COCKHIDE FARM RESTORATION

Environmental Permit Application

Hydrogeological Risk Assessment

Prepared for: Ingrebourne Valley Ltd

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1.0 INTRODUCTION

SLR Consulting Limited (SLR) has been retained by Ingrebourne Valley Limited (IVL) to prepare an Environmental Permit (EP) application to authorise the deposit of waste for recovery in the restoration of Cockhide Farm Quarry, South Ockendon, Essex RM14 2XB, hereafter referred to as 'the Site'.

The EP application seeks the use of inert waste in the restoration of a sand and gravel quarry to an agricultural paddock at the Site.

As part of the permit application, SLR has undertaken a Hydrogeological Risk Assessment (HRA). This document describes the manner in which the assessment has been carried out and presents the overall findings of the work.

1.1 Site Location

Centred on grid reference TQ 56983 82930, the Site is located approximately 1.5km north of Aveley in Essex. It is located within a predominantly agricultural landscape supplemented with woodland and surface water ponds.

The Site sits within the footprint of a former quarry complex known as Baldwins Farm, operated by Redland Aggregates in the 1970s and 1980s. Much of the surrounding land has been worked for minerals and restored using imported materials. The Site is the only land within the former Baldwins Farm Quarry area to contain mineral resources. Access to the Site is gained from the north west corner of the Site via Cockhide Farm, approximately 735m south of Bramble Lane.

The location of Cockhide Farm Quarry is illustrated on Drawing EP1. The Site Layout is illustrated in Drawing EP2 whilst the working scheme is illustrated in Drawing EP5.

The Site is currently overlain by agricultural land and covers an area of 1.83 hectares.

There are farm buildings associated with Cockhide Farm, adjacent to the northeastern boundary of the Site. It should be noted that Cockhide Farm is derelict and owned by Ingrebourne Valley. The farm house and associated outbuildings will be restored following completion of the quarry's restoration.

Belhus Woods Country Park is located immediately to the south-east of the site, this consists of a mixture of ancient woodland, forestry, flower meadows, open grassland and waterbodies which developed within historic sand and gravel quarries.

1.2 Objectives

This report presents the conceptual site model (CSM) developed for the Site and assesses the risk to the hydrogeological regime posed by the proposed restoration of the site using inert waste material.

The objectives of the assessment are to demonstrate that the site will be compliant with Schedule 22 (Groundwater Activities) of the Environmental Permitting (England and Wales) Regulations 2016 (as amended) (EPR) and the Inert Waste Guidance (2009). These Regulations require that certain substances (Hazardous Substances) are not discharged to groundwater such that they are discernible, and that the discharge of other substances (Non-Hazardous Pollutants) is limited *"so as to prevent pollution"*.

2.0 Conceptual Hydrogeological Site Model

The details of the proposed design and the environmental setting of the site are set out in the Hydrogeological Impact Appraisal (HIA)[1] and Flood Risk Assessment (FRA)[2] (included as Appendix 01 and 02) and are summarised below:

- The quarry is to work the Lynch Hill Gravels to the base of the gravels / top of the London Clay (2.2 – 4.0m)
- The Site is to be worked wet through a picture framing approach whereby a low permeability sidewall barrier is installed through the digging of trenches around the perimeter of the Site prior to working of the main sand and gravel in a phased basis;
- Infilling will take place within the void to pre-development ground levels (17 – 19mAOD) using a combination of site derived materials and imported inert waste;
- The landfill will be constructed with an engineered sidewall geological barrier with a maximum permeability equivalent to 1m at 1x10-7m/sec;
- The base of the landfill will be located on 150m+ of low permeability London Clay deposits, there is therefore no requirement for an engineered basal geological barrier;
- The Site will accept only inert waste; and
- Due to the nature of the waste streams, leachate collection systems, artificial sealing liner and landfill cap are not required.

Comprehensive details on the hydrogeological setting of the site are provided within the HIA, and include the following:

- aquifer characteristics;
- groundwater flow and quality;
- groundwater quality;
- licensed groundwater abstractions; and
- Source Protection Zones.

The conceptual hydrogeological site model is based on the source-pathway-receptor linkages. The conceptual model is shown in Drawing No. HRA1 and key elements of the hydrogeological model are discussed in further detail below.

2.1 Landfill Source

Cockhide Farm quarry will be restored using imported inert waste material. The landfill source term has been assessed based on Waste Acceptance Criteria (WAC) limits as outlined within section 2.1.2 of the Landfill Directive 2003/33/EC, and reproduced in Table 2-1 and Table 2-2.

Table 2-1
Limit values for waste acceptable at Landfills for Inert Waste

Component	L/S = 2 l/kg (mg/kg dry substance)	L/S = 10 l/kg (mg/kg dry substance)	C_0 (Percolation Test) (mg/l)
Arsenic	0.1	0.5	0.06
Barium	7	20	4
Cadmium	0.03	0.04	0.02
Chromium (Total)	0.2	0.5	0.1
Copper	0.9	2.0	0.6
Mercury	0.003	0.01	0.002
Molybdenum	0.3	0.5	0.2
Nickel	0.2	0.4	0.12
Lead	0.2	0.5	0.15
Antimony	0.02	0.06	0.1
Selenium	0.06	0.1	0.04
Zinc	2	4	1.2
Chloride	550	800	460
Fluoride	4	10	2.5
Sulphate	560*	1000*	1500
Phenol	0.5	1	0.3
DOC**	240	500	160
TDS***	2500	4000	-

Note: * if the waste does not meet these values for sulphate, it may still be considered as complying with the acceptance criteria if the leaching does not exceed either of the following values: 1,500mg/l as C_0 at L/S = 0.1l/kg and 6000mg/kg at L/S = 10l/kg.** If the waste does not meet these values for DOC at its own pH value, it may alternatively be tested at L/S = 10 l/kg and a pH between 7,5 and 8,0. The waste maybe considered as complying with the acceptance criteria for DOC, if the result of this determination does not exceed 500 mg/kg.
*** The values for total dissolved solids (TDS) can be used alternatively to the values for sulphate and chloride.

Table 2-2
Limit for Total Content of Organic Contaminants

Parameter	Value (mg/kg)
TOC (total organic carbon)	3%
BTEX (benzene, toluene, ethylbenzene and xylenes)	6.0
PCBs (polychlorinated biphenyls, 7 congeners)	1.0
Mineral oil (C10 to C40)	500
PAHs (polycyclic aromatic hydrocarbons)	100

Environment Agency guidance *'Testing for Disposal to Landfill*[3]*'* clarifies: *"While limits are set for these tests in the Council Decision annex, the Environmental Permitting Regulations, schedule 10 state that the L:S 10 l/kg test must be used."*. It is therefore proposed that the L:S 10l/kg WAC limits will be used for determining priority contaminants.

2.1.1 Site Design and Construction

The Site will be worked wet through a 'picture framing' approach whereby a low permeability sidewall barrier is installed in trenches around the perimeter of the site prior to working of the main sand and gravel in a phased basis. Extraction will extend to the base of the Lynch Hill Gravels / top of the London Clay between 2.2m and 4.0m below ground level (bgl).

Due to the small size of the Site, landfilling will be undertaken in a single phase, and will therefore commence after all excavation has been completed. Infilling will be completed to pre-development ground levels (17 – 19mAOD) using a combination of site derived materials and imported waste. In order to ensure adequate drainage, a slight domed restoration profile is proposed. The final restoration gradient will be approximately 1:30 to permit surface water runoff to the south and southwest of the Site to existing drainage ditches feeding an existing seasonal pond to the southwest of the Site.

Restoration will be undertaken in lifts to achieve the restoration profile minus the top soil and sub soil layer.

Groundwater is present within the sand and gravels to be extracted; 0.44m and 1.55m bgl. As such, following extraction of the mineral, the void will be partially filled with water. Due to elevated concentrations of PAHs in the groundwater from historical landfilling activities in the area, there is no suitable outlet to dewater the Site. As such, it is proposed that the Site is restored 'wet' by the tipping of restoration materials in to water.

To mitigate the risk to groundwater, the Site will be constructed with an engineered sidewall geological barrier with a maximum permeability equivalent to 1m at $1x10^{-7}$m/sec. The base of the landfill will be located on low permeability London Clay deposits (>150m thick). Therefore, there is no requirement for an engineered basal geological barrier.

The following sections provide further details of the principal components of the landfill development.

2.1.2 Basal Geological Barrier

The Site is underlined by 150m + of London Clay. The London Clay is classified as "Unproductive Strata" and typically exhibits permeabilities of c. $1x10^{-7}$m/s – $1x10^{-11}$ m/sec. The clay therefore meets the requirements of a geological barrier and no further artificial basal barrier is required underneath the Site.

[3] Environment Agency (March 2013). Waste Sampling and Testing for Disposal to Landfill. Ref. EBPRI 11507B Final

2.1.3 Sidewall Geological Barrier

In advance of mineral extraction, a geological barrier will be constructed around the perimeter of the site which will be at least 1m thick with a maximum permeability of <1x10^{-7}m/s. This will be installed in trenches a minimum of 1m wide dug to the top of the London Clay.

2.1.4 Capping

The site will be brought to level with the imported inert fill and then the sub-soils and top-soils originally removed will be replaced. There is no requirement for an engineered cap.

2.1.5 Waste Quality & Priority Contaminants

There is no confirmed waste stream for the site; therefore the Inert WAC (IWAC) limits set for the site have been used as an estimate of the worst-case leachate source within the inert waste. Table 2-3 includes an assessment of the WAC limits (10l/kg) converted to mg/l and assessed against respective UK Drinking Water Standards (DWS) and background groundwater quality to determine which substances pose the highest risk to the groundwater receptor for inorganic substances.

Table 2-3
Inorganic Inert Waste Quality

Component	L/S = 10 l/kg (mg/kg dry substance)	Conversion to mg/l (L/S=10 value divided by 10)	Hazardous or Non-Hazardous	UK DWS (mg/l)	Average background GW quality (mg/l)	Risk Factor[1]
Arsenic	0.5	0.05	Haz	0.01	0.0046	10.9
Barium	20	2	Non-Haz	-		
Cadmium	0.04	0.004	Non-Haz	0.005	0.000058	68.97
Chromium (Total)	0.5	0.05	Non-Haz	0.05	0.0012	41.7
Copper	2.0	0.2	Non-Haz	2.0	0.0024	83.33
Mercury	0.01	0.001	Haz	0.001	0.000006	16.6
Molybdenum	0.5	0.05	Non-Haz	-		
Nickel	0.4	0.04	Non-Haz	0.02	0.0293	2.0
Lead	0.5	0.05	Haz	0.01	0.00014	357.1
Antimony	0.06	0.006	Non-Haz	0.005		1.20
Selenium	0.1	0.01	Non-Haz	0.01		1.0
Zinc	4	0.4	Non-Haz	0.087[2]	0.0067	59.7
Chloride	800	80	Non-Haz	250	145	0.55

Component	L/S = 10 l/kg (mg/kg dry substance)	Conversion to mg/l (L/S=10 value divided by 10)	Hazardous or Non-Hazardous	UK DWS (mg/l)	Average background GW quality (mg/l)	Risk Factor[1]
Fluoride	10	1	Non-Haz	1.5		0.66
Sulphate	1000 (6000)	100 (600)	Non-Haz	250	61.50	9.75
DOC	500	50	N/A	-	39.11	-
TDS	4000	400	N/A	-		-

Note: [1] Risk factor calculated as assumed max waste concentration quality divided by lowest of DWS or background groundwater quality
[2] Bioavailable EQS

Based on the risk factors outlined in Table 2-3 it is proposed that lead, arsenic, mercury, cadmium, sulphate, copper and zinc are the inorganic substances which pose the highest risk from the site.

An assessment of organic substances is outlined in Table 2-4.

Table 2-4
Organic Waste Quality

Component	Speciated Substance	L/S = 10 l/kg (mg/kg dry substance)	Conversion to mg/l	MRV[5]	Average background GW quality (mg/l)	Risk Factor
Phenol		1.0	0.1[1]	-	<0.03	6.66
BTEX	Benzene	6.0	1.26[2]	0.001	<0.001	1260
	Toluene		0.464[2]	0.004	<0.001	116
	Ethylbenzene		0.218[2]	0.001	<0.001	218
	Xylenes		0.218[2]	0.003	<0.001	72.7
PAHs	Acenaphthene	100	0.0705[3]	0.01	<0.005	7.05
	Acenaphthylene		0.198	0.01	<0.005	19.8
	Anthracene		0.0169	0.01	0.0142	1.19
	Benzo(a)anthracene		0.00644	0.01	0.0835	0.077
	Benzo(a)pyrene		0.00388	0.01	0.1451	0.027
	Benzo(b)fluoranthene		0.00477	0.01	0.1802	0.026
	Benzo(g,h,i)perylene		0.0012	0.01	0.1002	0.012
	Benzo(k)fluoranthene		0.00338	0.01	0.0884	0.038
	Chrysene		0.0091	0.01	0.0916	0.099

Component	Speciated Substance	L/S = 10 l/kg (mg/kg dry substance)	Conversion to mg/l	MRV[5]	Average background GW quality (mg/l)	Risk Factor
	Dibenzo(a,h)anthracene		0.00269	0.01	0.0270	0.099
	Fluoranthene		0.0275	0.01	0.2005	0.137
	Fluorene		0.0362	0.01	<0.005	3.62
	Indeno(1,2,3-cd)pyrene		0.00574	0.01	0.0938	0.062
	Naphthalene		0.762	0.01	<0.01	76.2
	Phenanthrene		0.0218	0.01	0.0565	0.38
	Pyrene		0.031	0.01	0.190	0.163
Mineral Oil (C10 – C40)	C10 – C12	500	2.28[4]	0.1	<0.10	45.6

Note: risk factor calculated as assumed max waste concentration quality divided by lowest of MRV or background groundwater quality
[1] L/S = 10 value divided by 10
[2] Back-calculated using remedial target worksheet based on typical porosity & bulk density of inert waste and substance specific Henry's Law and soil water partition coefficients (assuming any one speciated substance will provide no more than 33% of the Total BTEX (i.e. 2.0mg/kg)
[3] Back-calculated using remedial target worksheet based on typical porosity & bulk density of inert waste and substance specific Henry's Law and soil water partition coefficients (assuming any one speciated substance will provide no more than 10% of the Total PAH (i.e. 10mg/kg)
[4] Back-calculated using remedial target worksheet based on typical porosity & bulk density of inert waste and substance specific Henry's Law and soil water partition coefficients (assuming any one speciated substance will provide no more than 20% of the Total Mineral Oil (i.e. 100mg/kg)
[5] MRV based on detection limit for groundwater in site samples, except for substances with MRV on EA website (benzene, toluene, xylene)

The above assessment indicates that the highest risk is posed from BTEX which have not been recorded in the background. Due to the presence of PAHs in the background groundwater the risk factor for most PAHs is very low, with the worst-case concentration lower than the background groundwater quality. The only PAHs to have a risk factor above 1 are those which have not been recorded in the background groundwater. Given that Naphthalene is classified as a Non-Hazardous Substance, Acenaphthylene is the most appropriate PAH for modelling purposes. It is also proposed that Aromatic C10-C12 is modelled as representative of mineral oil.

The following key determinands are to be included in the detailed quantitative assessment:

Hazardous Substances:

- Lead;
- Arsenic;
- Mercury;
- Benzene;
- Acenaphthylene;
- Aromatic C10-C12

Non-Hazardous Pollutants:

- Cadmium;
- Sulphate;

- Copper; and
- Zinc;

2.2 Pathways

2.2.1 Geology

A detailed description of the regional geology of the area was presented in the HIA. The following summary is based on the information presented in that report and additional information from the installation of perimeter groundwater monitoring boreholes.

The regional geology comprises of superficial Lynch Hill Gravels overlying London Clay bedrock. The London Clay is underlain at depth by the Lambeth Group, Thanet Formation and White Chalk. The regional geological sequence is summarised in Table 2-5.

Table 2-5
Regional Geology

Geological Strata	Description	Typical Thickness
Lynch Hill Gravels	Medium to coarse sand and gravel	2.20m - 4.0m
London Clay	Very stiff grey silty clay with bands of silt and sand	Up to 150m
Lambeth Group	Variable sequences mainly of clay, some silty or sandy, with some sands and gravels, minor limestones and lignites and occasional sandstone and conglomerate	Up to 39m
Thanet Formation	Glauconite-coated, nodular flint at base, overlain by pale yellow-brown, fine-grained sand that can be clayey and glauconitic. Rare calcareous or siliceous sandstones.	0 to 30m
White Chalk Sub Group	White Chalk with flints	100m+

Site investigations (SI) were undertaken at the site in August 2015; which included the drilling of three investigation boreholes to confirm the thickness and composition of the Sands & Gravels, and February 2019; which included the drilling and installation of four groundwater monitoring wells around the perimeter of the site. The borehole logs are included as Appendix 03.

The local geology across the site is summarised in Table 2-6.

Table 2-6
Local Geology

Geological Strata	Sub-Strata	Description	Recorded Thickness (m)
Topsoil		Brown sandy gravelly clay	0 – 0.40m
Made Ground		Brown sandy gravel of concrete and brick	0 – 0.60m
Lynch Hill Gravels	Clayey sand & Gravel	Greenish brown to light brown mottled sandy clay or clayey sand	0.00 – 1.00m
	Sand & Gravel	Brown Sand & Gravel	0.50 – 3.30m
London Clay		Stiff Grey Clay	>1.00

2.2.2 Hydrogeology

A detailed description of the hydrogeology of the area was presented in the HIA. The following summary is based on the information presented in that report and additional information collected from four perimeter groundwater monitoring boreholes installed in February 2019.

Aquifer Characteristics

The Environment Agency (EA) classify the Lynch Hill Gravels as a Secondary A Aquifer, described as:

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

The underlying London Clay deposits are classified as Unproductive Strata.

A laboratory permeability test undertaken on a single bulk sample of the Lynch Hill gravels and included in the HIA recorded a coefficient of permeability of $4.1x10^{-4}$m/sec.

Groundwater Levels and Flow

Groundwater levels have been regularly monitored from ten boreholes around the wider Baldwins Farm site since January 2012, although some of these have been installed in historic waste deposits replacing the Lynch Hill Gravels. Monthly monitoring data is also available for four boreholes installed around the perimeter of the Cockhide site since February 2019.

The monitoring data for the boreholes installed within the sands and gravels and the perimeter boreholes are summarised in Table 2-7.

Table 2-7
Cockhide and Baldwins Groundwater Levels

Location	BHID	Monitoring Period	Count	Groundwater Level (mAOD)			Range
				Min	Mean	Max	
Cockhide	BHA	Feb – July 2019	6	17.27	17.45	17.69	0.42
	BHB	Feb – July 2019	6	17.86	18.27	18.55	0.69

Location	BHID	Monitoring Period	Count	Groundwater Level (mAOD)			Range
				Min	Mean	Max	
	BHC	Feb – July 2019	6	14.66	15.00	15.22	0.56
	BHD	Feb – July 2019	6	14.66	14.97	15.21	0.55
Baldwins Farm	BF01	2012 - 2019	92	17.33	18.03	18.90	1.57
	BF03	2012 - 2019	78	14.46	15.65	16.60	2.14
	BF06	2012 - 2019	89	19.84	20.29	20.75	0.91
	BF08	2012 - 2019	90	14.76	15.48	16.28	1.52
	BF10	2012 - 2019	89	19.79	20.22	21.06	1.27

A review of the groundwater levels outlined in Table 2-7, the hydrographs included in Appendix 04 and the groundwater contours included on Drawing HRA1 indicates:

- groundwater levels across the site range from c.18.55mAOD (BHB) to 14.66mAOD (BHC and BHD);
- there is a slight seasonal variation observed at the site of between 20cm to 50cm, though historic monitoring of wider boreholes indicates wider seasonal variation;
- groundwater flow is in a broadly southerly to south-easterly direction across the site with a relatively shallow hydraulic gradient of between 0.015 to 0.025;
- the saturated thickness of the sands and gravels ranges between 0.60m (BHC) and 2.73m (BHB);
- the unsaturated thickness across the site ranges between 0.44m (BHA) and 2.20m (BHC).

2.2.3 Groundwater Quality

Groundwater quality at Cockhide has been monitored from four perimeter boreholes. BHA and BHB are located along the northern boundary of the site and will ultimately be the site background boreholes and BHC and BHD are located along the southern boundary and comprise the down-gradient compliance boreholes.

It is however noted that as no site activity has taken place to date all four boreholes could be reflective of "background" groundwater. The monitoring data for all key ions and metals are summarised in Table 2-8.

Table 2-8
Groundwater Quality at Cockhide Farm (2019)

Determinand	UK DWS	Count	Concentration (mg/l)		
			Min	Mean	Max
Alkalinity, Total as CaCO3 (diss.filt)		26	190	669.8	1540
Ammoniacal Nitrogen as N (low level)	0.39	26	0.142	**21.21**	**58.60**
Chloride	250	26	19.7	145	**369**
Conductivity @ 20 deg.C	2000	26	420	1476.5	**3310**

Determinand	UK DWS	Count	Concentration (mg/l)		
			Min	Mean	Max
Cyanide, Total (low level)		16	<0.005	-	<0.05
pH	5 – 9	26	6.92	7.29	8.26
Sulphate	250	26	15.3	61.53	119
Arsenic (diss.filt)	0.01	26	0.000588	0.0046	**0.0138**
Cadmium (diss.filt)	0.005	26	<0.00008	0.000059	0.000148
Calcium (Diss.filt)	-	26	61	158.61	370
Chromium (diss.filt)	0.05	26	<0.001	0.00117	0.00405
Copper (diss.filt)	2.0	26	<0.0003	0.0024	0.00919
Iron (diss. filt)	0.20	26	<0.019	**4.11**	**15.9**
Lead (diss.filt)	0.01	26	<0.0002	0.000136	0.000936
Magnesium (diss. filt)	-	26	20.5	44.55	87.3
Manganese (diss.filt)	0.05	26	**0.177**	**0.98**	**2.19**
Mercury (diss.filt)	0.001	12	<0.00001	0.000006	0.000012
Nickel (diss.filt)	0.02	26	0.00462	**0.0293**	**0.0678**
Potassium (diss. filt)	-	26	1.17	49.74	216
Sodium (diss. filt)	200	26	9.48	128.0	**313**
Zinc (diss.filt)	-	26	0.00277	0.00667	0.0195
Note: Values in **bold** exceed UK DWS					

A review of the monitoring data summarised in Table 2-8 and time-series graphs included in Appendix 05 indicates that there is a significant impact on groundwater quality across the site from historic landfilling around the site, notably within the boreholes along the northern edge of the site, the following is noted:

- elevated ammoniacal nitrogen has been recorded in all four boreholes but with the highest concentrations recorded in up-gradient boreholes BHA (average of 30.25mg/l) and BHB (average of 46.7mg/l). Concentrations within the down-gradient boreholes are lower (average of 0.72mg/l in BHC and 5.54mg/l in BHD) although remain above the UK Drinking Water Standard (DWS);
- elevated chloride concentrations have also been recorded in up-gradient borehole BHB which has regularly recorded concentrations above DWS (25mg/l) with a maximum of 369mg/l recorded in February 2019. Concentrations are lowest in BHC (average of 32.5mg/l) i.e. relatively clean groundwater. Sodium demonstrates a very similar pattern to chloride with concentrations elevated above the DWS in BHB and lower concentrations in the down-gradient boreholes;
- several metals have also been recorded above their respective Drinking Water Standards including arsenic, iron, manganese and nickel; in all instances the highest concentrations are recorded in up-gradient borehole BHA or BHB. The iron and manganese concentrations are notably elevated with

concentrations well above the DWS in all four boreholes for manganese and in three of the boreholes (BHA, BHB and BHC) for iron;

Overall the monitoring data indicates that the historic landfills located to the north of the site are impacting groundwater quality locally, although there is a notable improvement across the site, indicating the natural dilution, dispersion and attenuation taking place within the aquifer is likely to limit any significant impact to the receptors further south.

Groundwater quality has also monitored for PAHs and BTEX, the monitoring data is summarised in Table 2-9 and borehole specific summary statistics are included in Appendix 05.

The monitoring data indicates that while there have been no BTEX detected within the groundwater (from a single monitoring round completed in June 2019), PAHs have however been detected within all four boreholes. The highest concentrations have typically been recorded in up-gradient borehole BHB, consistent with the inorganics outlined above. Given the elevated concentrations of PAHs in groundwater across the site it is not considered appropriate to dewater groundwater (to avoid discharging water with elevated Hazardous Substances) hence the quarrying and landfilling activities will take place wet using a picture-framing methodology to develop the required sidewall geological barrier.

Table 2-9
PAHs & BTEX Detected in Groundwater

Determinand		Count	Concentration (µg/l)		
			Min	Mean	Max
PAHs	PAH, Total Detected USEPA 16 (aq)	16	<0.082	1.289	5.33
	Acenaphthene (aq)	16	<0.005	-	<0.025
	Acenaphthylene (aq)	16	<0.005	-	<0.025
	Anthracene (aq)	16	<0.005	0.0142	0.0526
	Benzo(a)anthracene (aq)	16	<0.005	0.0835	0.405
	Benzo(a)pyrene (aq)	16	<0.002	0.1451	0.665
	Benzo(b)fluoranthene (aq)	16	<0.005	0.1802	0.885
	Benzo(g,h,i)perylene (aq)	16	<0.005	0.1002	0.412
	Benzo(k)fluoranthene (aq)	16	<0.005	0.0884	0.402
	Chrysene (aq)	16	<0.005	0.0916	0.421
	Dibenzo(a,h)anthracene (aq)	16	<0.005	0.0270	0.0975
	Fluoranthene (aq)	16	<0.005	0.2005	0.831
	Fluorene (aq)	16	<0.005	-	<0.025
	Indeno(1,2,3-cd)pyrene (aq)	16	<0.005	0.0938	0.343
	Naphthalene (aq)	16	<0.01	-	<0.05

Determinand		Count	Concentration (µg/l)		
			Min	Mean	Max
	Phenanthrene (aq)	16	<0.005	0.0565	0.242
	Pyrene (aq)	16	<0.005	0.190	0.801
BTEX	Benzene	4	<1	-	<1
	Ethylbenzene	4	<1	-	<1
	m,p-Xylene	4	<1	-	<1
	o-Xylene	4	<1	-	<1
	Sum of detected Xylenes	4	<2	-	<2
	Toluene	4	<1	-	<1

Based on the above, the background groundwater quality for inclusion in modelling is summarised in Table 2-10.

Table 2-10
Background Groundwater Quality Summary

Determinand	Minimum	Average	Maximum
Non-Hazardous Pollutants			
Cadmium	0.00004	0.000059	0.000148
Sulphate	15.3	61.53	119
Copper	0.00015	0.0024	0.00919
Zinc	0.00277	0.00667	0.0195
Phenol	ND		
Hazardous Substances			
Arsenic	0.000588	0.0046	0.0138
Mercury	0.000005	0.000006	0.000012
Lead	0.0001	0.000136	0.000936
Benzene	ND		
Acenaphthylene	ND		
Aromatic C10-C12	No Data		
Note: ND = Not Detected			

2.3 Receptors

2.3.1 Abstractions and Source Protection Zones

As outlined within the HIA, the site is not located within a groundwater source protection zone and there are no licensed or private abstractions located within a 2km radius of the site.

2.3.2 Surface Water

Although there are several minor drainage ditches around the perimeter of the site these are typically recorded as dry and are therefore not considered to be a significant receptor for groundwater flow within the Lynch Hill gravels.

A small pond is located in the south-western corner of the site which will act as a potential receptor, although given its shallow depth it is unclear whether the pond is in continuity with the groundwater or perched above it.

The primary surface water receptors are therefore considered to be the larger waterbodies located within Belhus Woods Country Park. These have formed within former sand and gravel quarries and are therefore considered to be in continuity with the wider groundwater table. These are located approximately 200m to the south-east of the site at the closest.

