E-13	1.2731E-21
165.9586907	9.07197E-13	2.93257E-21
190.5460718	2.26027E-12	4.24643E-21
218.7761624	3.77793E-12	1.75959E-21
251.1886432	3.36713E-12	-9.97607E-21
288.4031503	-2.95404E-12	-3.33662E-20
331.1311215	-1.88217E-11	-5.76325E-20
380.1893963	-4.15866E-11	-5.13982E-20
436.5158322	-5.54057E-11	2.57038E-20
501.1872336	-3.16611E-11	1.82748E-19
575.4399373	5.48985E-11	3.53306E-19
660.693448	2.00517E-10	4.2165E-19
758.577575	3.73955E-10	4.11947E-19
870.96359	6.11556E-10	8.68298E-19
1000	1.27049E-09	3.30451E-18

Yes	Inorganic	Good cont	Yes	**s_per_year**
	List I			**s_per_day**
	List II			86400
				tlarge
				1.00E+40
				tscale
				1.148154

CALCULATIONS START HERE...			
Type of solution to use (determines flows and areas to use)	Solution_type	a	
Coefficient of mechanical dispersion	D_mech	0	-
Longitudinal mechanical dispersion in the clay	Dl_cl	0	m2/s
Calculated concentrations and hydraulic conductivities			
Concentration at top of clay barrier	Conc_def	0.001	mg/l
		1.26478E-08	
		2.29247E-12	
		1.23686E-08	
		5.83209E-12	
Fluxes into the landfill			
Inward Darcy flow in absence of geomembrane	Q_darcy	0.00000147	m3/s
Inward flux into the landfill	Q	0.00000147	m3/s
Velocities			
Velocity through the clay	vel_cl	-6.17284E-09	m/s
Maximum velocity through centre of a pore in mineral liner	umax	-1.5E-09	m/s

Summary of parameters for mass calculations			
Leachate concentration	C_LF	0.001	mg/l
Concentration at edge of barrier	C_bar	1.27049E-09	mg/l
Diffusion coefficient	D_used	1E-09	m2/s
Distance	x_used	1	m
Outward flux area	Area_flux	1470	m2
Inward flow area	Area_flow	1470	m2

WARNING: Concentrations at the compliance point are predicted to exceed 10% of the leachate concentration. The boundary conditions used are only valid for low concentrations, and results may be unreliable above 10% of the leachate concentration.
WARNING: This spreadsheet has expired! Please contact the Environment Agency for an updated version.

Area_delam_check	1
Area_defect_check	1
Aquifer base check	3
Head base check	4.5
Head out base check	5.5
Head check	1
CM3 check	1
Area check	1
elev check	9

WARNING: The delaminated area should be less than or equal to the area of the landfill!
WARNING: The base of the landfill should be higher than the base of the aquifer!
WARNING: The leachate head should be higher than the base of the landfill!
WARNING: The groundwater head should be higher than the base of the landfill!
WARNING: The leachate head should be lower than the groundwater head!
WARNING: The base of the landfill should be lower than the top of the aquifer!
WARNING: The leachate head should be greater than the elevation of the base of the aquifer
WARNING: The area over which the geomembrane is delaminated must be greater than zero and not greater than the area of the liner below the water table.
WARNING: The dimensions of the defects should not be set to zero! Set the density of the required defect to zero to indicate the defect is not present.

Whisby IBA Cells 1-4 **5th July 2023**
Alice Daly

CONCEPTUAL MODEL AND LANDFILL CONSTRUCTION				Justification / Reference / Notes
Scenario		3		
Is a geomembrane present?		No		
Basal width perpendicular to groundwater flow	Width_LF	210	m	Width of IBA Cells 1-4
Basal length parallel to groundwater flow	Length_LF	280	m	Length of IBA Cells 1-4
Elevation of base of landfill	LFbase_elev	3	maOD	Construction/design
Elevation of base of aquifer	Aqbound_elev	6	maOD	Base of Sand and Gravel Aquifer
Leachate head inside landfill	Head_inLF	7.5	maOD	1m below minimum rest groundwater level
Groundwater head outside landfill	Head_outLF	8.5	maOD	Minimum rest groundwater level interpolated from adjacent groundwater boreholes