2.3.3 Receptor Locations for Modelling

The primary receptors assumed for this assessment are in accordance with those required by Schedule 22 (Groundwater Activities) of the EPR, these are as follows:

- for Hazardous Substance the receptor is assumed to be the groundwater within the Lynch Hill Gravels outside of the sidewall geological barrier taking account of immediate dilution in the aquifer[4] but without any dispersion or attenuation in the aquifer pathway; and
- for Non-Hazardous Pollutants the receptor has been assumed to be the groundwater at the down-gradient site boundary (down-gradient boreholes in the Lynch Hill Gravels).

2.4 Determination of Environmental Assessment Limits (EALS)

The setting of Environment Assessment Limits (EALs) [5] is necessary in order to assess whether the requirements of the EPR are being met.

With regard to the proposed site, the following EALs are considered appropriate:

- for Hazardous Substances, the EALs shall be the minimum reporting values (MRV's) as defined in the current EA HRA guidance[6] or similar low concentrations; and
- for Non-Hazardous Pollutants the EALs have been set at either the Drinking Water Standards (DWS) or Environmental Quality Standard (EQS); whichever is lowest, as a worst case.

The selected EALs for Hazardous Substances and Non-Hazardous Pollutants are summarised in Table 2-11.

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[4] https://www.gov.uk/government/publications/groundwater-protection-technical-guidance/groundwater-protection-technical-guidance

[5] An EAL can be defined as a water quality standard that is defined by either UK Regulations (e.g. Water Supply (Water Quality) Regulations 2010) or another relevant source (e.g. non-statutory Environmental Quality Standards)

[6] https://www.gov.uk/government/publications/values-for-groundwater-risk-assessments/hazardous-substances-to-groundwater-minimum-reporting-values

Table 2-11
Environmental Assessment Limits

Determinand	UK Drinking Water Standard [mg/l]	Environmental Quality Standard [mg/l]	Minimum Reporting Value (MRV)	Maximum Background Groundwater Quality (mg/l)	Proposed EAL [mg/l]
Non-Hazardous Pollutants					
Cadmium	0.005	-	-	0.000148	0.005
Copper	2.0	0.046[a]	-	0.00919	0.046
Sulphate	250	400	-	119	250
Zinc	-	0.087[a]	-	0.0195	0.087
Hazardous Substances					
Lead	0.01	0.02	0.005[c]	0.00094	0.005
Arsenic	0.01	-	0.005 [c]	0.0138	0.0138
Mercury	0.001	-	0.0005 [c]	0.000012	0.0005
Benzene	0.0001	-	0.001[d]	<0.001	0.001
Acenaphthylene	-	-	0.00001[b]	<0.0005	0.00001
Aromatic C10-C12	-	-	0.10[b]		0.1

Note: Minimum reporting Value for Hazardous Substance is Limit of Quantification (2016) which is the concentration in groundwater below which the danger of deterioration in the quality of the receiving groundwater is avoided.
[a] Bioavailable EQS calculated using EA BAT Tool
[b] set based on achievable detection limit from laboratory testing
[c] Limit of quantification from UK Technical Advisory Group (UKTAG) on the Water Framework Directive (September 2016): Technical Report in Groundwater Hazardous Substances [https://www.wfduk.org/resources/groundwater-hazardous-substances-standards]
[d] EA Guidance (January 2017) *Guidance: Hazardous Substances to Groundwater: Minimum Reporting Values*, https://www.gov.uk/government/publications/values-for-groundwater-risk-assessments/hazardous-substances-to-groundwater-minimum-reporting-values

2.5 Summary of Hydrogeological Site Conceptual Model

The Site's hydrogeological conceptual model is summarised in Table 2-12.

Table 2-12
Summary of Hydrogeological Site Conceptual Model

Linkage	Site Details
Source	The void created by extraction of the Lynch Hill Gravels will be restored with inert wastes. Given the nature of the waste streams no leachate collection system or artificial sealing liner is required. The wastes will be partly emplaced below the permanent water table within the Lynch Hill Gravels. The waste placed within the void will comprise inert material only and will meet inert WAC limits. The sidewalls of the landfill, adjacent to the Lynch Hill Gravels will be constructed from site derived clay and/or imported clay waste with a permeability equivalent to 1 metre at 1 x 10^{-7}m/s. Where considered necessary any imported clay waste will be subject to WAC testing to confirm it is inert. Due to the nature of the underlying London Clay there is no requirement for an artificial basal geological barrier. Capping material will consist of top soil removed prior to sand and gravel excavation. Proposed final restoration contours will be similar to the current topography prior to development of the quarry void.
Pathway	Any potential leachate generated by infiltration into the inert waste will migrate through the artificially established sidewall geological barrier and into the adjacent groundwater. Degradation and/or attenuation of potential contaminants will take place within the geological barrier.
Receptor	In order to comply with Schedule 22 (Groundwater Activities) of the EPR, the following are considered appropriate receptors: • for Hazardous Substance the receptor is assumed to be the groundwater within the Lynch Hill Gravels Formation outside of the sidewall geological barrier of the Site taking account of immediate dilution in the aquifer but without any dispersion or attenuation in the aquifer pathway; and • for Non-Hazardous Pollutants the receptor has been assumed to be the groundwater at the down-gradient site boundary (down-gradient boreholes) within the Lynch Hill Gravels.
Compliance Points	For the purposes of defining receptors, the compliance points are taken to be at the down-gradient site boundaries. It is noted that there may be other, physical receptors further away from the down-gradient site boundaries. Compliance with the Regulations at the points defined above will ensure that other receptors are adequately protected.

3.0 Hydrogeological Risk Assessment

3.1 Nature of the Hydrogeological Risk Assessment

As set out within current HRA technical guidance[7], the *"appropriate complexity of assessment for a site should be determined from the potential risks presented by the site, which are linked to the nature of potential hazards, the sensitivity of the surrounding environment, degree of uncertainty and likelihood of a risk being realised."*

Given the nature of the Site and its environmental setting within a Secondary A aquifer, it is considered appropriate to carry out a detailed quantitative assessment.

The site will accept inert waste, which is defined as follows;

(a) it does not undergo any significant physical, chemical or biological transformations;

(b) it does not dissolve, burn or otherwise physically or chemically react, biodegrade or adversely affect other matter with which it comes into contact in a way likely to give rise to environmental pollution or harm to human health; and

(c) total leachability, pollutant content and the ecotoxicity of its leachate are insignificant and, in particular, do not endanger the quality of any surface water or groundwater.

Based on this definition of inert waste, the site should not produce any leachate that could result in any significant discharge of Hazardous Substances or Non-Hazardous Pollutants throughout the lifecycle of the site.

Therefore, with regard to this inert waste stream, the site:

- presents a negligible risk to groundwater and surface water quality;
- falls outside the scope of the EPR (Schedule 22 Groundwater Activities); and
- does not require environmental management systems (artificial sealing liner, leachate management or other engineering and management structures), or the consideration of the degradation of such systems.

However, notwithstanding the above, it is considered that a quantitative risk assessment is required given that the EPR Inert Waste Guidance[8] 2009 states that a quantitative risk assessment is likely to be necessary for an inert landfill where the receiving environment is particularly sensitive, for example below the water table in a major aquifer which is in continuity with down-gradient surface water bodies.

The proposed site is located below the water table within a Secondary A Aquifer which provides important water supplies for baseflow to watercourses.

In order to assess the risk to the environment, it is considered appropriate to assess the potential worst-case leachate quality that could potentially be generated from the site.

3.2 The Proposed Assessment Scenario

3.2.1 Lifestyle Phases

It is recognised that the HRA must assess the proposed development compliance with the requirements of Schedule 22 of the EPR, throughout the lifecycle of the landfill, i.e. from the start of operation until the point at which the landfill no longer poses an unacceptable environmental risk.

[7] https://www.gov.uk/guidance/landfill-developments-groundwater-risk-assessment-for-leachate
[8] Environment Agency (July 2009): *Environmental Permitting Regulations: Inert Waste Guidance*

Based on the hydrogeological conceptual site model, as outlined within Section 2.0, there are two potential pathways for leachate to impact groundwater quality; diffusive migration of contaminants across the geological barrier when groundwater levels are higher than leachate levels and advective migration of leachate across the sidewall barrier in the event that leachate heads rise above groundwater. Therefore it is considered appropriate to assess the risk to groundwater in the following two scenarios:

- Scenario 1: Hydraulic Containment – assumes groundwater levels equal to or higher than leachate levels post closure; assessed using the Environment Agency 'Contaminant Flux from Hydraulic Containment Landfills' worksheet
- Scenario 2: Advective Migration – assessment of advective migration of leachate across sidewall barrier in the event of leachate heads rising above groundwater levels within the Lynch Hill Gravels Formation; assessed using LandSim V2.5.17

3.2.2 Justification of Modelling Approach and Software

Detailed quantitative risk assessments are carried out in a quantitative manner using stochastic/probabilistic techniques to realise analytical solutions or mathematical solutions.

The HRA has been carried out using conservative, but realistic assumptions regarding the source, pathways and receptors. Site specific data have been used wherever possible to parameterise the risk assessment. Using measured site data reduces uncertainty in the risk assessment process.

For the diffusion model (Scenario 1), an inward gradient to the landfill will exist and as such the only mechanism for contaminant transport to groundwater will be a diffusive flux. Inward hydraulic gradients therefore act to contain the outward advective flow. For this Scenario, the Environment Agency's Spreadsheet for the assessment of diffusive fluxes[9] was used. The model has been run using worst case assumptions.

For the advective model (Scenario 2) the Environment Agency's LandSim software (version 2.5.17) has been used to provide an estimate of the potential risks associated with the site. This software was used for the following reasons:

- it is the Environment Agency's recommended software for quantitative hydrogeological risk assessment modelling and allows consideration of the entire life of the site;
- it uses Monte Carlo (stochastic) techniques and so allows a probabilistic appreciation of the landfill's performance;
- it provides a consistent approach to the estimation of hydrogeological risks in respect to landfills and groundwater;
- it provides an audited and verified code that is widely accessible;
- it aids comprehensive reporting of input values, assumptions and results;
- the model provides a good indication of the potential leakage rates. This is important as the installation's compliance with the requirements of Schedule 22 (Groundwater Activities) of EPR, depends significantly upon the functioning of the containment system;
- it allows the estimation of the potential attenuation of contaminants through the mineral element of the liner. This is particularly important for the consideration of Hazardous Substances; and
- it allows the dilution and attenuation of Non-Hazardous Pollutants within the aquifer's saturated zone.

[9] Environment Agency (2004) Contaminant Fluxes from Hydraulic Containment Landfills Worksheet Version 1

All modelling carried out for this risk assessment has been carried out in a stochastic fashion. Throughout this assessment the acceptable probability of an undesirable outcome occurring is set at the 95%ile for stochastic estimations carried out for a complex HRA. In addition, the 95%ile is commonly selected as a reasonable worst case against which it is acceptable to make decisions considering the assumptions and limitations of the modelling process.

3.2.3 Accidents and their Consequences

Details of accidental occurrences at the site that could present a potential risk to groundwater quality adjacent to the site are provided in Table 3-1 below:

Table 3-1
Qualitative Assessment of Accidents and Mitigation

Accidental Occurrence	Risk to Groundwater	Likelihood of Occurrence	Mitigation and Corrective Measures
Deposition of non-inert wastes.	Generation of leachate containing Hazardous Substances or Non-Hazardous Pollutants.	Low – due to the essential and technical precautions.	Any incorrectly accepted wastes will be immediately returned to the customer or moved to a suitable storage area prior to removal to a suitable site.
Spillage of fuels from storage tanks or vehicles.	Release of hydrocarbons (Hazardous Substances) into the ground and migration to groundwater.	Low – fuel stores will be bunded in accordance with Regulations. A traffic system and speed limit will be imposed at the site to reduce both the risk of accidents and the likelihood of spillage occurring.	Any spillage will be cleaned up immediately and any resulting contaminated soils removed to a suitable installation.

With respect to the deposition of potentially contaminated wastes, it is considered that the risks and potential consequences of such accidents are extremely low for the following reasons:

- all waste deliveries will be pre-arranged and come from known sources to ensure no contaminated material is delivered;
- if deemed necessary, characterisation testing will be undertaken to demonstrate that the waste will not give rise to polluting leachate, prior to the acceptance of waste at the site;
- if deemed necessary compliance testing will be undertaken to ensure the continued acceptability of the waste stream;
- visual inspection will be undertaken of every waste load deposited at the site; and
- in the event of suspicion regarding the acceptability of the waste, quarantine procedures will be enforced.

In the unlikely event of contaminants from a rogue load being deposited at the site, attenuation processes will occur within the waste body, and most organic Hazardous Substances are very likely to be degraded and retarded during migration through the surrounding inert wastes within the landfill and geological barrier. Other processes such as volatilisation can also be expected for volatile and semi-volatile organic substances resulting in a mass loss of contaminant from the waste.

3.3 Numerical Modelling

3.3.1 Model Parameterisation

The nature of all of the input parameters used, together with the appropriate probability distributions used to describe them are presented in the following:

- Drawing No. HRA2: provides an indication of the site's conceptual model; and
- Appendix 06: presents the detailed EA Diffusion Spreadsheet parameterisation (Scenario 1).
- Appendix 07: presents the detailed LandSim parameterisation (Scenario 2)

Parameter values were determined from information directly measured at site wherever possible. If no site data were available, conservative parameter values were taken from authoritative sources or after previous SLR experience at similar sites.

3.3.2 Assessment Methodology

In order to represent worst case conditions and assess the most sensitive determinands risk factors were used to choose suitable determinands which pose the greatest risk of causing either pollution to the aquifer or a deterioration of groundwater quality. As detailed within Section 2.1.5 the following determinands have been modelled:

- Hazardous Substances: lead, arsenic, mercury, benzene, acenaphthylene and Aromatic C10-C12; and
- Non-Hazardous Pollutants: cadmium, copper, sulphate and zinc

As detailed in Section 3.2 above, the fate of Hazardous Substances and Non-Hazardous Pollutants has been considered using LandSim v2.5.17 and the Environment Agencies Contaminant Fluxes from Hydraulic Containment Landfills Worksheet. The following assumptions are built into the models:

- this sidewall geological barrier is engineered to a thickness of 1m and a maximum permeability of $1x10^{-7}$m/s; and
- a declining source term is used to represent the temporal change in leachate quality.

4.0 Assessment Results

The predicted discharge from the development has been assessed against EALs presented in Table 2-11 to determine whether the site complies with the requirements of Schedule 22 (Groundwater Activities) of the EPR.

Hard copies of the model results are presented in Appendix 08 and 09 respectively and an electronic copy of the models and results is presented in Appendix 10

4.1 Scenario 1: Diffuse Migration across the Sidewall Geological Barrier

Scenario 1 assesses the potential for the diffusion of leachate across the sidewall geological barrier when leachate heads are below groundwater levels within the Lynch Hill Gravels.

4.1.1 Hazardous Substances

Hazardous Substances have been assessed against their respective EALs at the outer edge of the geological barrier, prior to any dilution or attenuation in the aquifer.

Results are presented in Table 4-1 below and demonstrate that predicted resultant concentrations are lower than the respective EALs. It is therefore considered that the modelling has shown that there would be no unacceptable discharges of Hazardous Substances from the landfill to groundwater under the scenarios modelled.

Table 4-1
Scenario 1: Hazardous Substances - Maximum Predicted Concentration at outer edge of geological barrier

Determinand	Discernible Concentration (EAL)	95%ile Resultant Concentration
Lead (mg/l)	0.005	$<1x10^{-10}$
Arsenic (mg/l)	0.0132	$5.89x10^{-5}$
Mercury (mg/l)	0.0005	$3.25x10^{-9}$
Benzene (mg/l)	0.001	$1.23x10^{-8}$
Acenaphthylene (mg/l)	0.00001	$6.89x10^{-8}$
Aromatic C10-C12 (mg/l)	0.1	0.00011

4.1.2 Non-Hazardous Pollutants

Non-Hazardous Pollutants have been assessed at the compliance point (at the down gradient site boundary). Results are presented in Table 4-2 and demonstrate that the predicted resultant concentrations are lower than the appropriate EALs. It is therefore considered that the modelling has shown that the discharge of Non-Hazardous pollutants is sufficiently limited so as to avoid pollution.

Table 4-2
Scenario 1: Non-Hazardous Pollutants - Maximum Predicted Concentration at Down-Gradient Compliance Point

Determinand	Maximum Background Concentration	EAL	95%ile Resultant Concentration
Cadmium (mg/l)	0.000148	0.005	2.62x10-9
Copper (mg/l)	0.00919	0.046	1.90x10-8
Sulphate (mg/l)	119	250	0.0039
Zinc (mg/l)	0.0195	0.087	2.17x10-7

The diffusion modelling has demonstrated that while leachate levels are below corresponding groundwater levels there will be no discernible release of either Hazardous Substances or Non-Hazardous Pollutants.

4.2 Scenario 2: Advective Migration of Contaminants across the Sidewall Geological Barrier

Scenario 2 has been assessed through the use of LandSim modelling. Both Hazardous Substances and Non-Hazardous Pollutants have been assessed at the notional LandSim 'monitor well' on the outside edge of the inert waste. The model results are summarised below and provided within Appendix 08.

4.2.1 Hazardous Substances

The modelling results for Hazardous Substances in Scenario 2 are presented within Table 4-3.

Table 4-3
Scenario 2: Hazardous Substances - Maximum Predicted Concentration at Monitor Well

Determinand	EAL	95%ile Resultant Concentration
Lead (mg/l)	0.005	0.00065
Arsenic (mg/l)	0.0132	0.0129
Mercury (mg/l)	0.0005	7.37×10^{-5}
Benzene (mg/l)	0.001	4.64×10^{-5}
Acenaphthylene (mg/l)	0.00001	$<1 \times 10^{-10}$
Aromatic C10-C12 (mg/l)	0.1	$<1 \times 10^{-10}$

4.2.2 Non-Hazardous Pollutants

The modelling results for Non-Hazardous Pollutants in Scenario 2 are presented within Table 4-4.

Table 4-4
Scenario 2: Non-Hazardous Pollutants - Maximum Predicted Concentration at Down-Gradient Compliance Point

Determinand	Maximum Background Concentration	EAL	95%ile Resultant Concentration
Cadmium (mg/l)	0.000148	0.005	0.00015
Copper (mg/l)	0.00919	0.046	0.0054
Sulphate (mg/l)	119	250	121.4
Zinc (mg/l)	0.0195	0.087	0.014

Table 4-3 and Table 4-4 demonstrate that the predicted resultant concentrations at the compliance point (monitoring well) are lower than the appropriate EALs. It is therefore considered that the modelling has shown that the discharge of Hazardous Substances and Non-Hazardous Pollutants is sufficiently limited so as to avoid pollution.

4.3 Assessment Conclusions

The modelling results demonstrate that the proposed Cockhide Farm site would remain compliant with the EPR provided that the landfill waste meets that as specified by the inert WAC limits.

4.4 Review of Technical Precautions

Essential and technical precautions are those measures required to ensure that the site complies with Schedule 22 (Groundwater Activities) of the EPR. Essential and technical precautions typically include both restrictions on waste types and the engineering and other environmental management measures. Given the proposed landfill classification, the Site will not require leachate management. However, the following essential and technical precautions will be required:

- a sidewall geological barrier with a minimum thickness of 1 metre and a maximum permeability of 1 x 10^{-7} m/s;
- all waste deliveries will be pre-arranged and come from known sources;
- all wastes will be subjected to stringent waste acceptance criteria and waste acceptance procedures;
- all wastes will be inspected at the weighbridge. All site operatives will be trained to inspect waste upon tipping to ensure that it meets the WAC and to implement an accident management plan to remove non-conforming materials immediately; and
- environmental monitoring, as specified in Section 5.0 be undertaken

4.5 Hydrogeological Completion Criteria

Due to the nature of the waste it is concluded that the site will be complete (that is, the site no longer has the potential to cause damage to or deterioration of the environment and risk to human health) with respect to hydrogeology immediately after the completion of restoration works and/or definite closure of the site.

5.0 Requisite surveillance

5.1 The Risk Based Monitoring Scheme

The EPR require that "*requisite surveillance*" is undertaken where disposal of substances potentially giving rise to Hazardous Substances or Non-Hazardous Pollutants has been authorised by the Environment Agency. Therefore environmental monitoring will be undertaken to provide assurance that the site is not resulting in any detrimental effects on water quality.

5.2 Leachate Monitoring

WAC testing will be completed on selected wastes prior to deposition at the site. There is no requirement for leachate monitoring.

5.3 Groundwater Monitoring

The monitoring of groundwater quality around the perimeter of the proposed landfill site will be carried out using the existing network of monitoring boreholes.

In keeping with inert landfill guidance, it is proposed that ongoing groundwater level and quality monitoring is undertaken from at least one up-gradient and two down-gradient boreholes within the underlying Lynch Hill Gravels.

Groundwater level monitoring indicates that groundwater flow is in broadly southerly direction across the site, it is therefore proposed that the following boreholes are used for groundwater quality monitoring purposes going forward:

- Background: BHA and BHB
- Down-Gradient: BHC and BHD

The proposed monitoring schedule is outlined in Table 5-1, below and monitoring locations are shown on Drawing HRA1. The proposed schedule is based on current EA landfill monitoring guidance and the results of this HRA.

The respective monitoring boreholes are based on the recorded groundwater contours and the understanding of the hydrogeological regime of the site.

Table 5-1
Proposed Groundwater Monitoring Schedule

Groundwater Monitoring Locations	Monitoring Frequency	Measurement and Analytical Suite
Up-gradient BHA BHB	Quarterly	Groundwater level (mAOD), electrical conductivity, chloride, ammoniacal nitrogen, pH, sulphate, lead, copper and arsenic.
Down-gradient BHC BHD	Annual	Cadmium, zinc, mercury, BTEX (benzene, toluene, ethylbenzene & xylene), Polychlorinated Biphenyls (PCB), Acenaphthylene, Total PAHs, Aromatic C10-C12, well base (mAOD).

5.4 Surface Water Monitoring

There are not considered to be any surface water receptors at immediate risk from Cockhide Farm therefore it is not proposed that any surface water monitoring is required. The location of the groundwater monitoring wells means that these provide early identification of any release which could impact the surface water down-gradient of the site. The relevant freshwater EQS have been taken into account in setting the proposed control and compliance limits.

5.5 Control Levels and Compliance Limits

5.5.1 Groundwater & Surface Water

The HRA has demonstrated that the site will limit the release of both Hazardous Substances and Non-Hazardous Pollutants. However, it is appropriate to set appropriate control levels and compliance limits for suitable representative determinands. Based on the above assessment it is considered appropriate to use the following determinands for compliance monitoring:

- Lead: common hazardous metal in inert waste with relatively low background concentrations;
- Benzene: representative BTEX;
- Arsenic: representative hazardous metal with relatively high risk factor; and
- Sulphate: conservative determinand which can potentially provide an early indicator of leachate leakage.

Control levels and compliance limits have been set for each of the determinands above for the proposed compliance boreholes within the Lynch Hill Gravels.

It is not considered appropriate to set a compliance limit for ammoniacal nitrogen or chloride as both have been recorded at notably elevated concentrations in background groundwater and are therefore not considered to be useful indicator species.

The control levels and compliance limits have been set as follows:

- Lead: compliance limit set at its UKTAG *'concentration in groundwater below which the danger of deterioration in the quality of the receiving groundwater is avoided';*
- Benzene: the compliance limit has been set at its Minimum Reporting Value / EAL;
- Arsenic: the compliance limit has been set at its mean background + 3X Standard Deviation, to reflect the fact that background arsenic is elevated in relation to its MRV and DWS. It is noted that this is above its EQS but this reflects the presence of arsenic in background groundwater and provides some leeway for potential future variation in background quality.
- Sulphate: the compliance limit has been set midway between maximum background quality (119mg/l) and the UK DWS (250mg/l) and the control level has been set at the mean background + 2X standard Deviations

The above approach is considered highly conservative as the proposed limits for sulphate and copper are well below the respective DWS limits. This approach has been used to reflect the potentially sensitivity of the aquifer and to ensure there is no significant deterioration in groundwater quality while allowing for potential future degradation in the background, as noted by the observed impact with relation to other determinands.

Table 5-2
Proposed Groundwater and Surface Water Compliance Limits and Control Levels

BHID	Determinand	Proposed Compliance Limit (mg/l)	Proposed Control Level (mg/l)
BHC BHD	Sulphate	185	115
	Arsenic	0.017	-
	Lead	0.005	-
	Benzene	0.001	-

6.0 Conclusions

6.1 Compliance with the Schedule 10 of the EPR

The results of this risk assessment have established the following:

- the proposed landfill will only accept inert waste streams, therefore there is no source and leachate management is not required;
- a sidewall geological barrier with a minimum thickness of 1 metre and a maximum permeability of 1 x 10^{-7}m/s will be provided;
- the modelling undertaken has demonstrated that the proposed landfill will not result in the release of Hazardous substances, and the release of Non-Hazardous Pollutants is sufficiently limited as to avoid pollution of the Lynch Hill Gravels aquifer;
- essential and technical precautions have been outlined;
- requisite surveillance, which includes the monitoring of groundwater around the site has been detailed to ensure the installation remains in compliance with the EPR.
- control levels /compliance limits have been set in order to ensure the adequate protection of ground and surface water resources; and
- the site will comply with the relevant requirements of the Schedule 10 of the EPR.

6.2 Compliance with Schedule 22 (Groundwater Activities) of the EPR

The results of this risk assessment have established the following:

- the proposed development poses a potential hazard to ground and surface water quality. Consequently, it falls within the scope of Schedule 22 (Groundwater Activities) of the EPR;
- this assessment has outlined the conceptual site model that must be carried out for landfills;
- the proposed and installed technical precautions will prevent the discernible discharge of Hazardous Substances to groundwater throughout the site's lifecycle;
- the proposed technical precautions will limit the introduction of Non-Hazardous Pollutants into groundwater so as to avoid pollution throughout the site's lifecycle; and
- the following essential and technical precautions have been identified as part of the hydrogeological risk assessment:
    - the wastes to be accepted to the site will meet inert WAC limits;
    - a risk-based programme of groundwater and surface water monitoring and the implementation of control levels and compliance limits have been outlined.

The site therefore complies with the relevant requirements of the Schedule 22 (Groundwater Activities) of the EPR.

APPENDICES

APPENDIX 01

Hydrogeological Impact Appraisal

Cockhide Farm Quarry

Hydrogeological Impact Appraisal

SLR Ref: 427-01526-00019
Version No: 1
February 2016

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1.0 INTRODUCTION

SLR Consulting has been appointed by Ingrebourne Valley to prepare a Hydrogeological Impact Appraisal (HIA) to accompany a planning application for a proposed extension to Baldwins Farm Quarry and restoration with inert waste. The extension site is referred to as Cockhide Farm and is located near to South Ockendon, Essex. The National Grid Reference for the centre of the Site is TQ 569 829. The extension is referred to as 'the Site' in this report. The location of the site is shown on Drawing 1.

The proposed development will work the in-situ Lynch Hill Gravel deposits. The purpose of the HIA is to assess the potential risk of the proposed development on hydrological or hydrogeological receptors and provide details of appropriate mitigation measures and a proposed working scheme which will limit any potential impact on identified receptors.

1.1 Background

The current site consists of a single agricultural field and apart from a small area to the southwest of the site it is surrounded by former gravel pits that have been restored with wastes.

Belhus Woods Country Park is located immediately to the south of the development area.

There is no history of any development at the site, which has remained in agricultural use. A large number of other quarries have been developed across the wider area and these have been partially restored to open water areas.

1.2 Methodology

This appraisal has been completed in accordance with the guidance provided within Environment Agency (EA) Science Report SC040020/SR1[1] and is structured as follows:

- Section 2.0 A baseline assessment of the site and includes a summary of the sites geology and hydrogeology including information on ground conditions, groundwater levels and flows and the location of potential receptors which could be impacted as a result of dewatering from the site. Finally a conceptual model of the current hydrogeological regime is provided
- Section 3.0 An assessment of the potential impact that the proposed development will have upon the identified receptors and regional hydrogeology.
- Section 4.0 A summary of the overall impact that the site could have upon the local hydrogeology and any identified receptors.

[1] Environment Agency (April 2007) Hydrogeological Impact Appraisal for Dewatering Abstractions, ref: SC040020/SR1

1.3 Sources of Information

The following sources of information have been consulted to characterise the geology, hydrogeology and hydrology of the area within and surrounding the application site:

- BGS online maps (www.bgs.ac.uk/data/mapViewers/home.html) for details of geology, borehole logs and groundwater classifications;
- Environment Agency Website (www.environment-agency.gov.uk) for details on aquifer classification, source protection zones, groundwater vulnerability, flood risk and Water Framework Directive classifications for groundwater, rivers and coast;
- Institute of Hydrology Flood Estimation Handbook CD ROM Version 3, 2009;
- National Soils Resource Institute Website for details on soils (https://www.landis.org.uk/soilscapes/);
- Natural England Website for details on groundwater and surface water dependent designated sites (http://www.natureonthemap.naturalengland.org.uk);
- Environment Agency information request providing details of licensed abstractions, discharges, environmental monitoring data including surface water flows and quality, groundwater levels and quality and rainfall data, details of flood risk including historic flood events, predicted flood levels etc.;
- Information request from Thurrock Borough Council for details of private water supplies; and
- Details of application site layout, proposed development, and other site details provided by Ingrebourne Valley; and
- Site investigation undertaken by SLR Consulting including borehole logs, groundwater levels and permeability testing.

2.0 BASELINE CONDITIONS

The geological and hydrogeological regime of the application site and the surrounding area is considered in a number of sections: geological setting, hydrogeological setting and hydrological setting, all of which have been used to develop the sites conceptual model.

2.1 Geological Setting

The British geological Survey (BGS) website, shows that the proposed development area is located on superficial deposits comprising Lynch Hill Gravels overlying London Clay bedrock and the Lambeth Group, Thanet Formation and White Chalk sub Group at depth. The geology of the site is shown on Drawings 2a and 2b which shows that most of the gravels adjacent to the Site have been excavated and the outcrop at Cockhide is isolated from the wider outcrop for gravels apart from a small connection in the south-west corner of the site. A summary of the geological sequence at the site is given in Table 2-1.

Table 2-1
Summary of Site Geology

Geological Strata	Description	Typical Thickness
Lynch Hill Gravels	Medium to coarse sand and gravel	2.20m - 4.0m
London Clay	Very stiff grey silty clay with bands of silt and sand	Up to 150m
Lambeth Group	Variable sequences mainly of clay, some silty or sandy, with some sands and gravels, minor limestones and lignites and occasional sandstone and conglomerate	Up to 39m
Thanet Formation	Glauconite-coated, nodular flint at base, overlain by pale yellow-brown, fine-grained sand that can be clayey and glauconitic. Rare calcareous or siliceous sandstones.	0 to 30m
White Chalk Sub Group	White Chalk with flints	100m+

A site investigation (SI) was undertaken at the site in August 2015 which included the drilling of three boreholes across the Site to depths of between 4.5m and 6m into the London Clay bedrock. Borehole logs for the SI are included as Appendix A and the particle size distribution of samples from the boreholes are summarised in Table 2-2.

The SI indicates that the sands and gravels are between 2.2m and 4m in thickness and described as *'medium to coarse sand and gravel'* with the underlying bedrock described as *'firm dark grey clay'*.

Table 2-2
Particle Size Distribution Analysis Results

Sieve Size	% Passing		
	Sample 1	Sample 2	Sample 3
125mm	100%	100%	100%
90mm	100%	100%	100%
75mm	100%	100%	100%
63mm	100%	100%	100%
50mm	100%	100%	98%
37.5mm	100%	97%	97%
28mm	98%	86%	93%
20mm	98%	71%	85%
14mm	98%	55%	78%
10mm	98%	46%	72%
6.3mm	98%	38%	66%
5mm	98%	35%	64%
3.35mm	98%	32%	61%
2mm	98%	29%	58%
1.18mm	97%	26%	53%
600µm	96%	22%	46%
425µm	96%	18%	33%
300µm	96%	5%	15%
150µm	38%	3%	6%
63µm	17%	2%	4%

The PSD results indicates that the Lynch Hill gravels range from a predominantly fine to medium sand (Sample 1) through to a predominantly medium to coarse gravel (Sample 2).

2.2 Hydrogeological Setting

2.2.1 Recharge Mechanisms

The MetOffice climate summary (1981 – 2010) for Stanford Le Hope[2], located c.8km east of the site, indicates that the average annual rainfall for the site is 571.3mm per annum.

The Environment Agency has provided summary data for a rainfall gauge in Central Park, Romford, located c. 7.8km north-west, for the period April 1990 to October 2015. The available monitoring data is summarised in Table 2-3.

Table 2-3
Average Monthly Rainfall at Central Park, Romford (April 1990 – October 2015)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
46.4	36.7	29.1	37.6	38.1	41.7	42.3	52.4	45.1	50.7	50.6	43.8	519.8

[2] MetOffice Website (Accessed 06/01/16) *http://www.metoffice.gov.uk/public/weather/climate/gcpsvg2yz*

The Site is located in a low rainfall area with high potential evapotranspiration. Recharge to the underlying aquifer will be low and typically of the order of 100 to 150mm per annum. Given that much of the gravel has been removed and the voids backfilled with relatively low permeability wastes and the sites capped, recharge to groundwater is likely to be very low.

2.2.2 Aquifer Characteristics and Groundwater Vulnerability

The Environment Agency (EA) classify the Lynch Hill Gravels as a Secondary A Aquifer, described as:

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

The underlying London Clay is classified as Unproductive Strata and the Lambeth Group and Thanet Sands are also Secondary A Aquifers. The underlying Chalk Sub Group if defined as a Principal aquifers that is:

> *"layers of rock or drift deposits that have high intergranular and/or fracture permeability - meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale."*

A laboratory permeability test undertaken on a single bulk sample of the Lynch Hill gravels. The permeability test results are included within Appendix B and recorded a coefficient of permeability of 4.1×10^{-4}m/sec.

2.2.3 Groundwater Levels and Flows

Groundwater level monitoring data has been provided by Ingrebourne Valley for ten boreholes installed within the Lynch Hill gravels across the wider Baldwins Farm site. Monitoring data is available for the period January 2012 to December 2015 and is summarised in Table 2-4.

Table 2-4
Groundwater Level Monitoring Data at Baldwins Farm

BHID	Strata Details	Groundwater Level (mAOD)				
		Count	Min	Mean	Max	Range (m)
BF01	Virgin ground	49	17.40	18.08	18.90	1.50
BF02	All made ground	49	14.41	15.00	15.61	1.20
BF03	Virgin ground	47	14.67	15.72	16.60	1.93
BF04	Made ground to 3.0, then virgin (?)	49	17.76	18.79	19.87	2.11
BF05	Made ground to 4.8 then sand and gravel.	49	19.39	20.13	21.24	1.85
BF06	Made ground to 1.6m, then virgin	49	19.84	20.27	20.75	0.91
BF07	All made ground	49	18.59	19.52	20.30	1.71
BF08	Made ground to 1.0m then virgin	49	14.77	15.53	16.28	1.51
BF10	Virgin ground	49	19.79	20.23	21.06	1.27
BF11	All made ground	49	19.04	19.49	20.19	1.15

The available monitoring data indicates that groundwater levels have a typical seasonal variation of approximately 1m, increasing to approximately 1.5m during the exceptionally wet period of December 2013 to January 2014.

The locations of groundwater monitoring boreholes are shown on Drawing 3. The boreholes are installed in a variety of ground conditions including virgin ground, made ground or a combination of the two. Groundwater contours for March 2015 showing typical high winter groundwater levels (Drawing 3). Groundwater flow across the area is in a predominantly south or south-easterly direction, following the regional topography which dips to the base of a valley in which the Running Water Brook flows. However, as described above some of the boreholes are installed in isolated remnants of the Lynch Hill Gravels and are separated by areas were the gravel has been excavated and the resulting void backfilled with waste materials, others are installed in backfilled material. The hydraulic characteristics of this material are not known but they are likely to have a relatively low permeability. Given the variability of ground conditions it is unlikely that a consistent water table and groundwaters flow direction is present in the area. Flow is likely to follow local permeable routes and discharge into ditches adjacent to the landfilled areas.

Despite the lack of a homogeneous aquifer groundwater levels show relatively consistent trends as shown in Figure 1 and Figure 2. Groundwater levels in the area are typically shallow; varying between ground level and 3m below ground level.

Figure 1
Groundwater Hydrographs Depth below Ground Level

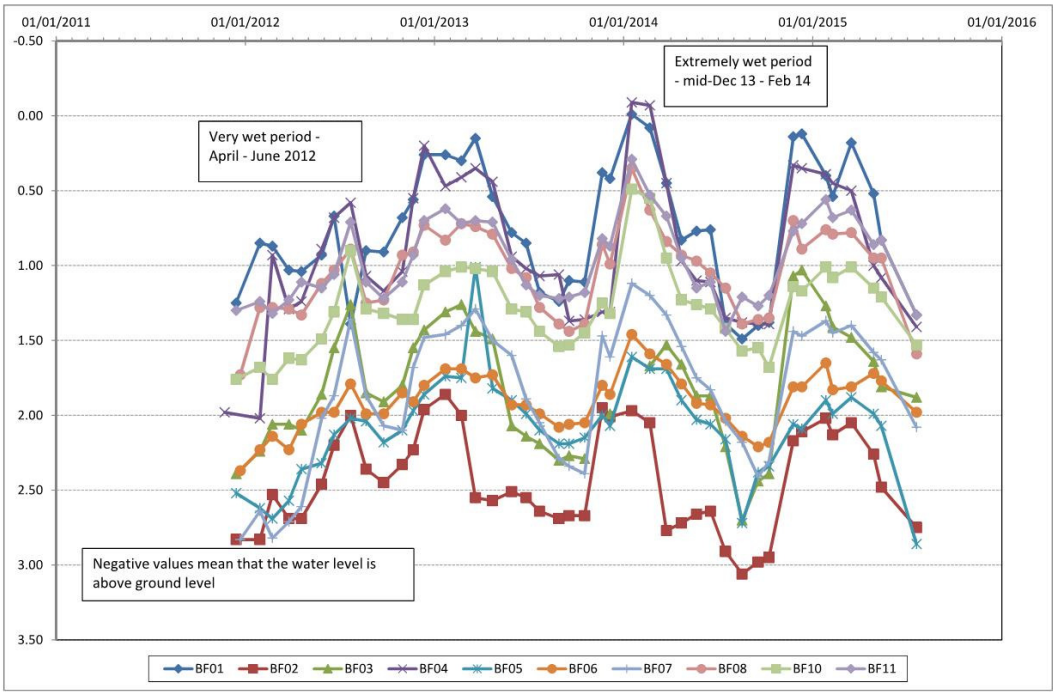
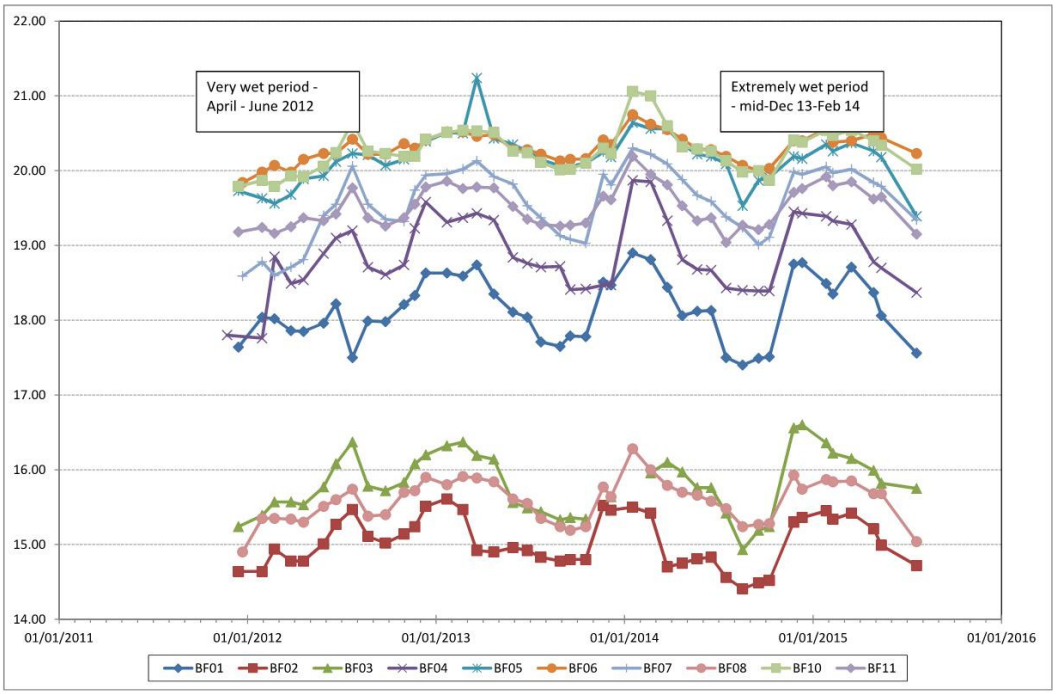


Figure 2
Groundwater Hydrographs Metres above Ordnance Datum



The nearest monitoring boreholes to the Site are BF08, located to the east and BF11, located to the north-west. The monitoring data for these two boreholes indicates that groundwater levels within these boreholes typically range between c.0.5m and 1.5m below ground level and exhibit comparable variations, indicating a good hydraulic continuity across the aquifer.

2.2.4 Groundwater Abstractions and Source Protection Zones

The Environment Agency has confirmed that the proposed development is not located within a groundwater Source Protection Zone (SPZ) and there are no licensed abstractions within a 2km radius of the application site.

Thurrock Borough Council has indicated that they do not have any records of private water supplies within a 2km radius of the site.

A review of the Thames catchment abstraction licensing strategy[3] indicates that the area is classified as having *"No water available".*

[3] Environment Agency (May 2014) *Thames Catchment Abstraction Licensing Strategy*

2.2.5 Water Dependent Ecological Sites

A review of the Natural England Magic Map webpage[4] indicates that there are no ecologically designated sites located within a 2km radius of the site. The closest are Ingrebourne Marshes Site of Special Scientific Interest (SSSI) located c.2.1km to the north-west which is also a designated as a Local Nature Reserve. It has been designated for its variety of flora and fauna associated with a series of lakes, marshes and lowland swamps.

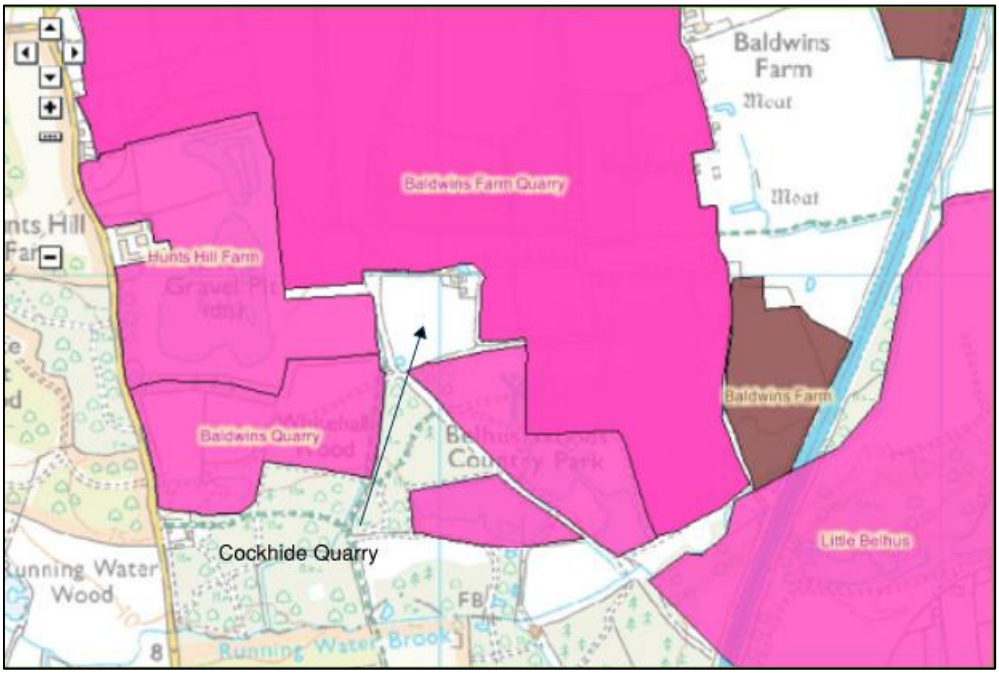
2.2.6 Landfill Sites

Extensive landfilling has taken place in the vicinity of the application site, primarily associated with quarrying of the superficial gravels with landfilling undertaken for backfilling of the quarry voids. The Environment Agency has confirmed that there are two authorised and 16 historic landfill sites recorded within a 2km radius of the application site.

The application site is surrounded on all sides by historic landfills including several landfills associated with Baldwins Farm Quarry to the north and east, Hunts Hill Farm Quarry to the west and south.

A plan form the Environment Agency website showing the location of the landfilled areas is shown as Figure 3.

Figure 3
Location of Landfilled Areas



The site is surrounded by four landfilled areas the details of which are given in Table 2-5.

[4] Natural England Magic Website (Accessed on 08/01/16)
http://www.natureonthemap.naturalengland.org.uk/MagicMap.aspx

Table 2-5
Adjacent Landfilled Area

Site Name	Location Relative to Cockhide Quarry	Start and Finish Dates	Waste type
Baldwins Farm Quarry	North and east	1947 1984	Industrial, commercial and household
Hunts Hill Farm	West	1979 to 1982	Inert, industrial and commercial
Baldwins Farm Quarry	South west	1980 to 1988	Inert
Hunts Hill Farm*	South	1979 1982	Inert, industrial and commercial

Notes: * Possible extension of the site to west.

Baldwins Farm quarry accepted waste between c.1947 and 1984 and is thought to have received a combination of industrial, commercial and household waste. Two permitted landfill areas are located to the east and north-east of the site respectively and receive non-biodegradable wastes.

Hunts Hill Farm quarry was active between 1979 and 1982 and received a combination of inert, industrial and commercial wastes.

2.2.7 Groundwater Quality

There is no groundwater quality data available for the application site.

2.2.8 Local Hydrology

The application site is located within the catchment of the Running Water Brook, a minor watercourse which flows in a predominantly westerly direction, approximately 500m to the south of the site.

The running water brook rises near to Kemp Farm, c.1.3km north-east of the site, and flows in a westerly or south-westerly direction, approximately 600m to the south of the site, towards the River Thames. The watercourse is renamed the Common Watercourse to the west to the Site and ultimately outfalls to the Thames at Rainham Marshes c.6km to the south-west of the Site.

There are no watercourses within the site boundary itself, although a minor watercourse flows in a southerly direction along the western edge of the track which forms the western boundary of the site. There is a small pond in the south west corner of the site that discharges to the water course referred to above. This watercourse flows in a southerly direction from the site and outfalls to the Running Water Brook in Running Water Wood.

Numerous other lakes and ponds are recorded within a 2km radius of the site, these have primarily been formed within the voids of historic sand and gravel quarries and are likely to be in hydraulic continuity with the regional groundwater.

Based on the groundwater levels and flows it is considered likely that the Running Water Brook is in hydraulic continuity with the groundwater within the superficial Lynch Hill Gravels.

2.3 Conceptual Site Model

The assessment of the baseline conditions of the Site indicates that the proposed development is located on a thin sand and gravel aquifer over low permeability clays. The aquifer is typically 2 to 4m thick and is saturated to within 0.5m of ground levels. It has a permeability of circa $4x10^{-4}$m/sec. Most of the adjacent sand and gravels have been excavated and the resultant voids backfilled with waste including inert, commercial, industrial and household wastes. Although groundwater contours indicate a groundwater flow direction of south or south-east given the disturbed and variable nature of ground conditions it is likely that flow directions are complex, varying over a short distances. There if no groundwater quality data for the Site for the adjacent areas but given the widespread landfilling in the area dating back nearly 70 years groundwater quality is likely to be poor.

3.0 HYDROGEOLOGICAL IMPACT APPRAISAL

3.1 Proposed Development

The proposed development includes the quarrying of sands and gravels associated with the Lynch Hill gravels superficial deposits. The proposals are to fully excavate to the base of the Lynch Hill gravels down to the top of the underlying London Clay. The site will be worked 'wet' (i.e. no dewatering is proposed) to minimise the potential impact from surrounding historic landfilling.

The sides of the excavation will be lined with low permeability clay barrier 1m tick with a maximum permeability of 1 x 10-7m/s or equivalent. The site will progressively be restored with inert waste. The site will ultimately be restored to agricultural use creating a slightly domed landform which will be restored using site soils. The proposed working and restoration scheme are included as Appendix C.

3.2 Prediction of Likely Level of Effort

In order to assess the likely level of effort required to complete the appraisal, the EA has devised a scoring exercise taking into account the hydrogeology and the site setting, and this is presented within Table 4-1 below.

Table 3-1
Scoring Criteria, Classes and Weights

Criteria and Classes	Score	Weight	Total	Description
Aquifer Characteristics				
Karst	4			
Principal Aquifer	3	2	4	Lynch Hill Gravels are classified as a Secondary Aquifer
Secondary Aquifer	***2***			
Unproductive Strata	1			
Water-dependent conservation sites				
Habitats Directive (Natura 2000) sites	4	4	4	No recorded water dependent conservation sites within vicinity of the site
Sites of Special Scientific Interest	3			
Other Designations	*2*			
None	***1***			
Water resource availability status				
Over-abstracted	4	1	2	Based on the Thames CAMS document
Over-licensed	3			
No water available	***2***			
Water available	*1*			
Dewatering Quantity				
Very large (>5,000m^3/day)	*4*			Estimated dewatering volume of <1000m^3/day as calculated in section 4.3.1 below.
Large (2,500 to 5,000m^3/day)	3	3	3	
Medium (1,000 to 2,500m^3/day)	2			
Low (<1,000m^3/day)	**1***			
Total			**15**	

Note: Score for application site shown in **bold**
* The site will not be actively dewatered

3.3 Assessment of Impact

Table 3-1 above indicates that the level of effort required for the hydrogeological impact appraisal should be low, given that the total weighted score for the application site is less than 21. As the site will not be actively dewatered impacts on the hydrogeological regime of the area of working the mineral is likely to be limited.

The site will be worked wet using a long arm excavator the impact of the development on groundwater levels will be insignificant. Following removal of the mineral the site will be lined with low permeability clay prior to restoration with inert wastes. This will form a local barrier to groundwater flow and could alter groundwater levels and flow directions. However, the site is a relatively isolated outcrop of gravel surrounded on three sides by landfilled areas, the impact on groundwater levels is therefore unlikely to be significant. The lack of sensitive water features such as abstractions or water dependant site indicates that the any impact from the development will be insignificant.

4.0 CONCLUSION

A hydrogeological impact appraisal has been undertaken to assess the potential impact of the proposed sand and gravel quarry at Cockhide Farm Quarry on the local hydrogeological and hydrological regime.

A review of the current baseline hydrogeology and hydrology of the site indicates that the local geology comprises of superficial Lynch Hill Gravels overlying London Clay at a depth of between 2.2 to 4m below ground level.

The London Clay is classified as unproductive strata and are considered to have minimal groundwater potential; the Lynch hill Gravels are classified as a Secondary A Aquifer. Such aquifers can be locally important for both abstractions and providing baseflow for local watercourses and water features. However the gravels at Cockhide Farm Quarry form an isolated outcrop surrounded on three sides by landfilled former quarry and is unlikely to provide significant flow to local watercourses.

The assessment has not identified groundwater dependant receptors which could be impacted by the proposed development; this includes water abstractions and water dependant ecosystems.

It is proposed that the site is worked wet and hence the impact on groundwater levels will be insignificant. The site will be restored with inert wastes which could form a barrier to groundwater flow. However as described above, due to the extensive landfilling in the area and the lack of receptors the impact on groundwater levels is unlikely to be significant.

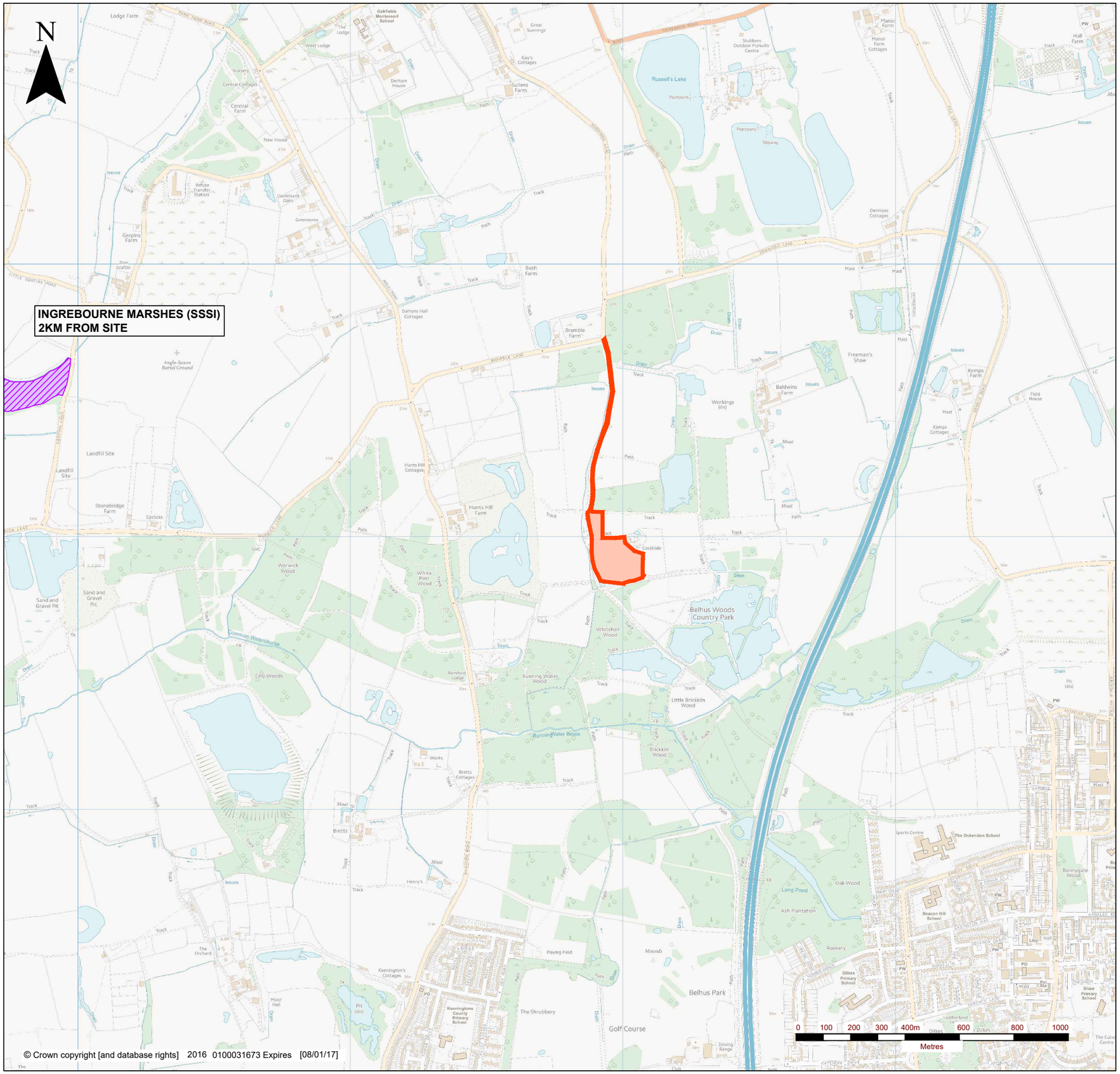
5.0 CLOSURE

This report has been prepared by SLR Consulting Limited with all reasonable skill, care and diligence, and taking account of the manpower and resources devoted to it by agreement with the client. Information reported herein is based on the interpretation of data collected and has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of Ingerbourne Valley; no warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the client and others in respect of any matters outside the agreed scope of the work.