CONTAMINANT PARAMETERS				
Contaminant name	Cont_Nme	Cadmium	-	
Contaminant type	Cont_Type	Inorganic	-	
Contaminant classification	Cont_Class	List I	-	
Concentration in landfill leachate	Conc_LF	0.001	mg/l	Source term value
Free water diffusion coefficient	Dw_cl	0.000000005	m2/s	Default value
Partition coefficient in clay	Kd_cl	100	l/kg	LQM/CIEH
Half life in clay (0 for no decay)	thalf_cl	0	days	
Decay in sorbed phase?	Decay_sorb	No	-	

MINERAL BARRIER / LINER				
Thickness of mineral liner	thick_clbr	1	m	Design spec
Hydraulic conductivity	k_cl	0.000000001	m/s	Design spec
Average pore radius	pore_radius	0.00001	m	Default value
Effective porosity	n	0.162	-	Default value
Dry bulk density	rho	1750	kg/m3	Typical clay values
Tortuosity	tau_cl	5	-	Default value

Contaminant Fluxes from Hydraulic Containment Landfills Worksheet Version 1.0

Produced under Science Group: Air, Land & Water Project SC0310

Statement of Use

This worksheet has been prepared to help assessors quantify the contaminant flux from a hydraulic containment landfill constructed to the specifications in the Landfill Regulations (2002). It has been prepared to allow Agency staff to assess third party calculations of the diffusive contaminant flux from hydraulic containment landfills.

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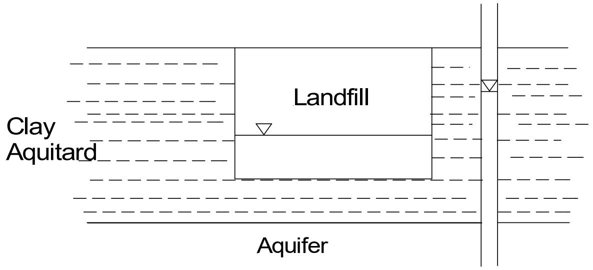
Site name
Whisby IBA Cells 1-4
Assessor's name
Alice Daly
Date
5th July 2023

SELECT LANDFILL CONSTRUCTION SCENARIO

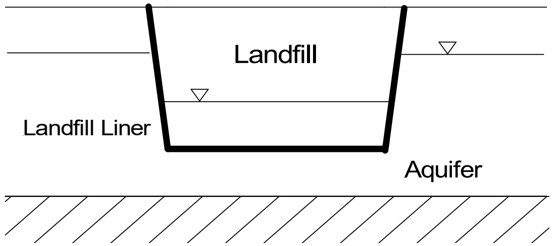
Scenario 1



The landfill is constructed in a clay pit, underlain by a confined aquifer.
Water and contaminant fluxes occur across the bottom of the landfill only.

○ Select Scenario 1

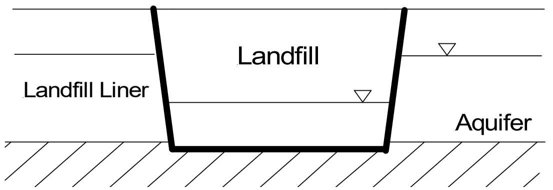
Scenario 2



The landfill is lined and located in a permeable formation a finite distance above an impermeable layer. The water and contaminant fluxes can occur through the base and sides of the landfill.

○ Select Scenario 2

Scenario 3



The landfill is lined and located in a permeable formation a finite distance below an impermeable layer. The water and contaminant fluxes can occur through the sides of the landfill only.

◉ Select Scenario 3

Whisby IBA Cells 1-4		5th July 2023	

CONCEPTUAL MODEL AND LANDFILL CONSTRUCTION

Conceptual model of landfill construction	CM	3	-
Is a geomembrane present?	GM_opt	No	-
Basal width perpendicular to groundwater flow	Width_LF	210	m
Basal length parallel to groundwater flow	Length_LF	280	m
Basal area	Base_Area	58800	m2
Elevation of base of landfill	LFbase_elev	3	maOD
Elevation of base of aquifer	Aqbound_elev	6	maOD
Leachate head inside landfill	Head_inLF	7.5	maOD
Groundwater head outside landfill	Head_outLF	8.5	maOD
Area of liner below the water table	Area_contact	1470	m2

CONTAMINANT PARAMETERS

Contaminant name	Cont_Nme	Chloride	-
Contaminant type	Cont_Type	Inorganic	-
Contaminant classification	Cont_Class	List II	-
Concentration in landfill leachate	Conc_LF	3657	mg/l
Free water diffusion coefficient	Dw_cl	5.00E-09	m2/s
Partition coefficient in clay	Kd_cl	0	l/kg
Retardation factor in clay	R_cl	1	-
Half life in clay (0 for no decay)	thalf_cl		days
Decay in sorbed phase?	Decay_sorb	No	-
Decay constant in clay	Decay_cl	0	1/s