Drawings



LEGEND

SITE LOCATION

SITE OF SPECIAL SCIENTIFIC INTEREST (SSSI)

INGREBOURNE VALLEY LTD

SLR global environmental solutions

69 POLSLOE ROAD
EXETER
DEVON
EX1 2NF
T: +44 (0)1392 490152
F: +44(0)1392 495572
www.slrconsulting.com

COCKHIDE FARM QUARRY

HYDROGEOLOGICAL IMPACT APPRAISAL

SITE LOCATION

DRAWING 001

Scale: SEE DRAWING (A3)

Date: FEBRUARY 2016

01526.00019.18.001.0_SITE_LOCATION.dwg

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NOTE

BGS DATA PURCHASED FROM EMAPSITE LICENCE NO. 2011/3PDL/349157 BRITISH GEOLOGICAL SURVEY © NERC.

LEGEND

SITE LOCATION

DRIFT GEOLOGY

- ALLUVIUM - CLAY, SILT, SAND AND GRAVEL
- HACKNEY GRAVEL MEMBER - SAND AND GRAVEL
- LYNCH HILL GRAVEL MEMBER - SAND AND GRAVEL
- TAPLOW GRAVEL FORMATION - SAND AND GRAVEL
- BOYN HILL GRAVEL MEMBER - SAND AND GRAVEL
- HEAD - CLAY, SILT, SAND AND GRAVEL
- BEDROCK AT OR NEAR SURFACE

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EX1 2NF

T: 0139 249 0152
www.slrconsulting.com

COCKHIDE FARM QUARRY

HYDROGEOLOGICAL IMPACT APPRAISAL

DRIFT GEOLOGY

DRAWING 2A

Scale 1:10,000 @ A3

Date FEBRUARY 2016

01526.00019.18.002A.0_DRIFT_GEOLOGY

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BGS DATA PURCHASED FROM EMAPSITE LICENCE NO. 2011/3PDL/349157 BRITISH GEOLOGICAL SURVEY © NERC.

LEGEND

SITE LOCATION

SOLID GEOLOGY

LONDON CLAY FORMATION - CLAY, SILT AND SAND

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T: 0139 249 0152
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COCKHIDE FARM QUARRY

HYDROGEOLOGICAL IMPACT APPRAISAL

SOLID GEOLOGY

DRAWING 2B

Scale 1:10,000 @ A3

Date FEBRUARY 2016

01526.00019.18.002B.0_SOLID_GEOLOGY

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N

Bush Farm

Track

Track

Bramble Farm

BRAMBLE LANE

22m

21m

22m

DENNISES LANE

BF01
18.71

BF05
20.37

BF06
20.40

BF10
20.54

BF11
19.85

BF07
20.02

BF04
19.28

BF02
15.42

BF03
16.15

BF08
15.85

Mast

Mast

Mast

Path

DENNIS ROAD

Drain

Drain

Drain

Drain

Drain

Issues

Issues

Track

Track

Track

Track

Track

Track

Track

Track

Track

Path

Path

Path

Path

Workings
(dis)

Baldwins Farm

Freeman's Shaw

Moat

Moat

Tk

Hunts Hill Farm

Cockhide

Belhus Woods

20

18

16

20

18

16

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NOTES

LYNCH HILL GRAVEL HAS BEEN EXTENSIVELY WORKED AND QUARRIES BACKFILLED. THE CONTINUITY OF THE WATER TABLE IS UNCERTAIN.

LEGEND

SITE LOCATION

BF04 19.28 GROUNDWATER MONITORING POINT

18 GROUNDWATER CONTOUR MARCH 2015 (m/bgl)

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69 POLSLOE ROAD
EXETER
DEVON
EX1 2NF
T: +44 (0)1392 490152
F: +44(0)1392 495572
www.slrconsulting.com

COCKHIDE FARM QUARRY

HYDROGEOLOGICAL IMPACT APPRAISAL

GROUNDWATER CONTOURS

DRAWING 003

Scale 1:5000 @ A3

Date FEBRUARY 2016

01526.00019.18.003.0_GROUNDWATER_CONTOURS.dwg

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Appendices

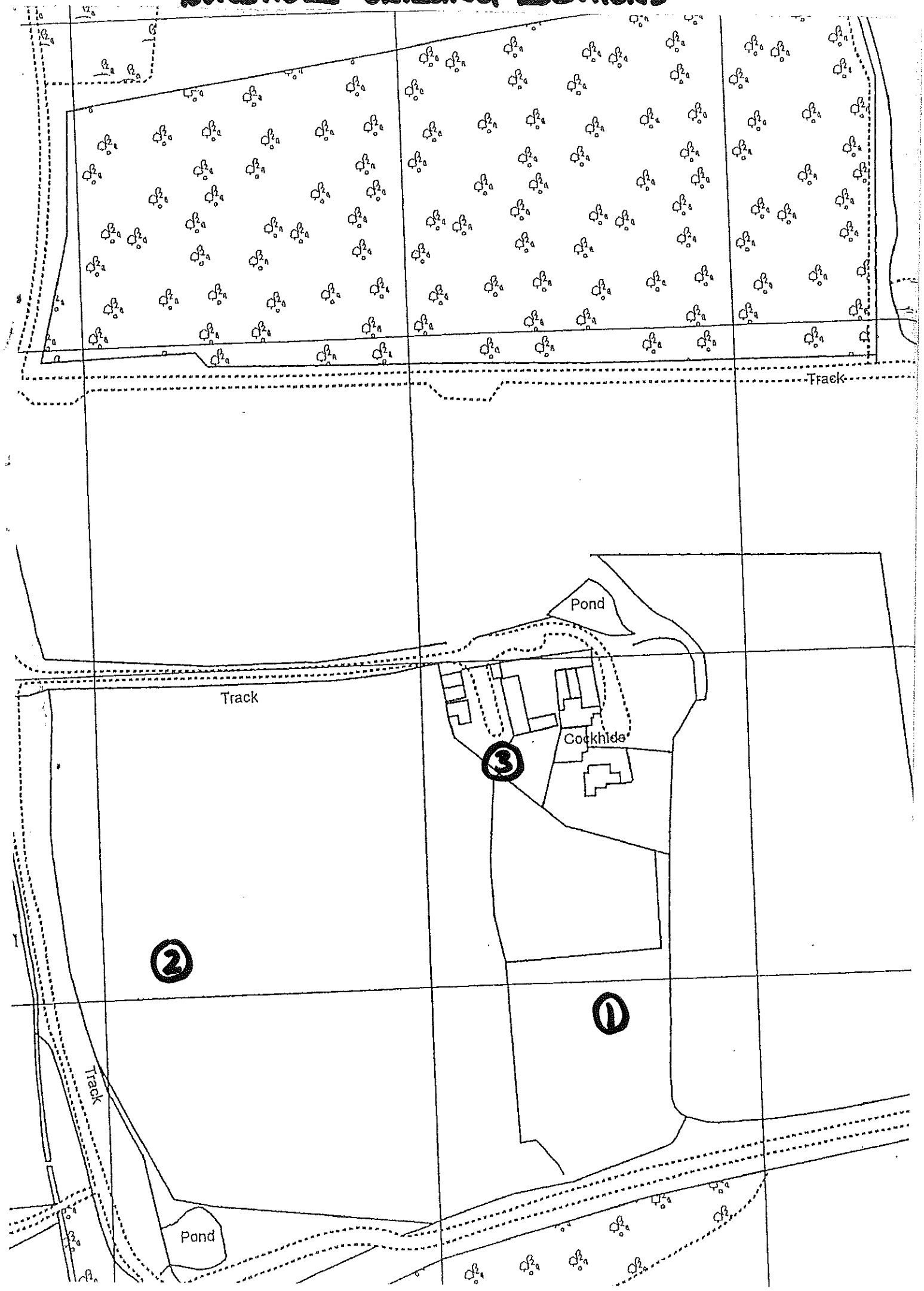
Appendix A Borehole Logs

BOREHOLE LOG Summary

SITE REF: South Ockendon
DATE: 26.08.15

BH	From(m)	To(m)	Description	Sample
01	0	0.2	v.sandy TS/SS	
	0.2	1.5	v.fine orange SAND, SILT and CLAY	01/1 (0.5-1.5m)
	1.5	3.8	seams v.fine SAND/v.silty fine SAND/v.clayey fine SAND	
	3.8	4.2	v.sandy GRAVEL (<50mm)	
	4.2	4.5	firm red/brown CLAY	
	4.5	6.0	firm dk grey CLAY	
02	0	0.2	sandy TS	02/1(0.5-2.4m)
	0.2	2.4	SAND and GRAVEL(<50mm)	
	2.4	4.5	firm dk brown/grey CLAY	
03	0	0.2	sandy TS/SS	
	0.2	3.0	med.-coarse SAND and GRAVEL	03/1(1.5-3.0m)
	3.0	4.5	firm dk grey CLAY	
04	0	0.2	TS/SS	
	0.2	1.8	v.fine orange SAND, SILT and CLAY	
	1.8	4.0	fine-med. pale SAND, occ. clay seam	
	4.0	5.8	med.-coarse pale SAND	
	5.8	6.0	dk grey CLAY	
05	0	0.2	TS/SS	
	0.2	1.7	fine SAND, SILT and CLAY	
	1.7	4.0	SAND	
	4.0	4.4	SAND and GRAVEL	
	4.4	4.7	brown CLAY	
	4.7	6.0	firm dk grey CLAY	
06	0	0.2	TS/SS	
	0.2	2.0	fine SAND, SILT and CLAY	
	2.0	3.0	wet fine SAND, SILT and CLAY	
	3.0	4.5	soft dk grey/grey CLAY	
07	0	0.2	TS/SS	
	0.2	1.8	slightly gravelly firm brown CLAY	
	1.8	2.6	wet sandy brown CLAY	
	2.6	5.4	grey SILT and CLAY	
	5.4	5.8	v.gravelly silty fine grey SAND	
	5.8	6.0	firm dk grey CLAY	
08	0	0.2	TS/SS	
	0.2	1.6	v.silty sl.clayey orange/grey SAND	
	1.6	2.4	soft dk grey SILT with organic matter	
	2.4	4.5	v.silty clayey grey SAND	
09	0	0.2	TS/SS	

BOREHOLE DRILLING LOCATIONS



Appendix B Lynch Gravel Permeability Test

TESTCONSULT LIMITED
Bruton House, Stadium Way, Harlow, Essex, CM19 5FT
Tel (01279) 729029 Fax (01279) 416879

LABORATORY TEST REPORT
SUBCONTRACTED TESTING REPORT

Project:	Cockhide	**Job No.:**	5652
Client:	Ingrebourne Valley	**SA Number:**	SA15691
	Cecil House,	**Date Recieved**	24/11/2015
	Foster Street,	**Date Sampled:**	24/11/2015
	Harlow,	**Date Reported:**	17/12/2015
	CM17 9HY	**Material:**	Sandy Clay
Originator	**Maria Anton-Garcia**		

Please see attached certificate

Approved Signature
TESTCONSULT LIMITED
■ Richard Lawry-Johns, Senior Laboratory Technician

Testconsult Harlow Limited
Bruton House
Stadium Way
Harlow
Essex
CM19 5FT

Date: 17 December 2015
Test Report Ref: STR 442836

Order No: RLJ/13010/2129

LABORATORY TEST REPORT

TEST REQUIREMENTS: To determine the Permeability of a sample by the Constant Head Method in accordance with **BS 1377: 1990: Part 5.**

SAMPLE DETAILS:

Certificate of sampling received:	**No**
Laboratory Ref. No:	**S56122**
Client Ref. No:	**SA15691**
Date and Time of Sampling:	**Unknown**
Date of Receipt at Lab:	**04/12/2015**
Date of Start of Test:	**14/12/2015**
Sampling Location:	**Unknown**
Name of Source:	**Unknown**
Method of Sampling:	**Unknown**
Sampled By:	**Client**
Material Description:	**Sandy Clay**
Target Specification:	**N/A**

RESULTS:

Diameter of Permeameter Cell:	**115mm**
Height of Permeameter Cell:	**450mm**
De aerated water used?	**~~Yes~~ / No**
Proportion and size of material removed before preparing test sample:	**0.2**
Method of placing and compacting:	**Hand tamping / ~~Placing under water~~**

Dry Density:	**1.205Mg/m^3**
Coefficient of Permeability k at 20°C:	**4.142x10^{-4}m/sec**

Comments
None

Certificate Prepared by:-
Joseph Parry
Job Coordinator

Approved by: -
Eric Goulden
Technical Manager

Celtest Company Limited. Registered in Wales and England 1533370. Vat No. 352-5034-81

Appendix C Site Layout and Phasing Plan

Access to Bramble Lane / Sunnings Lane via wheelbath (see inset detail)

Public Footpath (Havering FP 259)

Access corridor (road width 3m with passing bays)

Passing bay

Public Footpath (Havering FP 258)

Overhead ETL

Passing bay

Car park / security compound

Screening bund (2m high)

Receiving area

Office & weighbridge

Screening bund (2m high)

COCKHIDE FARM (derelict buildings)

Existing pond

Temporary stockpile area

Application boundary (red line)

General direction of operations

Drainage

Screening bund (3m high)

EXTRACTION AREA

Public Footpath (Thurrock FP 140)

Track

Pond

Drain

1.22m RH

SUNNINGS LANE

BRAMBLE LANE

Hardcore section of access road with proposed location of wheel bath

Road widens to c.6m from this point north to entrance onto Bramble Lane / Sunnings Lane

Overhead ETL

Passing bay

Access corridor to excavation & receiving area (road width 3m with passing bays)

INSET DETAIL SHOWING ACCESS ROAD AND WHEEL BATH SCALE - 1:2,500

N

0m 50m 100m

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Version / amendment: 1211/C/O/1 v4

D.K. Symes Associates

Illustrative Operations Plan

Scale - **1:2,500** (at A3)

Date - **01-08-2016**

Plan No. **1211/C/O/1**

ABERDEEN
214 Union Street,
Aberdeen AB10 1TL, UK
T: +44 (0)1224 517405

AYLESBURY
7 Wornal Park, Menmarsh Road,
Worminghall, Aylesbury,
Buckinghamshire HP18 9PH, UK
T: +44 (0)1844 337380

BELFAST
Suite 1 Potters Quay, 5 Ravenhill Road,
Belfast BT6 8DN, UK, Northern Ireland
T: +44 (0)28 9073 2493

BRADFORD-ON-AVON
Treenwood House, Rowden Lane,
Bradford-on-Avon, Wiltshire BA15 2AU,
UK
T: +44 (0)1225 309400

BRISTOL
Langford Lodge, 109 Pembroke Road,
Clifton, Bristol BS8 3EU, UK
T: +44 (0)117 9064280

CAMBRIDGE
8 Stow Court, Stow-cum-Quy,
Cambridge CB25 9AS, UK
T: + 44 (0)1223 813805

CARDIFF
Fulmar House, Beignon Close, Ocean
Way, Cardiff CF24 5PB, UK
T: +44 (0)29 20491010

CHELMSFORD
Unit 77, Waterhouse Business Centre,
2 Cromar Way, Chelmsford, Essex
CM1 2QE, UK
T: +44 (0)1245 392170

DUBLIN
7 Dundrum Business Park, Windy
Arbour, Dundrum, Dublin 14 Ireland
T: + 353 (0)1 2964667

EDINBURGH
4/5 Lochside View, Edinburgh Park,
Edinburgh EH12 9DH, UK
T: +44 (0)131 3356830

EXETER
69 Polsloe Road, Exeter EX1 2NF, UK
T: + 44 (0)1392 490152

GLASGOW
4 Woodside Place, Charing Cross,
Glasgow G3 7QF, UK
T: +44 (0)141 3535037

GRENOBLE
BuroClub, 157/155 Cours Berriat,
38028 Grenoble Cedex 1, France
T: +33 (0)4 76 70 93 41

GUILDFORD
65 Woodbridge Road, Guildford
Surrey GU1 4RD, UK
T: +44 (0)1483 889 800

LEEDS
Suite 1, Jason House, Kerry Hill,
Horsforth, Leeds LS18 4JR, UK
T: +44 (0)113 2580650

LONDON
83 Victoria Street,
London, SW1H 0HW, UK
T: +44 (0)203 691 5810

MAIDSTONE
19 Hollingworth Court, Turkey Mill,
Maidstone, Kent ME14 5PP, UK
T: +44 (0)1622 609242

MANCHESTER
8th Floor, Quay West, MediaCityUK,
Trafford Wharf Road,
Manchester M17 1HH, UK
T: +44 (0)161 872 7564

NEWCASTLE UPON TYNE
Sailors Bethel, Horatio Street,
Newcastle-upon-Tyne NE1 2PE, UK
T: +44 (0)191 2611966

NOTTINGHAM
Aspect House, Aspect Business Park,
Bennerley Road, Nottingham NG6 8WR,
UK
T: +44 (0)115 9647280

SHEFFIELD
Unit 2 Newton Business Centre,
Thorncliffe Park Estate, Newton
Chambers Road, Chapeltown,
Sheffield S35 2PW, UK
T: +44 (0)114 2455153

SHREWSBURY
2nd Floor, Hermes House, Oxon
Business Park, Shrewsbury SY3 5HJ,
UK
T: +44 (0)1743 239250

STAFFORD
8 Parker Court, Staffordshire Technology
Park, Beaconside, Stafford ST18 0WP,
UK
T: +44 (0)1785 241755

STIRLING
No. 68 Stirling Business Centre,
Wellgreen, Stirling FK8 2DZ, UK
T: +44 (0)1786 239900

WORCESTER
Suite 5, Brindley Court, Gresley Road,
Shire Business Park, Worcester WR4
9FD, UK
T: +44 (0)1905 751310

www.slrconsulting.com

APPENDIX 02

Flood Risk Assessment

Cockhide Farm Quarry and Landfill

Flood Risk Assessment

SLR Ref: 402-01526-00019
Version No: 1
February 2016

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DRAWINGS

Drawing 001 **SuDS Drainage Design**

1.0 INTRODUCTION

1.1 Terms of Reference

SLR Consulting Limited was appointed by Ingrebourne Valley Ltd to prepare a Flood Risk Assessment (FRA) to support a planning application for a proposed gravel quarry and subsequent infilling with inert waste of land at Cockhide Farm, Nr South Ockendon, Essex (The Site). The proposed development is an extension to the historic Baldwins Farm quarry, located to the north and east of the site.

1.2 Background and Aims

This report has been prepared to consider the risk of flooding to the application site and to offsite receptors as a result of the proposed development and to recommend mitigation measures, where considered appropriate. In addition, the impact of the proposed restoration on the risk of flooding elsewhere has been considered.

The provisions of National Planning Policy Framework[1] (NPPF) and associated Planning Practice Guidance[2] (PPG) have been considered in preparing the FRA.

The indicative flood maps published on the Environment Agency's website show that the proposed site is located entirely within Flood Zone 1 – low probability, defined as land assessed as having a less than 1 in 1,000 annual probability of river flooding (<0.1%).

Although the flood risk is considered low, because the Site cover an area greater than 1ha, with reference to footnote 20 of the NPPF any planning application must be accompanied by an FRA. An extract of the Environment Agency's indicative flood map is included in Appendix A.

[1] National Planning Policy Framework, Department for Communities and Local Government (2012)
[2] Planning Practice Guidance: Flood Risk and Coastal Change [Online] (March 2014) http://planningguidance.planningportal.gov.uk/blog/guidance/flood-risk-and-coastal-change/

2.0 DEVELOPMENT DESCRIPTION AND LOCATION

2.1 Site Description

The application site is located to the north-west of the town of South Ockendon and immediately to the north of Belhus Woods Country Park. The site is centred at National Grid Reference (NGR) TQ 570 829, as shown by Drawing 001.

The site is currently agricultural fields and is bounded on all sides by former sand and gravel quarries which have either been restored through landfilling or by the creation of lakes and associated habitat, such as at Belhus Woods Country Park to the south.

2.2 Topography

A review of Ordnance Survey (OS) mapping indicates that regionally ground levels fall in a south or south-westerly direction towards the base of the valley of the Running Water Brook. Locally ground levels are relatively flat, falling from c.20mAOD along the northern boundary of the site to c.19mAOD in the south-western corner.

2.3 Hydrological Features

The site is located within the catchment of a small, un-named stream which flows along the western boundary of the site and forms a tributary of the Running Water Brook, which flows from west to east, c.500m to the south of the Site.

The minor watercourse rises to the north-west of the site and runs adjacent to the track which runs along the western boundary of the site. The watercourse flows in a southerly direction, ultimately outfalling to the Running Water Brook within the Running Water wood, c.500m south of the site.

The running water brook rises to the north-east of the site and flows in a predominantly westerly or south-westerly direction towards the River Thames at Rainham Marshes.

Several small ponds are recorded on Ordnance Survey mapping, one just to the north of Cockhide Farm buildings in the north-eastern corner of the site and the other in the south-western corner of the site. Both of these ponds are outside of the working boundary of the site and are likely to be retained. Given the size of the ponds it is unlikely that they are in continuity with groundwater and are likely to be fed by surface water run-off only.

2.4 Geological and Hydrogeological Features

The geological and hydrogeological setting are discussed in detail within Hydrogeological Impact Appraisal[3] and are summarised below.

The local geology comprises of superficial Lynch Hill gravels overlying London Clay Bedrock.

A site investigation undertaken in August 2015 recorded sand and gravel deposits associated with the Lynch Hill gravels of between 2.2m and 4m thick .

[3] SLR Consulting (January 2016) *Cockhide Farm Quarry Hydrogeological Impact Appraisal,* Ref 402-01526-00019

The Environment Agency classify the Lynch Hill Gravels as a 'Secondary A Aquifer' while the underlying London Clay classified as 'Unproductive Strata'.

Available groundwater level monitoring data for the wider Baldwins Farm development indicates that groundwater flow is in a southerly to south-easterly direction across the site with a typical seasonal variation of around 1m. Groundwater levels across the site are estimated to vary from less than 50cm below ground level to up to 2m below ground level.

Available permeability data for the site provided by Ingrebourne Valley indicates that the permeability of the in-situ sands and gravels is in the order of $4x10^{-4}$m/sec (1.44m/hr)[4]

[4] SLR Consulting (Feb 2016) *Cockhide Farm Quarry: hydrogeological Impact Appraisal*, SLR Ref: 427-01526-00019

3.0 DEVELOPMENT PROPOSAL

3.1 Description

The proposed development is for the creation of a quarry to extract the Lynch Hill Gravels. The quarry will be extended to the base of the superficial gravels and will subsequently be restored using inert waste and original Topsoils. The final landform will be comparable to the pre-development situation. The site will be worked 'wet' (i.e. no dewatering is proposed) to minimise the potential impact from surrounding historic landfilling. The proposed working scheme for the site is included as Appendix B.

3.2 Vulnerability Classification

With reference to PPG *Table 2: Flood risk vulnerability classification*, sites used for *'sand and gravel workings'* are considered as a *'Water Compatible Development'* .

3.3 Planning Context

The application site lies within the the Thurrock Borough Local Plan Area which is currently in production. The local plan will be guided by the 2011 Core Strategy[5] which outlined the current policies in the local area until the local plan is produced. The key policies with relation to flood risk are outlined below:

- *Policy CSTP27:Management and Reduction of Flood Risk*
  - *I. The Council will ensure that flood risk management is implemented and supported through effective land use planning. The Sequential, and where necessary Exception Test, as set out in PPS25 will be employed when allocating sites for development and an Emergency Plan for the Borough will be completed.*
  - *II. The Council will also continue to work collaboratively with the Environment Agency by supporting the area based policy approach adopted in the Thames Estuary 2100 Project. In particular the Council will seek to safeguard existing flood defences and new areas for flood defences, water storage and drainage areas, as well as seeking secondary defences for key assets.*
  - *III. The Council will support the work of the Environment Agency in the Environmental Enhancement Project for the Mucking Flats and Marshes to ensure the delivery of appropriate flood mitigation and environmental enhancement measures.*
  - *IV. The Council will work with the Environment Agency and other main stakeholders to ensure that fluvial and surface water flood risk is managed within Thurrock. This will include supporting the policies identified in the South Essex Catchment Flood Management Plan, such as identifying and safeguarding areas of land for existing and future areas of water storage in Policy Units 9, 10, 11 & 12 and in formulating System Asset Management Plans (SAMP) and the Integrated Urban Drainage Plans for Stanford-le-Hope, Tilbury and Purfleet. A Surface Water Management Plan will also be carried out to assist in the identification and mapping of areas susceptible to surface water flooding as recommended by Defra and the Pitt Review. Development proposals that will affect these locations will be expected to contribute towards infrastructure improvements in these locations to enable the development to proceed.*
  - *V. The Council will ensure that, where necessary, new development throughout the Borough contains space for water including naturalisation and environmental enhancement.*

[5] Thurrock Council (Dec 2011) *Core Strategy and Policies for Management of Development*

VI. *Developers will be required to contribute towards flood risk management infrastructure where appropriate.*
VII. *Planning applications received for sites within Flood Zone 3 will be treated in accordance with PPS25, this policy and Policy PMD15.*

- *Policy PMD15 – Flood Risk Assessment*

1. *Sites not covered by the Thurrock Sequential Test will be required to provide a site-specific Sequential Test to demonstrate compliance with PPS25 or any successor to be provided by the applicant. To reflect the nature of Thurrock's defended floodplain, particular reference should be made to the hazard rating for each site where covered by the Thurrock Strategic Flood Risk Assessment.*
2. *Only those applications classified under the 'minor development' or 'changes of use' categories will be exempt from applying the Sequential Test, but will still be expected to meet the requirements for Flood Risk Assessments and flood risk reduction as set out in Annex E of PPS25 and the associated Design and Sustainability SPD.*
3. *Development proposals subject to the Exception Test in Thurrock must show that the following criteria have been met (in addition to FRA requirements outlined in PPS25):*
   I. *To assist with part a) of the Exception Test, reference should be made to the main assessment criteria outlined in the Thurrock Sustainability Appraisal and any opportunities to reduce the overall flood risk posed to the community, including schemes to make space for water;*
   II. *The FRA must demonstrate that the development will be 'safe', without increasing flood risk elsewhere, and where possible will reduce flood risk overall. For Thurrock, this will mean addressing the following points in particular:*
      i. *Flood hazard must be fully considered and reference should be made in the site-specific FRA to the SFRA, or site-specific modelling. This should be used to inform a sequential approach to planning within the site;*
      ii. *Where it is deemed acceptable to reduce flood storage as a result of development, level for level compensation storage must be provided to ensure that there is no increased flood risk elsewhere;*
      iii. *Where appropriate, an emergency plan for the development must be submitted that is consistent with the emergency plan for the area. This will include evidence that 'more vulnerable' development can achieve safe access/egress to a communal*
      iv. *refuge point or unaffected area accessible to the emergency services. In highly exceptional cases where access/egress to a place of safe refuge cannot be achieved, these will be considered on their individual merits;*
      v. *Where appropriate, flood avoidance, flood resistance and flood resilience measures must be incorporated into the design of any development;*
      vi. *Evidence that surface water management schemes, and other flood defence measures that are required on-site in order to allow a development to take place will be adequately maintained for the lifetime of that development by the site owner;*
      vii. *Evidence that the proposed development will not interfere with the potential for future maintenance or improvements to flood defences.*
4. *Developers may be required to provide Developer Contributions towards the improvement of Emergency Planning services and flood defence measures within Thurrock as part of flood management mitigation.*
5. *Developments will be expected to incorporate Sustainable Drainage Systems (SUDS) to reduce the risk of surface water flooding, both to the site in question and to the surrounding area. Where the potential for surface water flooding has been identified, site specific Flood Risk Assessments should ensure that suitable SUDS techniques are incorporated as part of the redevelopment.*

4.0 POTENTIAL SOURCES OF FLOODING

4.1 Screening Study

There are a number of potential sources of flooding and these include:

- Flooding from rivers or fluvial flooding;
- Flooding from the sea or tidal flooding;
- Flooding from land;
- Flooding from groundwater;
- Flooding from sewers; and
- Flooding from reservoirs, canals, and other artificial sources.

The flood risk from each of these potential sources is discussed below.

4.1.1 Flooding from Rivers or Fluvial Flooding

With reference to the indicative flood map published by the Environment Agency, the proposed site is located entirely within Flood Zone 1, Low probability. The risk of fluvial flooding is therefore not considered significant.

Flooding from this source has not therefore been considered further.

4.1.2 Flooding from the Sea or Tidal Flooding

As the application site is remote from the coast, the risk of tidal flooding is not therefore considered significant.

Flooding from this source has not therefore been considered further.

4.1.3 Flooding from Land

The site has gentle topographies with the combination of perimeter drains and the high permeability of the underlying sand aquifer limiting the potential for surface water flooding of the development site.

Flooding from this source has not therefore been considered further.

4.1.4 Flooding from Groundwater

Available groundwater level monitoring indicates that groundwater levels within the superficial sands and gravels are variable with a typical seasonal variation of between 1m and 1.5m. Groundwater levels within boreholes close to the proposed site range from c.0.5m to 2m below ground level.

Given the proximity of groundwater levels to surface there is considered a potential risk of groundwater flooding to the site.

Flooding from groundwater sources is therefore considered further in Section 5.0.

4.1.5 Flooding from Sewers

Due to the rural site setting it is not anticipated that there are any sewers located within the boundary or up-gradient of the proposed site.

Therefore, the risk of sewer flooding is not significant and has not been considered further.

4.1.6 Flooding from Reservoirs, Canals and Other Artificial Sources

With reference to the Environment Agency Risk of flooding from reservoirs mapping the site is not located within the predicted flood extent of any reservoirs or canals.

Flooding from this source has not therefore been considered further.

4.1.7 Flooding due to Infrastructure Failure

Dewatering is not proposed at the site, there is therefore not considered to be any flood risk associated with infrastructure failure.

Flooding due to infrastructure failure is therefore discussed further in Section 5.0.

4.2 Summary of Sources of Flooding

A summary of the potential sources of flooding is presented in Table 4-1.

Table 4-1
Potential Sources of Flooding

Potential Source	Flood Risk at the Application Site
Fluvial flooding	No
Tidal flooding	No
Overland flow flooding	No
Flooding from rising / high groundwater	Yes (Localised)
Flooding from artificial drainage systems	No
Flooding due to infrastructure failure	No

5.0 ASSESSMENT OF FLOOD RISK

5.1 Historical Flooding

As detailed above there is no historic record of flooding at or near to the application site.

5.2 Probability of the Application Site Flooding

Following the screening study summarised at Section 4.2, the risk posed by the potential sources of flooding identified have been assessed below.

The assessment of flood risk in this report is based on the definitions in PPG *Table 1: Flood zones*, which recognises the following Flood Zones:

- Flood Zone 1 is defined as land which could be at risk of flooding from fluvial or tidal flood events with less than 0.1% (1:1,000 year) annual probability of occurrence i.e. considered to be at 'low probability' of flooding.

- Flood Zone 2 is defined as land which could be at risk of flooding with an annual probability of occurrence between 1% and 0.1% from fluvial sources and between 0.5% and 0.1% from tidal sources i.e. considered to be at 'medium probability of flooding.

- Flood Zone 3a is defined as land which could be at risk of flooding with an annual probability of occurrence greater than 1% (1:100 year) from fluvial sources and greater than 0.5% (1:200 year) from tidal sources i.e. considered to be at 'high probability' of flooding.

5.3 Fluvial Flood Risk

The EA flood mapping indicates that the application site is located entirely within Flood Zone 1, low probability, which with reference to PPG *Table 3: Flood risk vulnerability and flood zone 'compatibility'* is suitable for the proposed development without the requirement for undertaking the exception test.

5.4 Groundwater Flood Risk

Groundwater Level monitoring has been provided for ten boreholes located across the Baldwins farm site for the period January 2012 to December 2015. The monitoring data indicates that groundwater levels within boreholes close to the proposed Site range from c.0.5m below ground level to 2m below ground level.

It is however noted that the maximum groundwater level recorded to date (January 2014) was recorded during an exceptionally wet period with rainfall in excess of 250% of the average for the period[6]. It is therefore considered that these levels are reminiscent of extreme maximum winter groundwater levels. It is considered that the risk of groundwater flooding at the surface either pre or post development is therefore low.

The proposed development will work the site 'wet' and will not require dewatering. There is a potential residual risk to employees at the site for rising groundwater levels during

[6] Met Office (July 2014) *Winter Storms, December 2013 to January 2014 (http://www.metoffice.gov.uk/climate/uk/interesting/2013-decwind)*

excavation rising above the working area, in such an event working at the site would be ceased and there are no proposals for placement of permanent machinery within the working quarry area. The groundwater flood risk will therefore be sufficiently managed as to minimise flood risk to employees at the site.

It is also noted that the client has extensive knowledge of safely working sand and gravel quarries with similar methods of working.

6.0 CLIMATE CHANGE

The most recent advice on climate change is reported in EA Guidance "*Climate Change allowances for Planners*"[7]. This advice confirms that peak rainfall intensity, sea level, peak river flow, offshore wind speed and extreme wave heights are all expected to increase in the future. The guidance recommends that considerations for future climate change are included in Flood Risk Assessments for proposed developments.

As such, in accordance with the advice contained within the EA guidance, the application site is likely to be subject to increases in rainfall intensity of 10% over its active lifetime and up to 30% in the long-term after restoration.

Peak river flows are predicted to increase by 20% over the same period.

The impact of climate change to the proposed development is negligible. Increased rainfall intensity could potentially increase the need for pumping however this would not fundamentally affect the flood risk to the site.

[7] Environment Agency (Sep 2013) *Climate Change Allowance for Planners; Guidance to Support the National Planning Policy Framework*

7.0 OFF SITE IMPACTS

7.1 Existing Surface Water Regime

Currently, rainfall falling upon the site either forms surface water run-off to the minor drains along the field boundary or infiltrates to groundwater via the shallow soils. Recharge rates at the development site are likely to be high.

7.2 Surface Water Management During Excavation

During excavation of surface water run-off from active areas will be routed to the base of the quarry where it will be allowed to infiltrate to groundwater. Given that there are no proposals for dewatering of the quarry there will be no requirement for a discharge from the site.

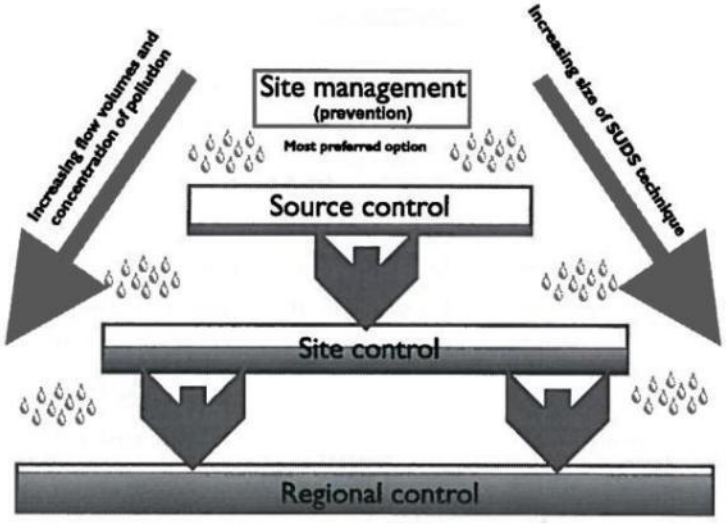
7.3 Surface Water Management Post Restoration

7.3.1 Sustainable Drainage Principles

Current best practice guidance relating to sustainable surface water management is outlined in the SuDS Manual[8] which provides details on the use of Sustainable Drainage Systems (SuDS) for managing surface water runoff.

The SuDS Manual identifies a hierarchy of SuDS for managing runoff, which is commonly referred to as a 'management train' as depicted in Figure 7-1.

Figure 7-1
SuDS Management Train (after CIRIA C697)



- **Prevention** – the use of good site design and housekeeping measures on individual sites to prevent runoff and pollution (e.g. minimise areas of hard standing).
- **Source Control** – control of runoff at or very near its source (such as the use of rainwater harvesting).
- **Site Control** – management of water from several sub-catchments (including routing water from roofs and car parks to one/several large soakaways for the whole site).

[8] CIRIA C697 (2007). The SUDS Manual.

- **Regional Control** – management of runoff from several sites, typically in a retention pond or wetland.

7.3.2 Proposed Drainage Design

Post development there is the potential for increased run-off rates from the site due to the generally low permeability of inert waste streams compared to the in-situ sands and gravels. The landfill will be restored to comparable ground levels to the existing site with levels sloping gradually to the south-west.

Due to the potentially shallow depths to groundwater, potentially as little as 0.5m below ground level it is not possible to solely rely upon infiltration for surface water management purposes. It is therefore proposed that an overflow is created to the pond located in the south-western corner of the site, this pond in turn connects to the western drainage ditch. The discharge rate will be limited to the pre-development greenfield rate.

The overflow is only likely to be required when groundwater levels are exceptionally high. During normal conditions it is envisaged that all surface water run-off will be allowed to soakaway to groundwater.

Greenfield Run-off rate

Greenfield runoff rates for the application site were estimated through application of the methodology outlined in IH R124[9] as set out within the Interim Code of Practice for SuDS (ICP) for catchment areas of 50 hectares or less. IH R124 is widely recognised as current best practice for estimation of catchment release rates for small rural catchments.

The IH R124 method can be used to estimate exceedance runoff release rates for a range of AEP events, or return periods, by applying regional growth curve factors to the mean annual peak runoff. The UK hydrological region for Newton Abbot is Region 8 therefore growth curve factors for this region have been used within the WinDES software suite.

The Greenfield run-off rates for the application site are outlined within Table 7-1 and summarised within Appendix C.

Table 7-1
Predicted Greenfield Run-off Rates

Catchment	Catchment Area (ha)	Greenfield Run-off Rate (l/sec)		
		50%AEP (1:2)	3.3%AEP (1:30)	1%AEP(1:100)
50ha Catchment	50	58.04	157.05	217.82
l/sec/ha	1	5.00[1]	5.00[1]	5.00[1]
Catchment	1.75	5.00[1]	5.50	7.62

Note: [1] A minimum rate of 5l/s applies to any site

[9] Institute of Hydrology Report No. 124 (1994) (IH R124); Flood estimation for small catchments.

7.3.3 Effective Impermeable Areas

Post development the quarry will be landfilled using inert wastes and restored to agricultural land using original soils. Given the likely nature of the inert waste it is considered likely that there will be a reduction in infiltration and increase in surface water run-off across the landfilled area.

The effective impermeable area has been estimated using the National Coal Board Nomogram methodology assuming:

- Soil Type: loam (to represent variable permeability of inert waste)
- Slope: 0.01 (equal to pre-development slope)
- Land-use: cultivated land

Assuming a total area of 1.75ha the effective impermeable area of the site is estimated as 0.77ha.

7.3.4 Surface Water Management Plan

The proposed surface water management will comprise of a perimeter drain which discharges to a shallow attenuation basin located in the south-west corner of the site. It is proposed that the perimeter drains will be unlined to encourage infiltration however as a worst case approach any attenuation provided has been omitted from the initial assessment.

The pond has been sized to assume infiltration through the sidewall of the pond only and for infiltration only possible through a 0.5m thickness, to represent the worst case unsaturated zone within the sands and gravels. In order to provide the requisite freeboard of c.300mm within the pond it is also proposed that the pond will be raised c.0.2m above ground level using a bund around the perimeter of the pond. This will provide some storage during extreme rainfall events if they were to occur simultaneously to high groundwater levels but is considered unlikely to provide any long term above ground storage.

The pond has been sized with the following dimensions and the modelling results are summarised in Table 7-2 and included as Appendix D.

- Basal Level: 19.5mAOD
- Basal Area: 275m^2
- Depth: 0.7m
- Top Area: 1131m^2
- Side Slopes: 1:10
- Infiltration Coefficient (Sides): 1.44m/hr
- Infiltration Coefficient (Base): 0.0
- Outfall Level: c.19.8mAOD
- Outfall Type: 100mm Pipe

Table 7-2
WinDES Modelling Results

AP (%)	Greenfield Run-off Rate (l/sec)	Water Depth (m)	Outfall Rate (l/sec)	Required Storage Volume (m$^{3)}$
100	5.0	0.091	0.0	28.7

AP (%)	Greenfield Run-off Rate (l/sec)	Water Depth (m)	Outfall Rate (l/sec)	Required Storage Volume ($m^{3)}$
3.3	5.5	0.232	0.5	90.4
1	7.6	0.318	4.1	138.9
1 + 30% CC		0.389	5.9	185.9

A review of Table 7-2, above, confirms that the proposed pond will provide sufficient attenuation to attenuate flows to pre-development greenfield run-off rates for rainfall events up to and including the 1%AEP plus climate change event. For events up to and including the 3.3%AEP (1 in 30yr) there will be no discharge from the pond with all attenuation being provided by infiltration alone.

It is also noted that the above assessment consists of a worst case approach, assuming groundwater levels within 0.5m of the surface. When groundwater levels are within their typical range of 1m – 2m below ground level infiltration will also be able to take place across the base of the pond. The model has been re-run for normal conditions and confirms that the maximum depth of water in the pond would be c.175mm and there would be no outfall from the pond

8.0 CONCLUSIONS

This report has been commissioned to assess the flood risk to the proposed development of a sand and gravel quarry and subsequent restoration using inert wastes at Cockhide Farm, Near South Ockendon, Essex.

With reference to the Environment Agency Flood Mapping the proposed development is located entirely within Flood Zone 1, low probability.

The assessment has demonstrated that there is limited flood risk from fluvial, surface water or artificial sources. The site is potentially at risk from groundwater flooding, however it is proposed that the site will be worked wet and therefore groundwater flood risk is not considered to be prohibitive to the development of the site.

There are no proposals for discharge of either surface water or groundwater from the site during the active quarrying as the site will be worked wet with no active dewatering. Any incidental rainfall to the working area will be allowed to infiltrate to groundwater.

The site will be restored using inert waste to create a landform which is comparable to the pre-development situation. The site will be restored to agricultural fields. Surface water run-off will be controlled by a perimeter drain which will collect surface water run-off shed from the restored landfill and route it to a shallow soakaway basin in the south-western corner of the site. An overflow will connect to an existing pond in the south-western corner of the site at a rate limited to the pre-development greenfield rate.

The proposed attenuation features have been assessed using a worst case approach in which no attenuation within the perimeter drain has been assumed and no infiltration through the base of the attenuation pond has been included to allow for a high groundwater scenario in which water levels are potentially as little as 0.5m below ground level. The modelling has demonstrated that in ‘normal’ groundwater conditions there would be no discharge of surface water from the site and during high groundwater conditions a discharge is only likely to occur during events in excess of a 3.3%AEP and will remain below greenfield rate for all events up to and including the 1%AEP plus climate change.

9.0 CLOSURE

This report has been prepared by SLR Consulting Limited with all reasonable skill, care and diligence, and taking account of the manpower and resources devoted to it by agreement with the client. Information reported herein is based on the interpretation of data collected and has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of Ingrebourne Valley; no warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the client and others in respect of any matters outside the agreed scope of the work.

DRAWING 001 – SURFACE WATER MANAGEMENT PLAN

PROPOSED LANDFILL PERIMETER DRAIN

WESTERN DRAIN

PIPE OUTFLOW
SIZE: 100mm
LEVEL: 0.3m ABOVE BASE

EXISTING POND

ATTENUATION BASIN
DEPTH: 0.7m
BASAL AREA: 271m²
TOP AREA: 1131m²

N

0 50 100 150 200m 300 400 500
Metres 1:5000

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NOTES

LEGEND

- COCKHIDE FARM SITE BOUNDARY
- BALDWINS FARM SITE BOUNDARY
- PROPOSED EXTENT OF QUARRY / LANDFILL
- PROPOSED PERIMETER DRAIN
- PROPOSED INFILTRATION BASIN
- PROPOSED INFILTRATION BASIN OUTFALL

Revision	By	Chk'd By	Date	Comments

SLR global environmental solutions
69 POLSLOE ROAD
EXETER
DEVON
EX1 2NF
T: +44 (0)1392 490152
F: +44(0)1392 495572
www.slrconsulting.com

Site
COCKHIDE FARM

Project
FLOOD RISK ASSESSMENT

Drawing Title
PROPOSED SURFAC WATER MANAGEMENT PLAN

Scale
1:5,000 @ A3

Date
FEBRUARY 2016

Drawing Number
DRAWING 001

Revision
1

402-01526-00019_FRA_2_SWMP.dwg

APPENDIX A – EXTRACT OF EA FLOOD MAPPING

Flood map centred on NGR 557000, 182900 - created November 2015 - HNL49320/AS

Environment Agency

Scale 1:10,001

N W E S

Flood Map for Planning (Rivers and Sea)

- Flood Map - Defences
- Areas Benefiting from Flood Defences
- Flood Map - Flood Storage Areas
- Flood Map - Flood Zone 3
- Flood Map - Flood Zone 2

Flood Map for Planning (Rivers and Sea)

(assuming no defences)

Flood Zone 3 shows the area that could be affected by flooding:

- from the sea with a 1 in 200 or greater chance of happening each year
- or from a river with a 1 in 100 or greater chance of happening each year.

Flood Zone 2 shows the extent of an extreme flood from rivers or the sea with up to a 1 in 1000 chance of occurring each year.

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APPENDIX B – PROPOSED SITE DEVELOPMENT PLAN

Access to Bramble Lane / Sunnings Lane via wheelbath (see inset detail)

Public Footpath (Havering FP 259)

Access corridor (road width 3m with passing bays)

Passing bay

Public Footpath (Havering FP 258)

Overhead ETL

Passing bay

Car park / security compound

Screening bund (2m high)

Receiving area

Office & weighbridge

Screening bund (2m high)

COCKHIDE FARM (derelict buildings)

Existing pond

Temporary stockpile area

Application boundary (red line)

General direction of operations

Drainage

Screening bund (3m high)

EXTRACTION AREA

Public Footpath (Thurrock FP 140)

Track

Pond

Drain

1.22m RH

SUNNINGS LANE

BRAMBLE LANE

Hardcore section of access road with proposed location of wheel bath

Road widens to c.6m from this point north to entrance onto Bramble Lane / Sunnings Lane

Overhead ETL

Passing bay

Access corridor to excavation & receiving area (road width 3m with passing bays)

INSET DETAIL SHOWING ACCESS ROAD AND WHEEL BATH SCALE - 1:2,500

N

0m 50m 100m

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Version / amendment: 1211/C/O/1 v4

D.K. Symes Associates

Illustrative Operations Plan

Scale - **1:2,500** (at A3)

Date - **01-08-2016**

Plan No. **1211/C/O/1**

APPENDIX C – IOH 124 GREENFIELD RUN-OFF RATE CALCULATIONS

HR Wallingford
Working with water

Greenfield runoff estimation for sites

Site name:	Baldwins Farm
Site location:	Nr South Ockendon

This is an estimation of the greenfield runoff rate limits that are needed to meet normal best practice criteria in line with Environment Agency guidance "Preliminary rainfall runoff management for developments", W5-074/A/TR1/1 rev. E (2012) and the CIRIA SUDS Manual (2007). It is not to be used for detailed design of drainage systems. It is recommended that every drainage scheme uses hydraulic modelling software to finalise volume requirements and design details before drawings are produced.

Site coordinates

Latitude:	51.52400° N
Longitude:	0.26327° E

Reference:	u10jjgxtn9sr / 1.75
Date:	15 Feb 2016

Site characteristics

Total site area	1.75	ha
Significant public open space	0	ha
Area positively drained	1.75	ha

Methodology

Greenfield runoff method	IH124

Qbar estimation method	Calculate from SPR and SAAR
SPR estimation method	Calculate from SOIL type
SOIL type	2
HOST class	N/A
SPR	0.30

Hydrological characteristics

	Default	Edited	
SAAR	547	547	mm
M5-60 Rainfall Depth	20	20	mm
'r' Ratio M5-60/M5-2 day	0.4	0.4	
FEH/FSR conversion factor	0.84	0.84	
Hydrological region	6	6	
Growth curve factor: 1 year	0.85	0.85	
Growth curve factor: 10 year	1.62	1.62	
Growth curve factor: 30 year	2.3	2.3	
Growth curve factor: 100 year	3.19	3.19	

Greenfield runoff rates

	Default	Edited	
Qbar	2.39	2.39	l/s
1 in 1 year	5.00	5.00	l/s
1 in 30 years	5.50	5.50	l/s
1 in 100 years	7.62	7.62	l/s

Please note that a minimum flow of 5 l/s applies to any site

HR Wallingford Ltd, the Environment Agency and any local authority are not liable for the performance of a drainage scheme which is based upon the output of this report.

HR Wallingford
Working with water

Greenfield runoff estimation for sites

Site name:	Baldwins Farm
Site location:	Nr South Ockendon

This is an estimation of the greenfield runoff rate limits that are needed to meet normal best practice criteria in line with Environment Agency guidance "Preliminary rainfall runoff management for developments", W5-074/A/TR1/1 rev. E (2012) and the CIRIA SUDS Manual (2007). It is not to be used for detailed design of drainage systems. It is recommended that every drainage scheme uses hydraulic modelling software to finalise volume requirements and design details before drawings are produced.

Site coordinates

Latitude:	51.52400° N
Longitude:	0.26327° E

Reference:	u10jjgxtn9sr / 1.75
Date:	15 Feb 2016

Site characteristics

Total site area	1.75	ha
Significant public open space	0	ha
Area positively drained	1.75	ha

Methodology

Greenfield runoff method	FEH

Qmed estimation method	Calculate from BFI and SAAR	
BFI and SPR estimation method	Calculate from dominant HOST	
HOST class	N/A	
BFI / BFIHOST	0.00	
Qmed	N/A	l/s
Qbar / Qmed Conversion Factor	N/A	

Hydrological characteristics

	Default	Edited	
SAAR	547	547	mm
M5-60 Rainfall Depth	20	20	mm
'r' Ratio M5-60/M5-2 day	0.4	0.4	
FEH/FSR conversion factor	0.84	0.84	
Hydrological region	6	6	
Growth curve factor: 1 year	0.85	0.85	
Growth curve factor: 10 year	1.62	1.62	
Growth curve factor: 30 year	2.3	2.3	
Growth curve factor: 100 year	3.19	3.19	

Greenfield runoff rates

	Default	Edited	
Qbar	---	---	l/s
1 in 1 year	---	---	l/s
1 in 30 years	---	---	l/s
1 in 100 years	---	---	l/s

Please note that a minimum flow of 5 l/s applies to any site

HR Wallingford Ltd, the Environment Agency and any local authority are not liable for the performance of a drainage scheme which is based upon the output of this report.