MINERAL BARRIER / LINER

Thickness of mineral liner	thick_clbr	1	m
Hydraulic conductivity	k_cl	1.00E-09	m/s
Average pore radius	pore_radius	1.00E-05	m
Effective porosity	n	0.162	-
Dry bulk density	rho	1750	kg/m3
Tortuosity	tau_cl	5	-

Chloride

STEADY STATE DILUTION

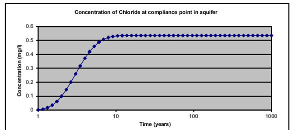
Hydraulic gradient in the aquifer	aq_I	0.004	-
Hydraulic conductivity of the aquifer	k_aq	1.00E-05	m/s
Downgradient distance of compliance point from landfill	dist_cp	100	m
Mixing width	Mix_W	210	m
Mixing depth	Mix_D	2.5	m
Dilution flow in aquifer downstream to the landfill	aq_Q	0.000021	m3/s

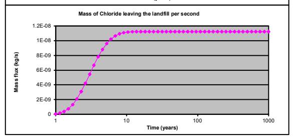
CONTAMINANT AND WATER FLUXES

Groundwater flux into landfill		0.00000294	m3/s
Maximum contaminant concentration at compliance point at tmax	C_comp	0.534970505	mg/l

CHART PARAMETERS

Minimum axis display	tmin	1	years
Maximum axis display	tmax	1.00E+03	years





Concentration c Mass of Chloride leaving the landfill per second

Time years	Concentration	Mass flux (kg/s)
1	0.002842271	5.96877E-11
1.148153621	0.007829671	1.64423E-10
1.318256739	0.017991152	3.77814E-10
1.513561248	0.035645347	7.48552E-10
1.737800829	0.062679545	1.31627E-09
1.995262315	0.099929976	2.09853E-09
2.290867653	0.146755282	3.08186E-09
2.630267992	0.200966645	4.2203E-09
3.01995172	0.259154203	5.44224E-09
3.467368505	0.31731425	6.6636E-09
3.981071706	0.371590947	7.80341E-09
4.570881896	0.418929035	8.79751E-09
5.248074602	0.457484862	9.60718E-09
6.025595861	0.486732107	1.02214E-08
6.918309709	0.50728966	1.06531E-08
7.943282347	0.520564504	1.09319E-08
9.120108394	0.528329354	1.10949E-08
10.47128548	0.532344248	1.11792E-08
12.02264435	0.534094039	1.1216E-08
13.80384265	0.534665761	1.1228E-08
15.84893192	0.53474736	1.12297E-08
18.19700859	0.534704072	1.12288E-08
20.89296131	0.534684091	1.12284E-08
23.98832919	0.53471639	1.1229E-08
27.54228703	0.534781476	1.12304E-08
31.6227766	0.534851931	1.12319E-08
36.30780548	0.53490927	1.12331E-08
41.68693835	0.534946622	1.12339E-08
47.86300923	0.534965329	1.12343E-08
54.95408739	0.534970505	1.12344E-08
63.09573445	0.53496777	1.12343E-08
72.44359601	0.534961599	1.12342E-08
83.17637711	0.534954862	1.12341E-08
95.4992586	0.534949042	1.12339E-08
109.6478196	0.53494466	1.12338E-08
125.8925412	0.534941695	1.12338E-08
144.5439771	0.534939882	1.12337E-08
165.9586907	0.534938901	1.12337E-08
190.5460718	0.534938464	1.12337E-08
218.7761624	0.534938352	1.12337E-08
251.1886432	0.534938411	1.12337E-08
288.4031503	0.534938546	1.12337E-08
331.1311215	0.534938702	1.12337E-08
380.1893963	0.534938849	1.12337E-08
436.5158322	0.534938974	1.12337E-08
501.1872336	0.534939074	1.12337E-08
575.4399373	0.534939153	1.12337E-08
660.693448	0.534939212	1.12337E-08
758.577575	0.534939254	1.12337E-08
870.96359	0.534939286	1.12337E-08
1000	0.534939309	1.12337E-08

Yes	Inorganic	Good cont	Yes	**s_per_year**
	List I			**s_per_day**
	List II			86400
				tlarge
				1.00E+40
				tscale
				1.148154

CALCULATIONS START HERE...