APPENDIX D – SOURCE CONTROL MODELLING RESULTS

Summary of Results for 1 year Return Period

Half Drain Time : 9 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	19.575	0.075	29.2	0.0	29.2	22.9	O K
30 min Summer	19.583	0.083	32.7	0.0	32.7	26.0	O K
60 min Summer	19.583	0.083	32.7	0.0	32.7	25.9	O K
120 min Summer	19.576	0.076	29.8	0.0	29.8	23.5	O K
180 min Summer	19.569	0.069	26.9	0.0	26.9	21.0	O K
240 min Summer	19.563	0.063	24.2	0.0	24.2	18.8	O K
360 min Summer	19.553	0.053	20.4	0.0	20.4	15.7	O K
480 min Summer	19.546	0.046	17.6	0.0	17.6	13.6	O K
600 min Summer	19.541	0.041	15.7	0.0	15.7	12.0	O K
720 min Summer	19.537	0.037	14.1	0.0	14.1	10.8	O K
960 min Summer	19.532	0.032	12.0	0.0	12.0	9.0	O K
1440 min Summer	19.525	0.025	9.3	0.1	9.3	6.9	O K
2160 min Summer	19.519	0.019	7.0	0.0	7.0	5.3	O K
2880 min Summer	19.516	0.016	5.9	0.0	5.9	4.3	O K
4320 min Summer	19.512	0.012	4.4	0.1	4.4	3.2	O K
5760 min Summer	19.509	0.009	3.4	0.0	3.4	2.5	O K
7200 min Summer	19.508	0.008	2.9	0.3	2.9	2.1	O K
8640 min Summer	19.507	0.007	2.5	0.3	2.5	1.8	O K
10080 min Summer	19.506	0.006	2.3	0.3	2.3	1.7	O K
15 min Winter	19.583	0.083	32.5	0.0	32.5	25.6	O K
30 min Winter	19.591	0.091	36.1	0.0	36.1	28.7	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	34.092	0.0	49.1	26
30 min Summer	21.264	0.0	61.3	34
60 min Summer	13.263	0.0	76.5	48
120 min Summer	8.273	0.0	95.4	78
180 min Summer	6.277	0.0	108.6	110
240 min Summer	5.160	0.0	119.1	140
360 min Summer	3.915	0.0	135.5	200
480 min Summer	3.218	0.0	148.6	260
600 min Summer	2.765	0.0	159.5	320
720 min Summer	2.442	0.0	169.1	380
960 min Summer	1.994	0.0	184.1	500
1440 min Summer	1.498	0.0	207.5	738
2160 min Summer	1.126	0.0	233.8	1104
2880 min Summer	0.919	0.0	254.6	1468
4320 min Summer	0.673	0.0	279.7	2184
5760 min Summer	0.540	0.0	299.1	2896
7200 min Summer	0.455	0.0	315.0	3592
8640 min Summer	0.395	0.0	328.5	4264
10080 min Summer	0.351	0.0	340.5	5024
15 min Winter	34.092	0.0	55.0	26
30 min Winter	21.264	0.0	68.6	33

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Summary of Results for 1 year Return Period

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
60 min Winter	19.588	0.088	34.8	0.0	34.8	27.6	O K
120 min Winter	19.575	0.075	29.2	0.0	29.2	22.9	O K
180 min Winter	19.563	0.063	24.4	0.0	24.4	19.1	O K
240 min Winter	19.555	0.055	21.2	0.0	21.2	16.4	O K
360 min Winter	19.544	0.044	16.8	0.1	16.8	12.9	O K
480 min Winter	19.537	0.037	14.1	0.1	14.1	10.8	O K
600 min Winter	19.533	0.033	12.3	0.0	12.3	9.3	O K
720 min Winter	19.529	0.029	11.0	0.1	11.0	8.3	O K
960 min Winter	19.524	0.024	9.1	0.1	9.1	6.8	O K
1440 min Winter	19.518	0.018	6.8	0.1	6.8	5.0	O K
2160 min Winter	19.514	0.014	5.1	0.1	5.1	3.8	O K
2880 min Winter	19.511	0.011	4.2	0.1	4.2	3.1	O K
4320 min Winter	19.508	0.008	3.0	0.2	3.0	2.2	O K
5760 min Winter	19.507	0.007	2.5	0.2	2.5	1.8	O K
7200 min Winter	19.506	0.006	2.1	0.2	2.1	1.5	O K
8640 min Winter	19.505	0.005	1.9	0.2	1.9	1.4	O K
10080 min Winter	19.505	0.005	1.7	0.2	1.7	1.2	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
60 min Winter	13.263	0.0	85.7	48
120 min Winter	8.273	0.0	106.9	80
180 min Winter	6.277	0.0	121.7	110
240 min Winter	5.160	0.0	133.4	140
360 min Winter	3.915	0.0	151.8	202
480 min Winter	3.218	0.0	166.4	262
600 min Winter	2.765	0.0	178.7	320
720 min Winter	2.442	0.0	189.4	378
960 min Winter	1.994	0.0	206.2	500
1440 min Winter	1.498	0.0	232.4	746
2160 min Winter	1.126	0.0	261.9	1104
2880 min Winter	0.919	0.0	285.2	1472
4320 min Winter	0.673	0.0	313.3	2208
5760 min Winter	0.540	0.0	335.0	2896
7200 min Winter	0.455	0.0	352.7	3656
8640 min Winter	0.395	0.0	368.0	4264
10080 min Winter	0.351	0.0	381.4	5232

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Rainfall Details

Rainfall Model	FEH
Return Period (years)	1
Site Location	GB 506000 178200 TQ 06000 78200
C (1km)	-0.025
D1 (1km)	0.319
D2 (1km)	0.295
D3 (1km)	0.232
E (1km)	0.304
F (1km)	2.585
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.750
Cv (Winter)	0.840
Shortest Storm (mins)	15
Longest Storm (mins)	10080
Climate Change %	+0

Time Area Diagram

Total Area (ha) 0.770

Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)
0	4	0.154	8	12	0.154	16	20	0.154
4	8	0.154	12	16	0.154			

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Model Details

Storage is Online Cover Level (m) 20.200

Infiltration Basin Structure

Invert Level (m) 19.500 Safety Factor 1.0
Infiltration Coefficient Base (m/hr) 0.00000 Porosity 1.00
Infiltration Coefficient Side (m/hr) 1.44000

Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	271.0	0.200	485.0	0.700	1131.0

Pipe Outflow Control

Diameter (m) 0.100 Entry Loss Coefficient 0.500
Slope (1:X) 200.0 Coefficient of Contraction 0.600
Length (m) 10.000 Upstream Invert Level (m) 19.700
Roughness k (mm) 0.600

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Summary of Results for 30 year Return Period

Half Drain Time : 11 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	19.703	0.203	86.9	0.0	86.9	75.9	O K
30 min Summer	19.714	0.214	91.5	0.1	91.6	81.2	O K
60 min Summer	19.704	0.204	87.3	0.0	87.3	76.3	O K
120 min Summer	19.680	0.180	76.2	0.0	76.2	65.3	O K
180 min Summer	19.660	0.160	66.8	0.0	66.8	56.2	O K
240 min Summer	19.644	0.144	59.1	0.0	59.1	49.2	O K
360 min Summer	19.620	0.120	48.4	0.0	48.4	39.4	O K
480 min Summer	19.603	0.103	41.0	0.0	41.0	33.0	O K
600 min Summer	19.591	0.091	35.8	0.0	35.8	28.6	O K
720 min Summer	19.581	0.081	31.9	0.0	31.9	25.3	O K
960 min Summer	19.568	0.068	26.3	0.0	26.3	20.5	O K
1440 min Summer	19.551	0.051	19.6	0.0	19.6	15.1	O K
2160 min Summer	19.538	0.038	14.5	0.0	14.5	11.0	O K
2880 min Summer	19.531	0.031	11.6	0.0	11.6	8.8	O K
4320 min Summer	19.522	0.022	8.3	0.0	8.3	6.2	O K
5760 min Summer	19.517	0.017	6.4	0.0	6.4	4.9	O K
7200 min Summer	19.515	0.015	5.5	0.0	5.5	4.0	O K
8640 min Summer	19.513	0.013	4.7	0.0	4.7	3.5	O K
10080 min Summer	19.511	0.011	4.2	0.0	4.2	3.1	O K
15 min Winter	19.722	0.222	94.8	0.2	95.0	85.2	O K
30 min Winter	19.732	0.232	99.0	0.5	99.5	90.4	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	107.252	0.0	154.7	27
30 min Summer	63.086	0.0	182.0	34
60 min Summer	37.108	0.0	214.2	50
120 min Summer	21.827	0.0	252.0	80
180 min Summer	16.002	0.0	277.1	110
240 min Summer	12.839	0.0	296.4	140
360 min Summer	9.413	0.0	326.0	200
480 min Summer	7.552	0.0	348.8	260
600 min Summer	6.366	0.0	367.5	320
720 min Summer	5.537	0.0	383.5	380
960 min Summer	4.411	0.0	407.5	500
1440 min Summer	3.203	0.0	443.8	740
2160 min Summer	2.325	0.0	483.3	1104
2880 min Summer	1.853	0.0	513.5	1468
4320 min Summer	1.311	0.0	545.1	2176
5760 min Summer	1.026	0.0	568.7	2936
7200 min Summer	0.848	0.0	587.8	3664
8640 min Summer	0.726	0.0	603.7	4376
10080 min Summer	0.637	0.0	617.6	5120
15 min Winter	107.252	0.0	173.3	26
30 min Winter	63.086	0.0	203.9	34

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Summary of Results for 30 year Return Period

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
60 min Winter	19.715	0.215	91.9	0.1	92.0	82.0	O K
120 min Winter	19.677	0.177	74.8	0.0	74.8	63.9	O K
180 min Winter	19.649	0.149	61.4	0.0	61.4	51.4	O K
240 min Winter	19.628	0.128	52.2	0.1	52.2	42.8	O K
360 min Winter	19.601	0.101	40.3	0.1	40.3	32.3	O K
480 min Winter	19.584	0.084	33.1	0.1	33.1	26.2	O K
600 min Winter	19.573	0.073	28.3	0.1	28.3	22.2	O K
720 min Winter	19.564	0.064	24.6	0.1	24.6	19.3	O K
960 min Winter	19.552	0.052	19.8	0.1	19.8	15.3	O K
1440 min Winter	19.538	0.038	14.5	0.1	14.5	11.0	O K
2160 min Winter	19.528	0.028	10.6	0.1	10.6	8.0	O K
2880 min Winter	19.523	0.023	8.5	0.1	8.5	6.3	O K
4320 min Winter	19.516	0.016	6.0	0.1	6.0	4.5	O K
5760 min Winter	19.513	0.013	4.7	0.2	4.7	3.5	O K
7200 min Winter	19.511	0.011	4.0	0.2	4.0	2.9	O K
8640 min Winter	19.509	0.009	3.4	0.2	3.4	2.5	O K
10080 min Winter	19.508	0.008	3.0	0.2	3.0	2.2	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
60 min Winter	37.108	0.0	239.9	50
120 min Winter	21.827	0.0	282.2	80
180 min Winter	16.002	0.0	310.4	112
240 min Winter	12.839	0.0	332.0	142
360 min Winter	9.413	0.0	365.2	202
480 min Winter	7.552	0.0	390.6	262
600 min Winter	6.366	0.0	411.6	322
720 min Winter	5.537	0.0	429.6	382
960 min Winter	4.411	0.0	456.4	502
1440 min Winter	3.203	0.0	497.0	742
2160 min Winter	2.325	0.0	541.4	1100
2880 min Winter	1.853	0.0	575.1	1468
4320 min Winter	1.311	0.0	610.5	2192
5760 min Winter	1.026	0.0	637.0	2848
7200 min Winter	0.848	0.0	658.3	3744
8640 min Winter	0.726	0.0	676.2	4336
10080 min Winter	0.637	0.0	691.8	5128

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Rainfall Details

Rainfall Model	FEH
Return Period (years)	30
Site Location	GB 506000 178200 TQ 06000 78200
C (1km)	-0.025
D1 (1km)	0.319
D2 (1km)	0.295
D3 (1km)	0.232
E (1km)	0.304
F (1km)	2.585
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.750
Cv (Winter)	0.840
Shortest Storm (mins)	15
Longest Storm (mins)	10080
Climate Change %	+0

Time Area Diagram

Total Area (ha) 0.770

Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)
0	4	0.154	8	12	0.154	16	20	0.154
4	8	0.154	12	16	0.154			

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Model Details

Storage is Online Cover Level (m) 20.200

Infiltration Basin Structure

Invert Level (m) 19.500 Safety Factor 1.0
Infiltration Coefficient Base (m/hr) 0.00000 Porosity 1.00
Infiltration Coefficient Side (m/hr) 1.44000

Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	271.0	0.200	485.0	0.700	1131.0

Pipe Outflow Control

Diameter (m) 0.100 Entry Loss Coefficient 0.500
Slope (1:X) 200.0 Coefficient of Contraction 0.600
Length (m) 10.000 Upstream Invert Level (m) 19.700
Roughness k (mm) 0.600

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Summary of Results for 100 year Return Period

Half Drain Time : 12 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	19.784	0.284	121.9	2.8	124.7	119.3	O K
30 min Summer	19.794	0.294	126.4	3.4	129.8	124.9	O K
60 min Summer	19.778	0.278	119.0	2.5	121.4	115.3	O K
120 min Summer	19.743	0.243	103.7	0.8	104.5	96.1	O K
180 min Summer	19.713	0.213	91.2	0.1	91.3	81.1	O K
240 min Summer	19.690	0.190	81.0	0.0	81.0	70.0	O K
360 min Summer	19.658	0.158	65.8	0.0	65.8	55.3	O K
480 min Summer	19.636	0.136	55.5	0.0	55.5	45.8	O K
600 min Summer	19.619	0.119	48.2	0.0	48.2	39.3	O K
720 min Summer	19.607	0.107	42.7	0.0	42.7	34.5	O K
960 min Summer	19.588	0.088	34.8	0.0	34.8	27.7	O K
1440 min Summer	19.566	0.066	25.7	0.0	25.7	20.1	O K
2160 min Summer	19.549	0.049	18.8	0.0	18.8	14.5	O K
2880 min Summer	19.539	0.039	14.9	0.0	14.9	11.4	O K
4320 min Summer	19.528	0.028	10.6	0.0	10.6	8.0	O K
5760 min Summer	19.522	0.022	8.1	0.0	8.1	6.1	O K
7200 min Summer	19.518	0.018	6.8	0.0	6.8	5.0	O K
8640 min Summer	19.515	0.015	5.7	0.0	5.7	4.3	O K
10080 min Summer	19.514	0.014	5.1	0.0	5.1	3.8	O K
15 min Winter	19.809	0.309	133.2	3.8	137.0	134.0	O K
30 min Winter	19.818	0.318	137.1	4.1	141.2	138.9	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	161.894	0.0	233.7	27
30 min Summer	93.242	0.0	269.1	34
60 min Summer	53.702	0.0	310.0	50
120 min Summer	30.929	0.0	357.1	80
180 min Summer	22.397	0.0	387.9	110
240 min Summer	17.813	0.0	411.4	140
360 min Summer	12.900	0.0	446.8	200
480 min Summer	10.259	0.0	473.8	260
600 min Summer	8.590	0.0	495.9	320
720 min Summer	7.429	0.0	514.7	382
960 min Summer	5.868	0.0	542.1	502
1440 min Summer	4.208	0.0	583.1	742
2160 min Summer	3.018	0.0	627.3	1104
2880 min Summer	2.384	0.0	660.6	1472
4320 min Summer	1.666	0.0	692.8	2188
5760 min Summer	1.293	0.0	716.5	2936
7200 min Summer	1.061	0.0	735.5	3664
8640 min Summer	0.904	0.0	751.3	4400
10080 min Summer	0.789	0.0	765.0	5040
15 min Winter	161.894	0.0	261.8	27
30 min Winter	93.242	0.0	301.4	34

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Summary of Results for 100 year Return Period

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
60 min Winter	19.793	0.293	125.7	3.3	129.0	124.0	O K
120 min Winter	19.739	0.239	102.2	0.7	102.9	94.4	O K
180 min Winter	19.699	0.199	85.4	0.0	85.4	74.1	O K
240 min Winter	19.671	0.171	71.9	0.0	71.9	61.2	O K
360 min Winter	19.635	0.135	55.1	0.1	55.1	45.4	O K
480 min Winter	19.612	0.112	44.9	0.1	44.9	36.3	O K
600 min Winter	19.596	0.096	38.0	0.1	38.0	30.4	O K
720 min Winter	19.584	0.084	33.1	0.1	33.1	26.2	O K
960 min Winter	19.568	0.068	26.3	0.1	26.3	20.6	O K
1440 min Winter	19.550	0.050	19.0	0.1	19.0	14.6	O K
2160 min Winter	19.536	0.036	13.7	0.1	13.7	10.4	O K
2880 min Winter	19.529	0.029	10.8	0.1	10.8	8.2	O K
4320 min Winter	19.520	0.020	7.6	0.1	7.6	5.7	O K
5760 min Winter	19.516	0.016	5.9	0.1	5.9	4.4	O K
7200 min Winter	19.513	0.013	4.9	0.1	4.9	3.6	O K
8640 min Winter	19.511	0.011	4.2	0.2	4.2	3.1	O K
10080 min Winter	19.510	0.010	3.6	0.2	3.6	2.7	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
60 min Winter	53.702	0.0	347.2	50
120 min Winter	30.929	0.0	400.0	82
180 min Winter	22.397	0.0	434.5	112
240 min Winter	17.813	0.0	460.7	142
360 min Winter	12.900	0.0	500.5	202
480 min Winter	10.259	0.0	530.8	262
600 min Winter	8.590	0.0	555.5	322
720 min Winter	7.429	0.0	576.5	382
960 min Winter	5.868	0.0	607.2	504
1440 min Winter	4.208	0.0	653.1	742
2160 min Winter	3.018	0.0	702.6	1100
2880 min Winter	2.384	0.0	739.9	1472
4320 min Winter	1.666	0.0	775.9	2208
5760 min Winter	1.293	0.0	802.5	2944
7200 min Winter	1.061	0.0	823.7	3672
8640 min Winter	0.904	0.0	841.5	4336
10080 min Winter	0.789	0.0	856.8	4984

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Rainfall Details

Rainfall Model	FEH
Return Period (years)	100
Site Location	GB 506000 178200 TQ 06000 78200
C (1km)	-0.025
D1 (1km)	0.319
D2 (1km)	0.295
D3 (1km)	0.232
E (1km)	0.304
F (1km)	2.585
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.750
Cv (Winter)	0.840
Shortest Storm (mins)	15
Longest Storm (mins)	10080
Climate Change %	+0

Time Area Diagram

Total Area (ha) 0.770

Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)
0	4	0.154	8	12	0.154	16	20	0.154
4	8	0.154	12	16	0.154			

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Model Details

Storage is Online Cover Level (m) 20.200

Infiltration Basin Structure

Invert Level (m) 19.500 Safety Factor 1.0
Infiltration Coefficient Base (m/hr) 0.00000 Porosity 1.00
Infiltration Coefficient Side (m/hr) 1.44000

Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	271.0	0.200	485.0	0.700	1131.0

Pipe Outflow Control

Diameter (m) 0.100 Entry Loss Coefficient 0.500
Slope (1:X) 200.0 Coefficient of Contraction 0.600
Length (m) 10.000 Upstream Invert Level (m) 19.700
Roughness k (mm) 0.600

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Summary of Results for 100 year Return Period (+30%)

Half Drain Time : 11 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	19.850	0.350	152.0	5.0	157.0	159.2	O K
30 min Summer	19.861	0.361	157.5	5.3	162.8	166.9	O K
60 min Summer	19.843	0.343	148.7	4.8	153.5	154.6	O K
120 min Summer	19.801	0.301	129.5	3.6	133.1	129.1	O K
180 min Summer	19.767	0.267	114.1	2.0	116.1	109.3	O K
240 min Summer	19.739	0.239	102.0	0.7	102.7	94.3	O K
360 min Summer	19.698	0.198	84.7	0.0	84.7	73.5	O K
480 min Summer	19.671	0.171	71.7	0.0	71.7	60.9	O K
600 min Summer	19.651	0.151	62.6	0.0	62.6	52.3	O K
720 min Summer	19.635	0.135	55.3	0.0	55.3	45.8	O K
960 min Summer	19.612	0.112	45.1	0.0	45.1	36.6	O K
1440 min Summer	19.585	0.085	33.5	0.0	33.5	26.5	O K
2160 min Summer	19.563	0.063	24.4	0.0	24.4	19.0	O K
2880 min Summer	19.551	0.051	19.4	0.0	19.4	14.9	O K
4320 min Summer	19.536	0.036	13.7	0.0	13.7	10.4	O K
5760 min Summer	19.528	0.028	10.6	0.0	10.6	8.0	O K
7200 min Summer	19.523	0.023	8.7	0.0	8.7	6.5	O K
8640 min Summer	19.520	0.020	7.4	0.0	7.4	5.6	O K
10080 min Summer	19.518	0.018	6.6	0.0	6.6	4.9	O K
15 min Winter	19.879	0.379	166.2	5.7	171.9	179.1	O K
30 min Winter	19.889	0.389	171.1	5.9	177.1	185.9	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	210.462	0.0	303.9	27
30 min Summer	121.214	0.0	349.9	35
60 min Summer	69.812	0.0	403.0	50
120 min Summer	40.208	0.0	464.3	80
180 min Summer	29.117	0.0	504.3	110
240 min Summer	23.157	0.0	534.8	142
360 min Summer	16.770	0.0	580.9	202
480 min Summer	13.337	0.0	616.0	262
600 min Summer	11.167	0.0	644.8	322
720 min Summer	9.658	0.0	669.2	382
960 min Summer	7.629	0.0	704.8	502
1440 min Summer	5.471	0.0	758.1	740
2160 min Summer	3.923	0.0	815.6	1104
2880 min Summer	3.099	0.0	858.9	1468
4320 min Summer	2.166	0.0	900.6	2184
5760 min Summer	1.680	0.0	931.4	2920
7200 min Summer	1.380	0.0	956.0	3592
8640 min Summer	1.175	0.0	976.8	4400
10080 min Summer	1.025	0.0	994.4	5136
15 min Winter	210.462	0.0	340.2	27
30 min Winter	121.214	0.0	391.9	34

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Summary of Results for 100 year Return Period (+30%)

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
60 min Winter	19.861	0.361	157.3	5.3	162.6	166.6	O K
120 min Winter	19.799	0.299	128.4	3.6	132.0	127.5	O K
180 min Winter	19.751	0.251	107.1	1.2	108.4	100.6	O K
240 min Winter	19.715	0.215	92.1	0.1	92.2	82.2	O K
360 min Winter	19.670	0.170	71.2	0.0	71.2	60.5	O K
480 min Winter	19.642	0.142	58.2	0.1	58.2	48.2	O K
600 min Winter	19.622	0.122	49.3	0.1	49.3	40.3	O K
720 min Winter	19.607	0.107	42.9	0.1	42.9	34.7	O K
960 min Winter	19.587	0.087	34.4	0.1	34.4	27.2	O K
1440 min Winter	19.564	0.064	24.9	0.1	24.9	19.3	O K
2160 min Winter	19.547	0.047	17.8	0.0	17.8	13.7	O K
2880 min Winter	19.537	0.037	14.1	0.1	14.1	10.7	O K
4320 min Winter	19.526	0.026	9.8	0.1	9.8	7.4	O K
5760 min Winter	19.521	0.021	7.7	0.1	7.7	5.8	O K
7200 min Winter	19.517	0.017	6.4	0.1	6.4	4.8	O K
8640 min Winter	19.515	0.015	5.5	0.1	5.5	4.0	O K
10080 min Winter	19.513	0.013	4.7	0.2	4.7	3.5	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
60 min Winter	69.812	0.0	451.4	50
120 min Winter	40.208	0.0	520.0	82
180 min Winter	29.117	0.0	564.8	112
240 min Winter	23.157	0.0	599.0	144
360 min Winter	16.770	0.0	650.6	204
480 min Winter	13.337	0.0	690.0	264
600 min Winter	11.167	0.0	722.1	324
720 min Winter	9.658	0.0	749.5	384
960 min Winter	7.629	0.0	789.4	502
1440 min Winter	5.471	0.0	849.1	740
2160 min Winter	3.923	0.0	913.4	1092
2880 min Winter	3.099	0.0	962.0	1448
4320 min Winter	2.166	0.0	1008.7	2216
5760 min Winter	1.680	0.0	1043.3	2912
7200 min Winter	1.380	0.0	1070.9	3600
8640 min Winter	1.175	0.0	1094.0	4304
10080 min Winter	1.025	0.0	1113.8	5096

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Rainfall Details

Rainfall Model	FEH
Return Period (years)	100
Site Location	GB 506000 178200 TQ 06000 78200
C (1km)	-0.025
D1 (1km)	0.319
D2 (1km)	0.295
D3 (1km)	0.232
E (1km)	0.304
F (1km)	2.585
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.750
Cv (Winter)	0.840
Shortest Storm (mins)	15
Longest Storm (mins)	10080
Climate Change %	+30

Time Area Diagram

Total Area (ha) 0.770

Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)
0	4	0.154	8	12	0.154	16	20	0.154
4	8	0.154	12	16	0.154			

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Model Details

Storage is Online Cover Level (m) 20.200

Infiltration Basin Structure

Invert Level (m) 19.500 Safety Factor 1.0
Infiltration Coefficient Base (m/hr) 0.00000 Porosity 1.00
Infiltration Coefficient Side (m/hr) 1.44000

Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	271.0	0.200	485.0	0.700	1131.0

Pipe Outflow Control

Diameter (m) 0.100 Entry Loss Coefficient 0.500
Slope (1:X) 200.0 Coefficient of Contraction 0.600
Length (m) 10.000 Upstream Invert Level (m) 19.700
Roughness k (mm) 0.600

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ABERDEEN
214 Union Street,
Aberdeen AB10 1TL, UK
T: +44 (0)1224 517405

AYLESBURY
7 Wornal Park, Menmarsh Road,
Worminghall, Aylesbury,
Buckinghamshire HP18 9PH, UK
T: +44 (0)1844 337380

BELFAST
Suite 1 Potters Quay, 5 Ravenhill Road,
Belfast BT6 8DN, UK, Northern Ireland
T: +44 (0)28 9073 2493

BRADFORD-ON-AVON
Treenwood House, Rowden Lane,
Bradford-on-Avon, Wiltshire BA15 2AU,
UK
T: +44 (0)1225 309400

BRISTOL
Langford Lodge, 109 Pembroke Road,
Clifton, Bristol BS8 3EU, UK
T: +44 (0)117 9064280

CAMBRIDGE
8 Stow Court, Stow-cum-Quy,
Cambridge CB25 9AS, UK
T: + 44 (0)1223 813805

CARDIFF
Fulmar House, Beignon Close, Ocean
Way, Cardiff CF24 5PB, UK
T: +44 (0)29 20491010

CHELMSFORD
Unit 77, Waterhouse Business Centre,
2 Cromar Way, Chelmsford, Essex
CM1 2QE, UK
T: +44 (0)1245 392170

DUBLIN
7 Dundrum Business Park, Windy
Arbour, Dundrum, Dublin 14 Ireland
T: + 353 (0)1 2964667

EDINBURGH
4/5 Lochside View, Edinburgh Park,
Edinburgh EH12 9DH, UK
T: +44 (0)131 3356830

EXETER
69 Polsloe Road, Exeter EX1 2NF, UK
T: + 44 (0)1392 490152

GLASGOW
4 Woodside Place, Charing Cross,
Glasgow G3 7QF, UK
T: +44 (0)141 3535037

GRENOBLE
BuroClub, 157/155 Cours Berriat,
38028 Grenoble Cedex 1, France
T: +33 (0)4 76 70 93 41

GUILDFORD
65 Woodbridge Road, Guildford
Surrey GU1 4RD, UK
T: +44 (0)1483 889 800

LEEDS
Suite 1, Jason House, Kerry Hill,
Horsforth, Leeds LS18 4JR, UK
T: +44 (0)113 2580650

LONDON
83 Victoria Street,
London, SW1H 0HW, UK
T: +44 (0)203 691 5810

MAIDSTONE
19 Hollingworth Court, Turkey Mill,
Maidstone, Kent ME14 5PP, UK
T: +44 (0)1622 609242

MANCHESTER
8th Floor, Quay West, MediaCityUK,
Trafford Wharf Road,
Manchester M17 1HH, UK
T: +44 (0)161 872 7564

NEWCASTLE UPON TYNE
Sailors Bethel, Horatio Street,
Newcastle-upon-Tyne NE1 2PE, UK
T: +44 (0)191 2611966

NOTTINGHAM
Aspect House, Aspect Business Park,
Bennerley Road, Nottingham NG6 8WR,
UK
T: +44 (0)115 9647280

SHEFFIELD
Unit 2 Newton Business Centre,
Thorncliffe Park Estate, Newton
Chambers Road, Chapeltown,
Sheffield S35 2PW, UK
T: +44 (0)114 2455153

SHREWSBURY
2nd Floor, Hermes House, Oxon
Business Park, Shrewsbury SY3 5HJ,
UK
T: +44 (0)1743 239250

STAFFORD
8 Parker Court, Staffordshire Technology
Park, Beaconside, Stafford ST18 0WP,
UK
T: +44 (0)1785 241755

STIRLING
No. 68 Stirling Business Centre,
Wellgreen, Stirling FK8 2DZ, UK
T: +44 (0)1786 239900

WORCESTER
Suite 5, Brindley Court, Gresley Road,
Shire Business Park, Worcester WR4
9FD, UK
T: +44 (0)1905 751310

www.slrconsulting.com

APPENDIX 03

Borehole Logs

SI DRILLING
Cable Percussion Ltd

Cable Percussive Borehole Record

BHA

Sheet 1 of 1

Project Ref: **409.01526.00019**	Client: Ingrebourne Valley	E:	N:
Location: Cockhide Farm	Consultant:	Date: 19/02/2019	
	Plant used: Dando 2000 Cable Percussive Rig	SPT Hammer Serial No:	

Geological Description	Legend	Depth (m)	Ground Level (maOD)	Sample / In-Situ Test Information			Date - Depth (m) Casing (Water)	Installation & Backfill
				Type	Depth	Results / Remarks		
TOPSOIL. Brown gravelly SAND. (Driller description)		0.20						
Brown mottled light brown clayey SAND. (Driller description)		0.50						
Firm brown mottled light brown very sandy CLAY. (Driller description)		1.30						
Brown SAND and GRAVEL. (Driller description)		1.80						
Firm to stiff grey CLAY. (Driller description)		2.80					19/02/2019 - 2.80 2.00 (Dry)	
Borehole completed at 2.80m.								

Chiselling Details		Water Added Records		Water Strike - General				Water Strike - Details		
Depths (m)	Duration (hh:mm)	Depth (m)	Litres	Date	Strike Depth (m)	Depth Sealed (m)	Casing Depth (m)	Time Elapsed (mins)	Standing Level (m)	Remarks
		1.30 - 1.80	40	19-02-2019	1.70	2.00	1.60	20	1.30	Slow flow

Hole Diameter by Depth		Casing Diameter by Depth	
Depth Base (m)	Diameter (mm)	Depth Base (m)	Diameter (mm)
2.80	150	2.00	150

Remarks:

1. Installation: 50mm standpipe GL to 0.50m plain, 0.50m to 1.80m slotted, 1.80m to 2.80m plain, fitted with gas tap and bung, installed with flush cover.
2. Backfill: GL to 0.50m bentonite, 0.50m to 1.80m gravel, 1.80m to 2.80m bentonite.

SI Drilling Cable Percussion Ltd
9 Vera Road
Norwich, Norfolk
NR13 6QP

E-mail: sales@sidrilling.co.uk
Website: www.sidrilling.co.uk

Drilled by: BM | Logged by: BM | Checked by: BM

SI DRILLING
Cable Percussion Ltd

Cable Percussive Borehole Record

BHB

Sheet 1 of 1

Project Ref: **409.01526.00019**	Client: Ingrebourne Valley	E:	N:
Location: Cockhide Farm	Consultant:	Date: 18/02/2019	
	Plant used: Dando 2000 Cable Percussive Rig	SPT Hammer Serial No:	

Geological Description	Legend	Depth (m)	Ground Level (maOD)	Sample / In-Situ Test Information			Date - Depth (m) Casing (Water)	Installation & Backfill
				Type	Depth	Results / Remarks		
MADE GROUND. Brown sandy GRAVEL of concrete and brick. (Driller description)								
Greenish brown clayey SAND and GRAVEL. (Driller description)		0.60						
Brown SAND and GRAVEL. (Driller description)		1.60						
Stiff grey CLAY. (Driller description)		3.20						
Borehole completed at 4.20m.		4.20					18/02/2019 - 4.20 4.00 (Dry)	

Chiselling Details		Water Added Records	
Depths (m)	Duration (hh:mm)	Depth (m)	Litres
		1.60 - 2.00	40

Water Strike - General			
Date	Strike Depth (m)	Depth Sealed (m)	Casing Depth (m)
18-02-2019	2.00	4.00	1.80

Water Strike - Details		
Time Elapsed (mins)	Standing Level (m)	Remarks
20	1.80	Slow flow

Hole Diameter by Depth		Casing Diameter by Depth	
Depth Base (m)	Diameter (mm)	Depth Base (m)	Diameter (mm)
4.20	150	4.00	150

Remarks:

1. Installation: 50mm standpipe GL to 0.50m plain, 0.50m to 3.20m slotted, 3.20m to 4.20m plain, fitted with gas tap and bung, installed with flush cover.
2. Backfill: GL to 0.50m bentonite, 0.50m to 3.20m gravel, 3.20m to 4.20m bentonite.

SI Drilling Cable Percussion Ltd
9 Vera Road
Norwich, Norfolk
NR13 6QP

E-mail: sales@sidrilling.co.uk
Website: www.sidrilling.co.uk

Drilled by: BM | Logged by: BM | Checked by: BM

SI DRILLING
Cable Percussion Ltd

Cable Percussive Borehole Record

BHC

Sheet 1 of 1

Project Ref: **409.01526.00019**	Client: Ingrebourne Valley	E:	N:
Location: Cockhide Farm	Consultant:	Date: 19/02/2019	
	Plant used: Dando 2000 Cable Percussive Rig	SPT Hammer Serial No:	

Geological Description	Legend	Depth (m)	Ground Level (maOD)	Sample / In-Situ Test Information			Date - Depth (m) Casing (Water)	Installation & Backfill
				Type	Depth	Results / Remarks		
TOPSOIL. Brown sandy gravelly CLAY. (Driller description).		0.40						
Firm brown mottled light brown sandy CLAY. (Driller description)		1.30						
Brown SAND and GRAVEL. (Driller description)		2.80						
Stiff grey CLAY. (Driller description)		3.80						
Borehole completed at 3.80m.							19/02/2019 - 3.80 3.00 (Dry)	

Chiselling Details		Water Added Records	
Depths (m)	Duration (hh:mm)	Depth (m)	Litres
		1.50 - 2.00	30

Water Strike - General			
Date	Strike Depth (m)	Depth Sealed (m)	Casing Depth (m)
19-02-2019	2.20	3.00	2.00

Water Strike - Details		
Time Elapsed (mins)	Standing Level (m)	Remarks
20	1.90	Slow flow

Hole Diameter by Depth		Casing Diameter by Depth	
Depth Base (m)	Diameter (mm)	Depth Base (m)	Diameter (mm)
3.80	150	3.00	150

Remarks:

1. Installation: 50mm standpipe GL to 0.50m plain, 0.50m to 2.80m slotted, 2.80m to 3.80m plain, fitted with gas tap and bung, installed with flush cover.
2. Backfill: GL to 0.50m bentonite, 0.50m to 2.80m gravel, 2.80m to 3.80m bentonite.

SI Drilling Cable Percussion Ltd
9 Vera Road
Norwich, Norfolk
NR13 6QP

E-mail: sales@sidrilling.co.uk
Website: www.sidrilling.co.uk

Drilled by: BM | Logged by: BM | Checked by: BM

SI DRILLING
Cable Percussion Ltd

Cable Percussive Borehole Record

BHD

Sheet 1 of 1

Project Ref: **409.01526.00019**	Client: Ingrebourne Valley	E:	N:
Location: Cockhide Farm	Consultant:	Date: 18/02/2019	
	Plant used: Dando 2000 Cable Percussive Rig	SPT Hammer Serial No:	

Geological Description	Legend	Depth (m)	Ground Level (maOD)	Sample / In-Situ Test Information			Date - Depth (m) Casing (Water)	Installation & Backfill
				Type	Depth	Results / Remarks		
TOPSOIL. Brown gravelly SAND. (Driller description)		0.30						
Brown SAND and GRAVEL. (Driller description)								
Stiff grey CLAY. (Driller description)		3.60						
Borehole completed at 4.60m.		4.60					18/02/2019 - 4.60 4.00 (Dry)	

Chiselling Details		Water Added Records	
Depths (m)	Duration (hh:mm)	Depth (m)	Litres
		1.00 - 2.00	40

Water Strike - General			
Date	Strike Depth (m)	Depth Sealed (m)	Casing Depth (m)
18-02-2019	1.80	4.00	1.60

Water Strike - Details		
Time Elapsed (mins)	Standing Level (m)	Remarks
20	1.70	Slow flow

Hole Diameter by Depth		Casing Diameter by Depth	
Depth Base (m)	Diameter (mm)	Depth Base (m)	Diameter (mm)
4.60	150	4.00	150

Remarks:

1. Installation: 50mm standpipe GL to 0.50m plain, 0.50m to 3.60m slotted, 3.60m to 4.60m plain, fitted with gas tap and bung, installed with flush cover.
2. Backfill: GL to 0.50m bentonite, 0.50m to 3.60m gravel, 3.60m to 4.60m bentonite.

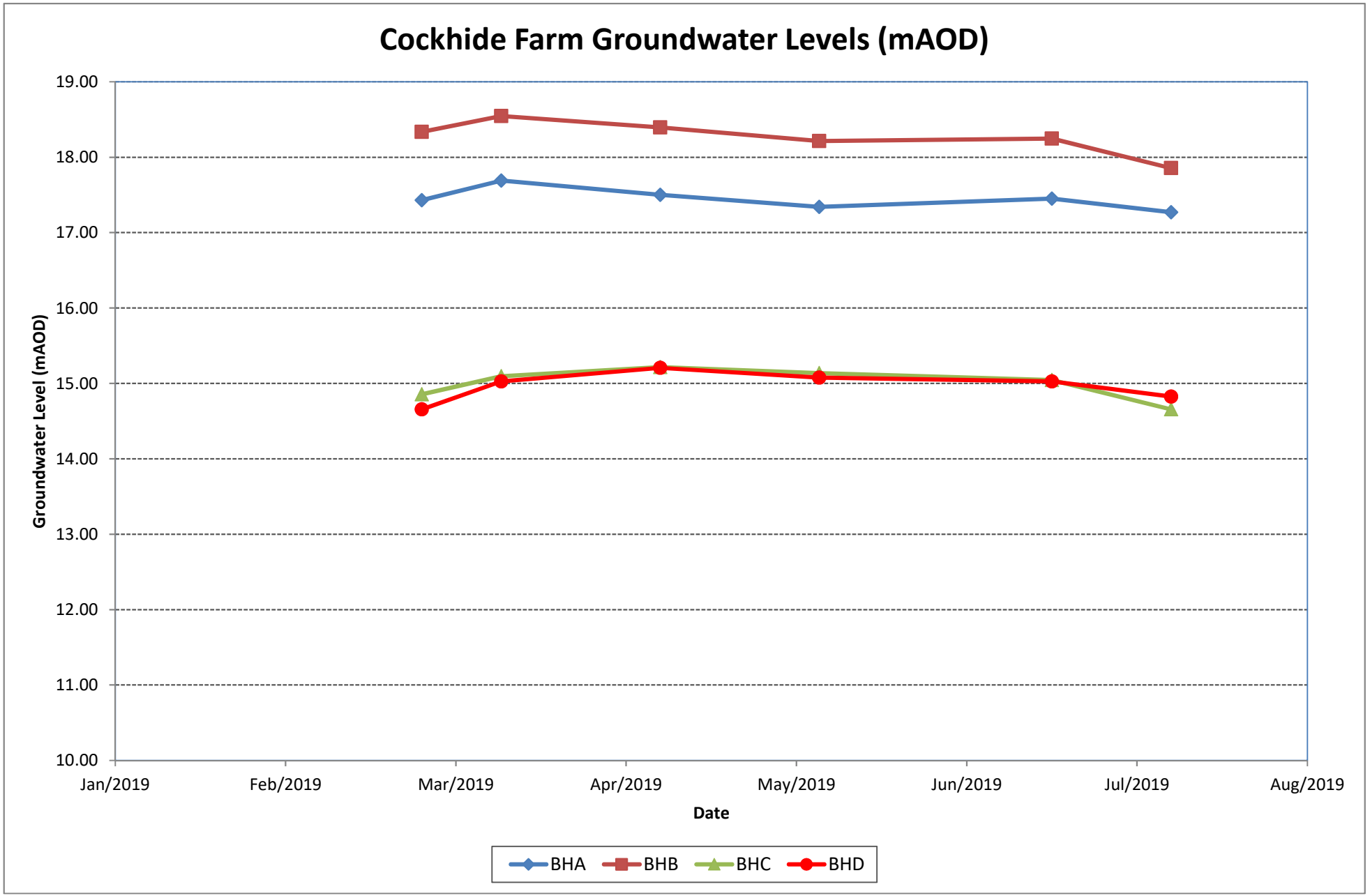
SI Drilling Cable Percussion Ltd
9 Vera Road
Norwich, Norfolk
NR13 6QP

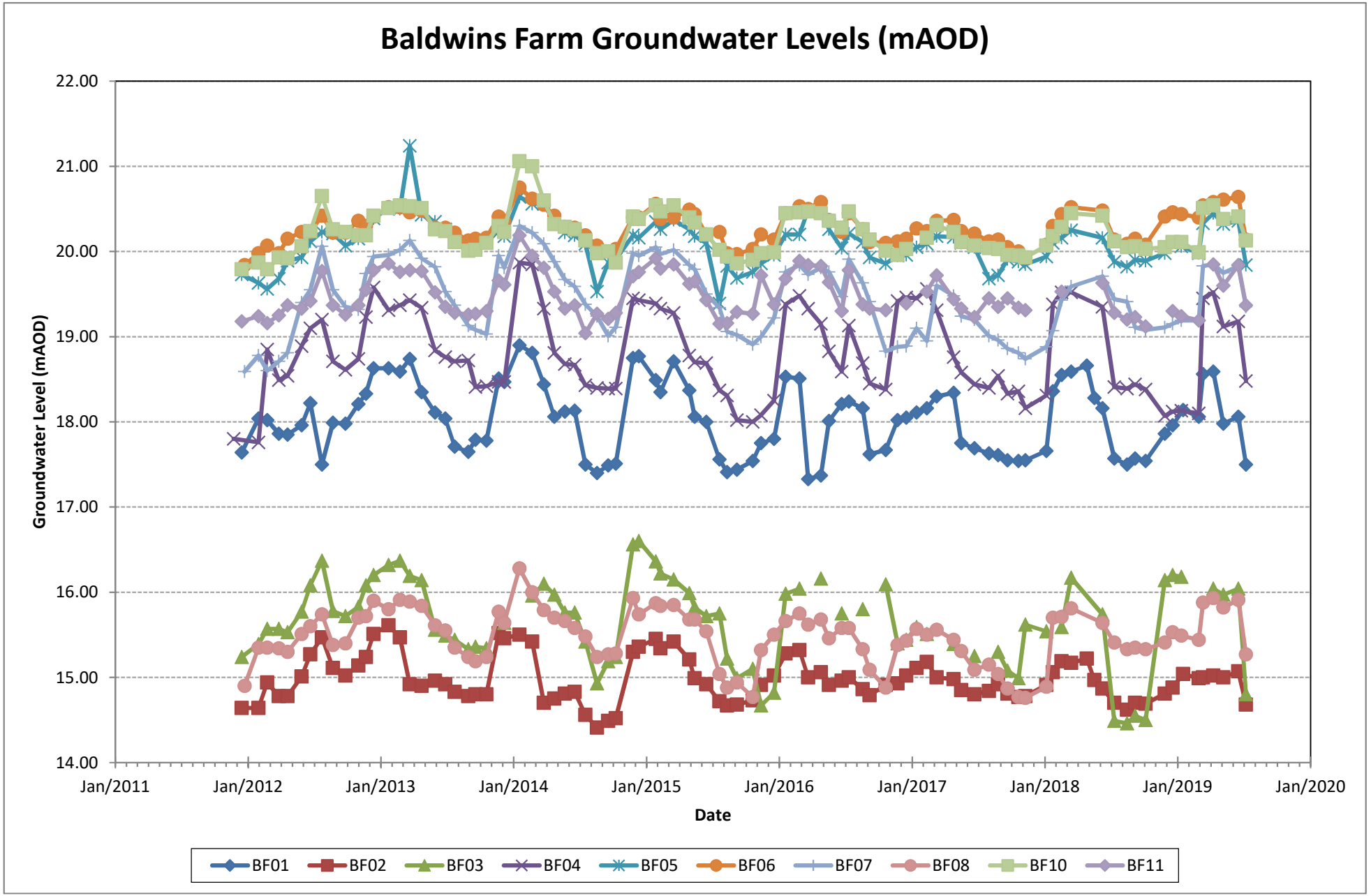
E-mail: sales@sidrilling.co.uk
Website: www.sidrilling.co.uk

Drilled by: BM | Logged by: BM | Checked by: BM

APPENDIX 04

Groundwater Hydrographs


Cockhide Farm Groundwater Levels (mAOD)
19.00
18.00
17.00
16.00
15.00
14.00
13.00
12.00
11.00
10.00
Groundwater Level (mAOD)
Jan/2019
Feb/2019
Mar/2019
Apr/2019
May/2019
Jun/2019
Jul/2019
Aug/2019
Date
BHA
BHB
BHC
BHD


Baldwins Farm Groundwater Levels (mAOD)
Groundwater Level (mAOD)
22.00
21.00
20.00
19.00
18.00
17.00
16.00
15.00
14.00
Jan/2011
Jan/2012
Jan/2013
Jan/2014
Jan/2015
Jan/2016
Jan/2017
Jan/2018
Jan/2019
Jan/2020
Date
BF01
BF02
BF03
BF04
BF05
BF06
BF07
BF08
BF10
BF11

APPENDIX 05

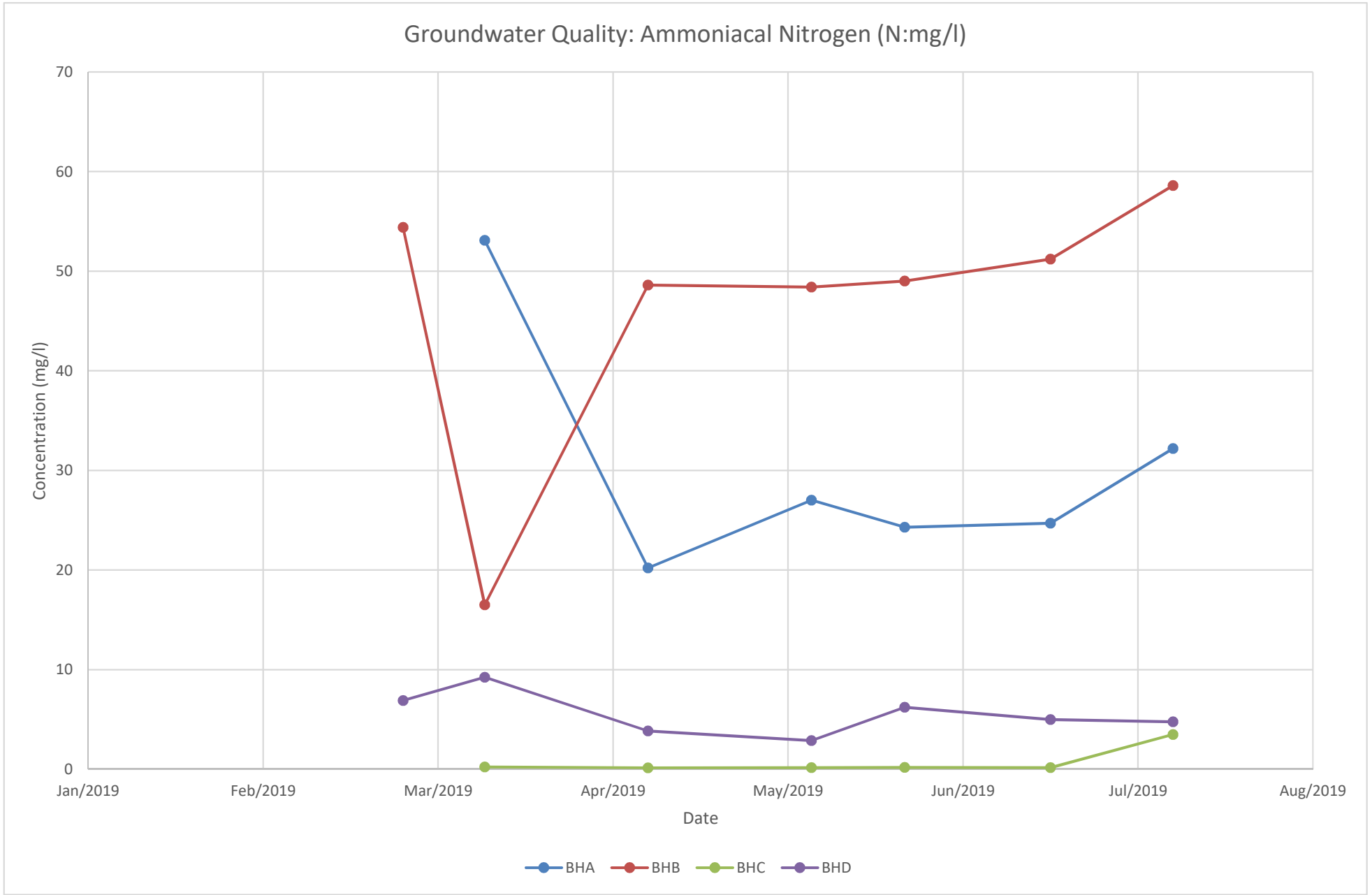
Groundwater Time-Series Graphs

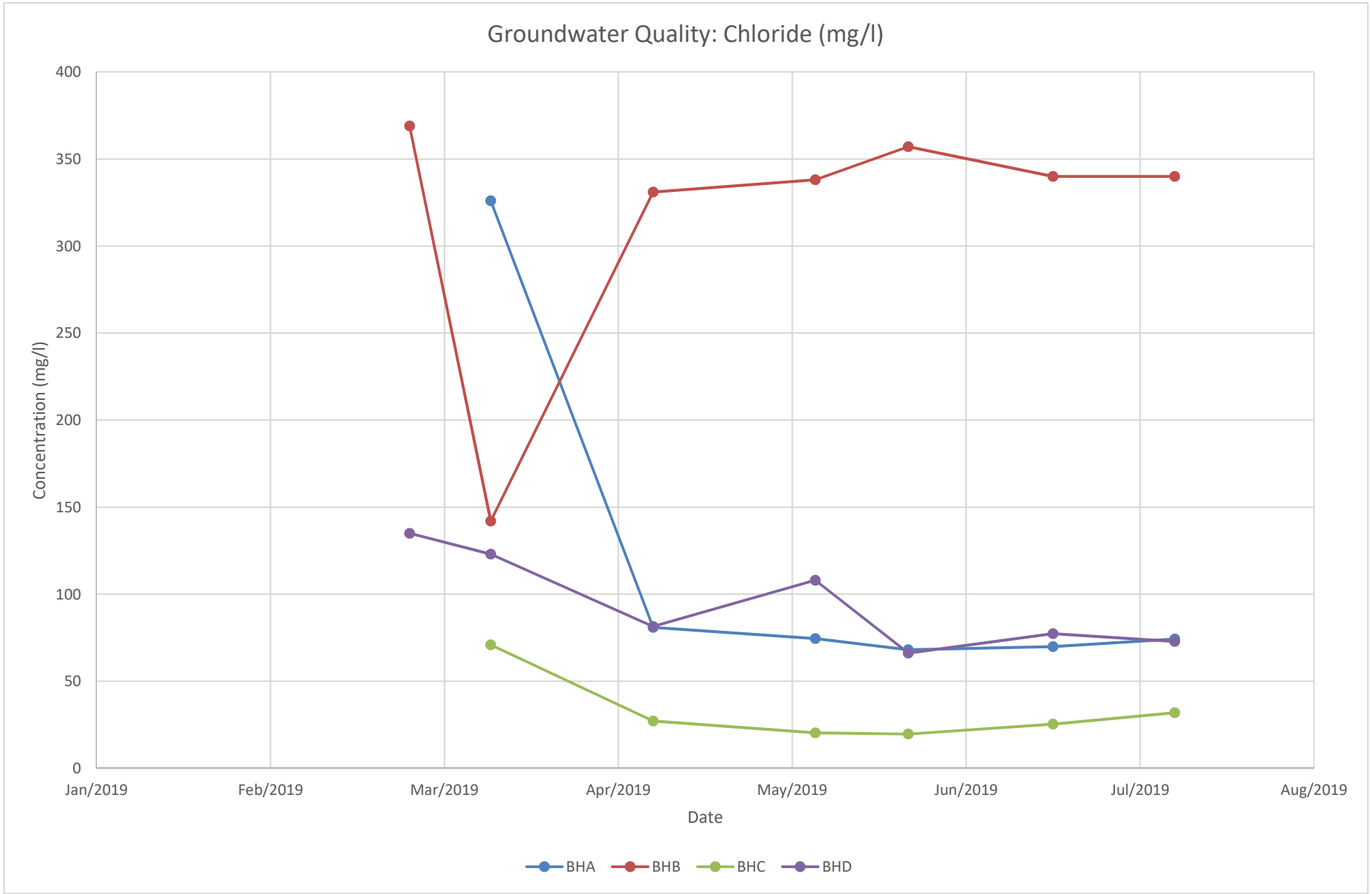
Determinand	Units	BHA				BHB			
		Count	Min	Mean	Max	Count	Min	Mean	Max
Carbon, Organic (diss.filt)	mg/l	6	21.6	35.12	94.5	7	21.1	92.17	114
Alkalinity,Total as CaCO3 (diss.filt)	mg/l	6	430	588.3	1230	7	435	1359.3	1540
Ammoniacal Nitrogen as N	mg/l	6	20.2	30.25	53.1	7	16.5	46.67	58.6
Chloride	mg/l	6	68.1	115.62	326	7	142	316.71	369
COD, unfiltered	mg/l	6	50.6	105.33	256	7	81.3	259.47	418
Conductivity @ 20 deg.C	us/cm	6	944	1317.7	2980	7	1310	2895.71	3310
Cyanide, Total (low level)	mg/l	4	<0.005	-	<0.05	4	<0.005	-	<0.05
Ionic balance	% Diff	6	-0.0772	4.59	9.75	7	-0.106	1.89	3.81
Oxygen, dissolved	mg/l	6	4.74	6.83	8.68	7	2.37	6.53	8.47
pH	pH Units	6	6.99	7.43	8.26	7	7	7.25	7.5
Sulphate	mg/l	6	33.6	49.45	103	7	52.5	73.43	119
Total Oxidised Nitrogen as N	mg/l	6	<0.1	0.12	0.464	7	<0.1	0.48	3.03
Arsenic (diss.filt)	mg/l	6	0.00247	0.0054	0.0102	7	0.00122	0.0094	0.0138
Cadmium (diss.filt)	mg/l	6	<0.00008	-	<0.00008	7	<0.00008	-	<0.00008
Calcium (Dis.Filt)	mg/l	6	75.2	134.03	370	7	82	303.7	349
Chromium (diss.filt)	mg/l	6	<0.001	0.00092	0.0024	7	<0.001	0.0026	0.00405
Copper (diss.filt)	mg/l	6	<0.0003	0.00064	0.0016	7	<0.0003	0.0012	0.00376
Iron (Dis.Filt)	mg/l	6	0.557	6.70	10.4	7	0.0583	8.22	15.9
Lead (diss.filt)	mg/l	6	<0.0002	0.00012	0.000202	7	<0.0002	0.0001	<0.0002
Magnesium (Dis.Filt)	mg/l	6	26.5	37.4	75.3	7	28.3	72.87	87.3
Manganese (diss.filt)	mg/l	6	1.17	1.34	1.54	7	0.787	1.50	2.19
Mercury (diss.filt)	mg/l	3	<0.00001	7.33E-06	0.000012	3	<0.00001	-	<0.00001
Nickel (diss.filt)	mg/l	6	0.0129	0.022	0.055	7	0.0128	0.0553	0.0678
Potassium (Dis.Filt)	mg/l	6	33.6	50.57	121	7	31.3	117.3	216
Sodium (Dis.Filt)	mg/l	6	71.8	113.2	282	7	189	263.4	313
Zinc (diss.filt)	mg/l	6	0.00296	0.0054	0.0119	7	0.00332	0.0102	0.0195
Total Monohydric Phenols (Landfill)	mg/l	3	<0.03	-	<0.03	3	<0.03	-	<0.03
GRO >C6-C8	µg/l	3	<10	-	<10	3	<10	-	<10
EPH Band >C12-C16 (aq)	µg/l	3	<100	-	<100	3	<100	-	<200
EPH Band >C16-C21 (aq)	µg/l	3	<100	-	<100	3	<100	-	<200
EPH Band >C21-C40 (aq)	µg/l	3	<100	80.33	141	3	<100	-	<200
EPH (C8-C12) (aq)	µg/l	3	<100	-	<100	3	<100	-	<100
Total EPH (C6-C40) (aq)	µg/l	3	102	176.33	322	3	<100	204.33	342
EPH Range >C10 - C40 (aq)	µg/l	1	<100	-	<100	1	<500	-	<500
Acenaphthene (aq)	µg/l	4	<0.005	0.008	0.018	4	<0.01	-	<0.025