Type of solution to use (determines flows and areas to use)	Solution_type	a	
Coefficient of mechanical dispersion	D_mech	0	-
Longitudinal mechanical dispersion in the clay	Dl_cl	0	m2/s

Calculated concentrations and hydraulic conductivities

Concentration at top of clay barrier	Conc_def	3657	mg/l

1.26478E-08

2.29247E-12

1.23686E-08

5.83209E-12

Fluxes into the landfill

Inward Darcy flow in absence of geomembrane	Q_darcy	0.00000147	m3/s
Inward flux into the landfill	Q	0.00000147	m3/s

Velocities

Velocity through the clay	vel_cl	-6.17284E-09	m/s
Maximum velocity through centre of a pore in mineral liner	umax	-1.5E-09	m/s

Summary of parameters for mass calculations

Leachate concentration	C_LF	3657	mg/l
Concentration at edge of barrier	C_bar	0.534970505	mg/l
Diffusion coefficient	D_used	1E-09	m2/s
Distance	x_used	1	m
Outward flux area	Area_flux	1470	m2
Inward flow area	Area_flow	1470	m2

WARNING: Concentrations at the compliance point are predicted to exceed 10% of the leachate concentration. The boundary conditions used are only valid for low concentrations, and results may be unreliable above 10% of the leachate concentration.
WARNING: This spreadsheet has expired! Please contact the Environment Agency for an updated version.

Area_delam_check	1
Area_defect_check	1
Aquifer base check	3
Head base check	4.5
Head out base check	5.5
Head check	1
CM3 check	1
Area check	1
elev check	9

WARNING: The delaminated area should be less than or equal to the area of the landfill!
WARNING: The base of the landfill should be higher than the base of the aquifer!
WARNING: The leachate head should be higher than the base of the landfill!
WARNING: The groundwater head should be higher than the base of the landfill!
WARNING: The leachate head should be lower than the groundwater head!
WARNING: The base of the landfill should be lower than the top of the aquifer!
WARNING: The leachate head should be greater than the elevation of the base of the aquifer
WARNING: The area over which the geomembrane is delaminated must be greater than zero and not greater than the area of the liner below the water table.
WARNING: The dimensions of the defects should not be set to zero! Set the density of the required defect to zero to indicate the defect is not present.

Whisby IBA Cells 1-4		5th July 2023		
Alice Daly				

CONCEPTUAL MODEL AND LANDFILL CONSTRUCTION

				Justification / Reference / Notes
Scenario		3		
Is a geomembrane present?		No		
Basal width perpendicular to groundwater flow	Width_LF	210	m	Width of IBA Cells 1-4
Basal length parallel to groundwater flow	Length_LF	280	m	Length of IBA Cells 1-4
Elevation of base of landfill	LFbase_elev	3	maOD	Construction/design
Elevation of base of aquifer	Aqbound_elev	6	maOD	Base of Sand and Gravel Aquifer
Leachate head inside landfill	Head_inLF	7.5	maOD	1m below minimum rest groundwater level
Groundwater head outside landfill	Head_outLF	8.5	maOD	Minimum rest groundwater level interpolated from adjacent groundwater boreholes

CONTAMINANT PARAMETERS

Contaminant name	Cont_Nme	Chloride	-	
Contaminant type	Cont_Type	Inorganic	-	
Contaminant classification	Cont_Class	List II	-	
Concentration in landfill leachate	Conc_LF	3657	mg/l	Source term value
Free water diffusion coefficient	Dw_cl	0.000000005	m2/s	Default value
Partition coefficient in clay	Kd_cl	0	l/kg	Conservative tracer
Half life in clay (0 for no decay)	thalf_cl	0	days	
Decay in sorbed phase?	Decay_sorb	No	-	

MINERAL BARRIER / LINER

Thickness of mineral liner	thick_clbr	1	m	Design spec
Hydraulic conductivity	k_cl	0.000000001	m/s	Design spec
Average pore radius	pore_radius	0.00001	m	Default value
Effective porosity	n	0.162	-	Default value
Dry bulk density	rho	1750	kg/m3	Typical clay values
Tortuosity	tau_cl	5	-	Default value

STEADY STATE DILUTION

Hydraulic gradient in the aquifer	aq_I	0.004	-	Calculated from GW levels
Hydraulic conductivity of the aquifer	k_aq	0.00001	m/s	Expected for Sand and Gravel Aquifer
Downgradient distance of compliance point from landfill	dist_cp	100	m	
Dilution flow in aquifer downstream to the landfill	aq_Q	0.000021	m3/s	

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