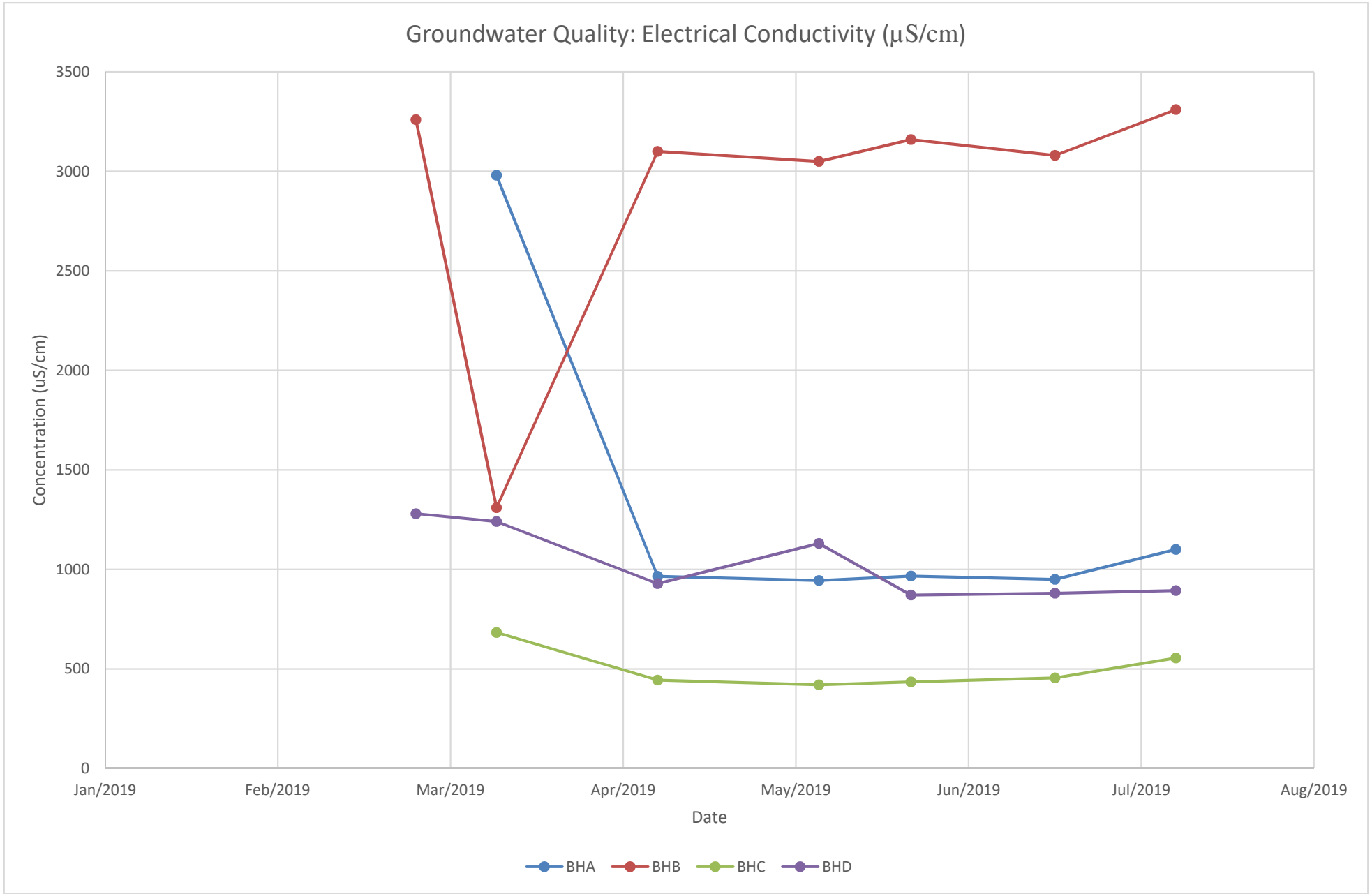
Determinand	Units	BHA				BHB			
		Count	Min	Mean	Max	Count	Min	Mean	Max
Acenaphthylene (aq)	**µg/l**	4	<0.005	0.005	0.013	4	<0.01	-	<0.025
Anthracene (aq)	**µg/l**	4	<0.005	0.009	0.027	4	<0.005	0.026	0.0526
Benzo(a)anthracene (aq)	**µg/l**	4	<0.005	0.050	0.183	4	<0.005	0.195	0.405
Benzo(a)pyrene (aq)	**µg/l**	4	<0.002	0.089	0.323	4	<0.002	0.306	0.665
Benzo(b)fluoranthene (aq)	**µg/l**	4	<0.005	0.117	0.430	4	<0.01	0.434	0.885
Benzo(g,h,i)perylene (aq)	**µg/l**	4	<0.005	0.078	0.240	4	<0.005	0.204	0.412
Benzo(k)fluoranthene (aq)	**µg/l**	4	<0.005	0.045	0.162	4	<0.005	0.190	0.402
Chrysene (aq)	**µg/l**	4	<0.005	0.055	0.188	4	<0.005	0.212	0.421
Dibenzo(a,h)anthracene (aq)	**µg/l**	4	<0.005	0.020	0.041	4	<0.005	0.045	0.0975
Fluoranthene (aq)	**µg/l**	4	<0.005	0.135	0.468	4	<0.005	0.397	0.831
Fluorene (aq)	**µg/l**	4	<0.005	0.004	0.010	4	<0.01	0.011	<0.025
Indeno(1,2,3-cd)pyrene (aq)	**µg/l**	4	<0.005	0.058	0.157	4	<0.005	0.158	0.343
Naphthalene (aq)	**µg/l**	4	<0.01	0.014	0.043	4	<0.02	0.026	<0.05
PAH, Total Detected USEPA 16 (aq)	**µg/l**	4	<0.082	0.834	2.830	4	<0.164	2.701	5.33
Phenanthrene (aq)	**µg/l**	4	<0.005	0.029	0.095	4	<0.01	0.118	0.242
Pyrene (aq)	**µg/l**	4	<0.005	0.128	0.441	4	<0.01	0.376	0.801
Benzene	**µg/l**	1	<1	-	<1	1	<1	-	<1
Ethylbenzene	**µg/l**	1	<1	-	<1	1	<1	-	<1
m,p-Xylene	**µg/l**	1	<1	-	<1	1	<1	-	<1
o-Xylene	**µg/l**	1	<1	-	<1	1	<1	-	<1
Sum of detected Xylenes	**µg/l**	1	<2	-	<2	1	<2	-	<2
Toluene	**µg/l**	1	<1	-	<1	1	<1	-	<1

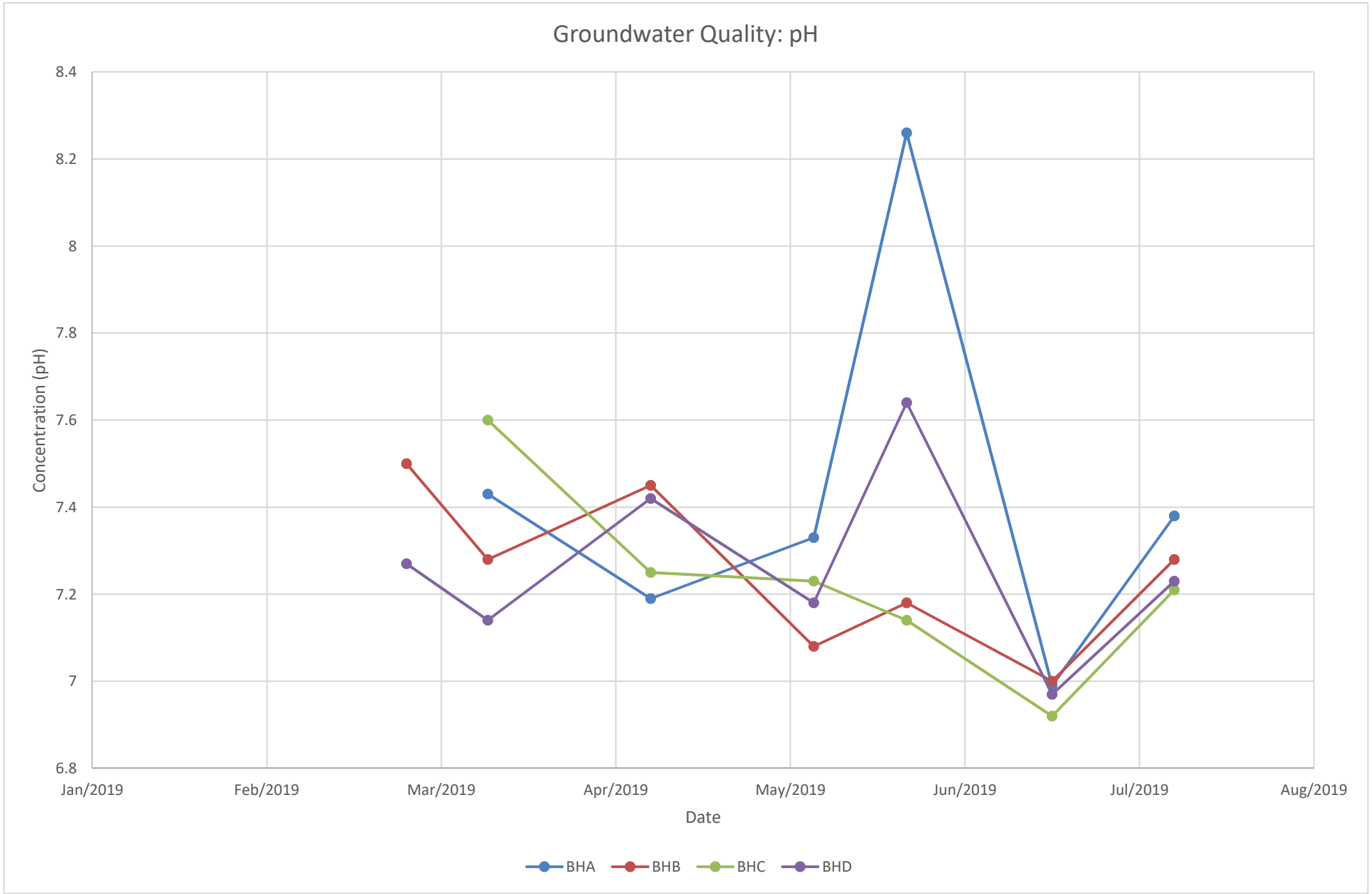
Determinand	Units	BHC				BHD			
		Count	Min	Mean	Max	Count	Min	Mean	Max
Carbon, Organic (diss.filt)	mg/l	6	6.39	8.23	10.5	7	7.57	15.95	20
Alkalinity,Total as CaCO3 (diss.filt)	mg/l	6	190	221.83	276	7	375	434.29	495
Ammoniacal Nitrogen as N	mg/l	6	0.142	0.73	3.49	7	2.87	5.54	9.23
Chloride	mg/l	6	19.7	32.58	70.9	7	66.2	94.83	135
COD, unfiltered	mg/l	6	<10	60.68	218	7	26.6	55.21	148
Conductivity @ 20 deg.C	us/cm	6	420	498.33	683	7	871	1031.86	1280
Cyanide, Total (low level)	mg/l	4	<0.005	-	<0.05	4	<0.005	-	<0.05
Ionic balance	% Diff	6	-2.17	1.77	5.65	7	-13.7	3.45	16.1
Oxygen, dissolved	mg/l	6	7.84	8.51	9.45	7	5.48	7.56	9.81
pH	pH Units	6	6.92	7.23	7.6	7	6.97	7.26	7.64
Sulphate	mg/l	6	15.3	40.78	76.1	7	55.4	77.77	110
Total Oxidised Nitrogen as N	mg/l	6	<0.1	0.18	0.328	7	0.508	1.10	1.75
Arsenic (diss.filt)	mg/l	6	0.000588	0.0024	0.00441	7	0.00086	0.00102	0.00147
Cadmium (diss.filt)	mg/l	6	<0.00008	0.00005	0.000097	7	<0.00008	0.00010	0.000148
Calcium (Dis.Filt)	mg/l	6	61	69.85	90.2	7	95.6	110.66	127
Chromium (diss.filt)	mg/l	6	<0.001	-	<0.001	7	<0.001	-	<0.001
Copper (diss.filt)	mg/l	6	<0.0003	0.00077	0.00221	7	0.00521	0.0064	0.00919
Iron (Dis.Filt)	mg/l	6	<0.019	1.509	4.37	7	<0.019	-	<0.019
Lead (diss.filt)	mg/l	6	<0.0002	0.000239	0.000936	7	<0.0002	-	<0.0002
Magnesium (Dis.Filt)	mg/l	6	20.5	23.48	27.9	7	33.3	40.43	48.8
Manganese (diss.filt)	mg/l	6	0.177	0.53	0.716	7	0.438	0.565	0.753
Mercury (diss.filt)	mg/l	3	<0.00001	6.67E-06	0.00001	3	<0.00001	-	<0.00001
Nickel (diss.filt)	mg/l	6	0.00462	0.0062	0.00803	7	0.0232	0.029	0.0419
Potassium (Dis.Filt)	mg/l	6	1.17	2.625	7.14	7	19.5	21.9	24
Sodium (Dis.Filt)	mg/l	6	9.48	21.68	46.1	7	63.9	96.44	138
Zinc (diss.filt)	mg/l	6	0.00322	0.0056	0.00911	7	0.00277	0.0051	0.00739
Total Monohydric Phenols (Landfill)	mg/l	3	<0.03	-	<0.03	3	<0.03	-	<0.03
GRO >C6-C8	µg/l	3	<10	-	<10	3	<10	-	<10
EPH Band >C12-C16 (aq)	µg/l	3	<100	-	<100	3	<100	-	<100
EPH Band >C16-C21 (aq)	µg/l	3	<100	-	<100	3	<100	-	<100
EPH Band >C21-C40 (aq)	µg/l	3	<100	131.33	294	3	<100	74	122
EPH (C8-C12) (aq)	µg/l	3	<100	-	<100	3	<100	-	<100
Total EPH (C6-C40) (aq)	µg/l	3	<100	150.67	352	3	<100	91	173
EPH Range >C10 - C40 (aq)	µg/l	1	588	588	588	1	<500	-	<500
Acenaphthene (aq)	µg/l	4	<0.005	-	<0.025	4	<0.005	-	<0.025

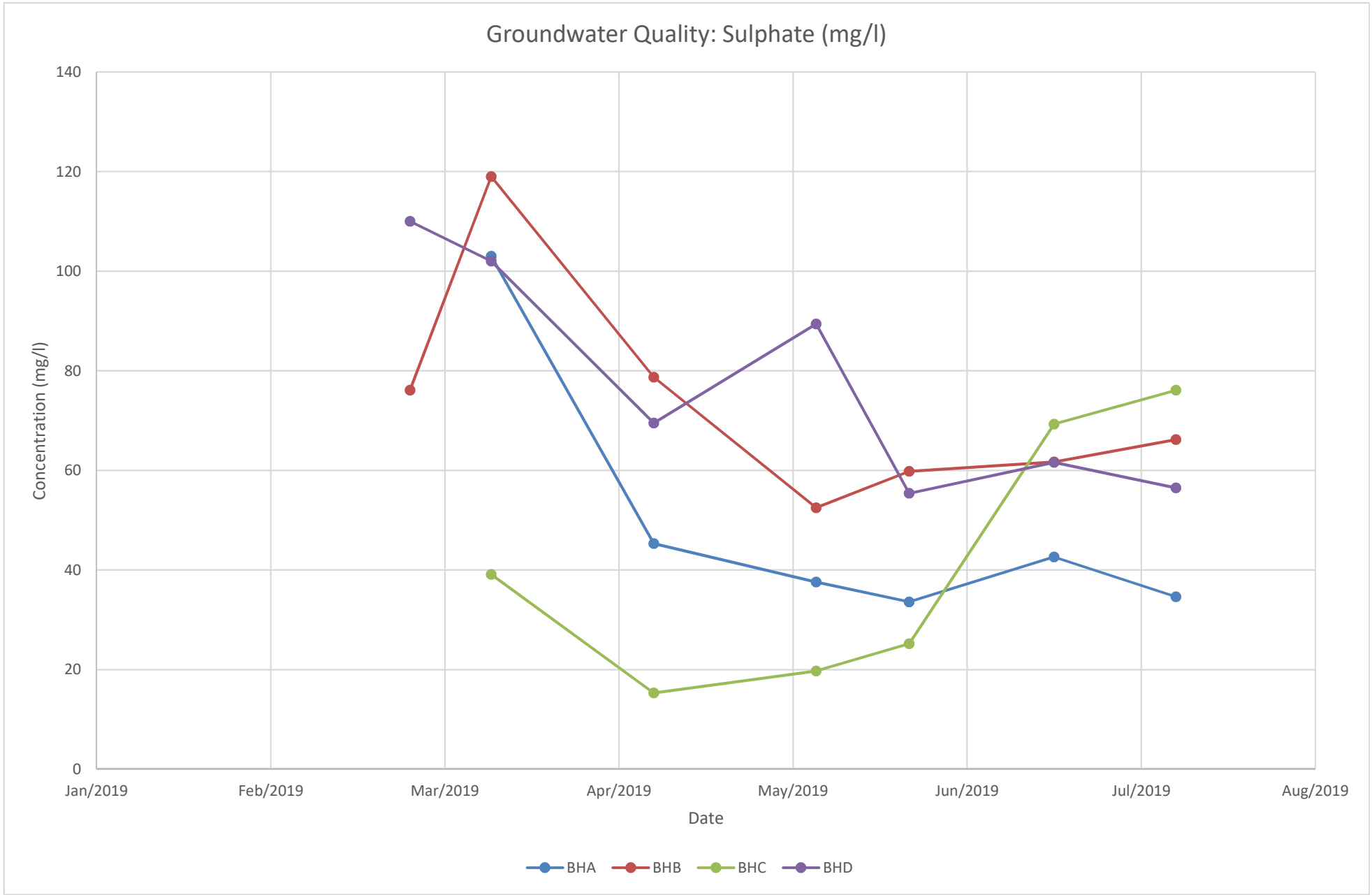
Determinand	Units	BHC				BHD			
		Count	Min	Mean	Max	Count	Min	Mean	Max
Acenaphthylene (aq)	**µg/l**	4	<0.005	-	<0.025	4	<0.005	-	<0.025
Anthracene (aq)	**µg/l**	4	<0.005	0.016	0.0299	4	<0.005	-	<0.025
Benzo(a)anthracene (aq)	**µg/l**	4	<0.005	0.068	0.177	4	<0.005	0.0218	0.0558
Benzo(a)pyrene (aq)	**µg/l**	4	<0.002	0.147	0.315	4	<0.002	0.0389	0.0824
Benzo(b)fluoranthene (aq)	**µg/l**	4	<0.005	0.110	0.403	4	<0.005	0.0598	0.128
Benzo(g,h,i)perylene (aq)	**µg/l**	4	<0.005	0.102	0.256	4	<0.005	0.0171	0.0508
Benzo(k)fluoranthene (aq)	**µg/l**	4	<0.005	0.091	0.188	4	<0.005	0.0275	0.0589
Chrysene (aq)	**µg/l**	4	<0.005	0.077	0.2	4	<0.005	0.0224	0.0503
Dibenzo(a,h)anthracene (aq)	**µg/l**	4	<0.005	0.035	0.0726	4	<0.005	0.0082	<0.025
Fluoranthene (aq)	**µg/l**	4	<0.005	0.208	0.439	4	<0.005	0.0623	0.129
Fluorene (aq)	**µg/l**	4	<0.005	-	<0.025	4	<0.005	0.0050	<0.025
Indeno(1,2,3-cd)pyrene (aq)	**µg/l**	4	<0.005	0.124	0.244	4	<0.005	0.0351	0.093
Naphthalene (aq)	**µg/l**	4	<0.01	0.01	<0.05	4	<0.01	0.0100	<0.05
PAH, Total Detected USEPA 16 (aq)	**µg/l**	4	<0.082	1.244	2.63	4	<0.082	0.3763	0.72
Phenanthrene (aq)	**µg/l**	4	<0.005	0.057	0.12	4	<0.005	0.0215	0.0473
Pyrene (aq)	**µg/l**	4	<0.005	0.197	0.412	4	<0.005	0.0588	0.121
Benzene	**µg/l**	1	<1	-	<1	1	<1	-	<1
Ethylbenzene	**µg/l**	1	<1	-	<1	1	<1	-	<1
m,p-Xylene	**µg/l**	1	<1	-	<1	1	<1	-	<1
o-Xylene	**µg/l**	1	<1	-	<1	1	<1	-	<1
Sum of detected Xylenes	**µg/l**	1	<2	-	<2	1	<2	-	<2
Toluene	**µg/l**	1	<1	-	<1	1	<1	-	<1

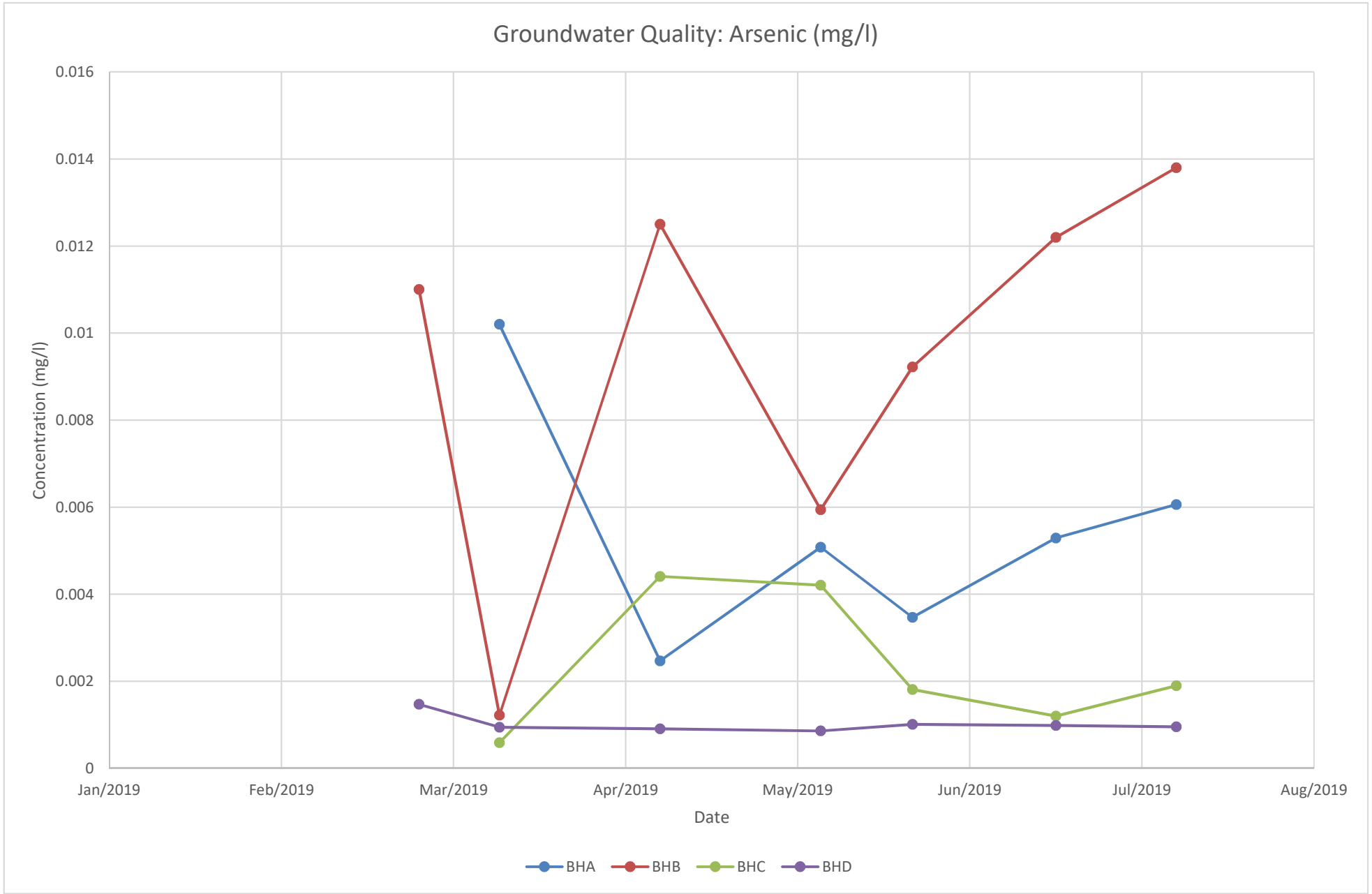

Groundwater Quality: Ammoniacal Nitrogen (N:mg/l)
Concentration (mg/l)
70
60
50
40
30
20
10
0
Jan/2019
Feb/2019
Mar/2019
Apr/2019
May/2019
Jun/2019
Jul/2019
Aug/2019
Date
BHA
BHB
BHC
BHD


Groundwater Quality: Chloride (mg/l)
Concentration (mg/l)
400
350
300
250
200
150
100
50
0
Jan/2019
Feb/2019
Mar/2019
Apr/2019
May/2019
Jun/2019
Jul/2019
Aug/2019
Date
BHA
BHB
BHC
BHD

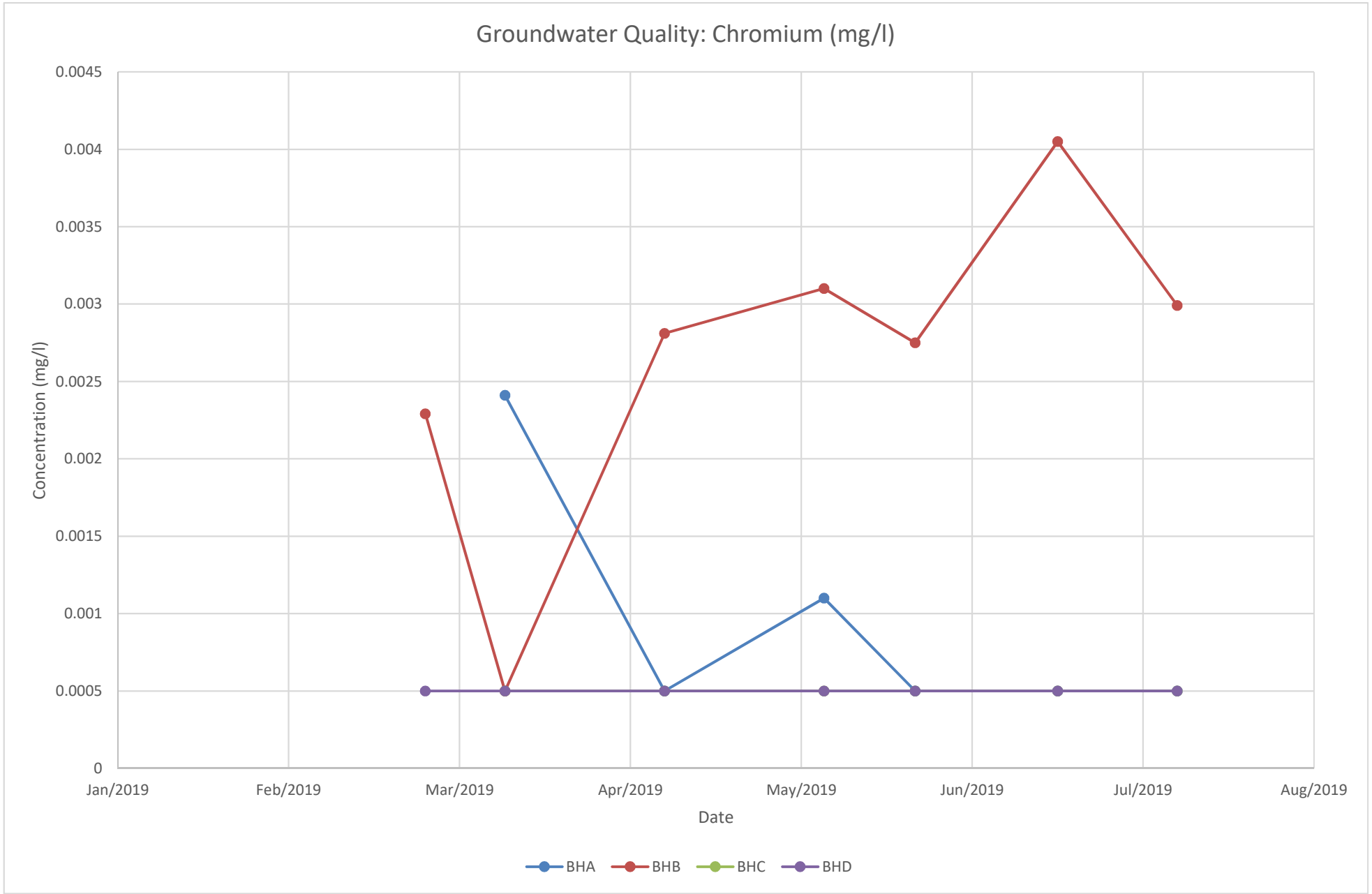

Groundwater Quality: Electrical Conductivity (µS/cm)
Concentration (uS/cm)
3500
3000
2500
2000
1500
1000
500
0
Jan/2019
Feb/2019
Mar/2019
Apr/2019
May/2019
Jun/2019
Jul/2019
Aug/2019
Date
BHA
BHB
BHC
BHD

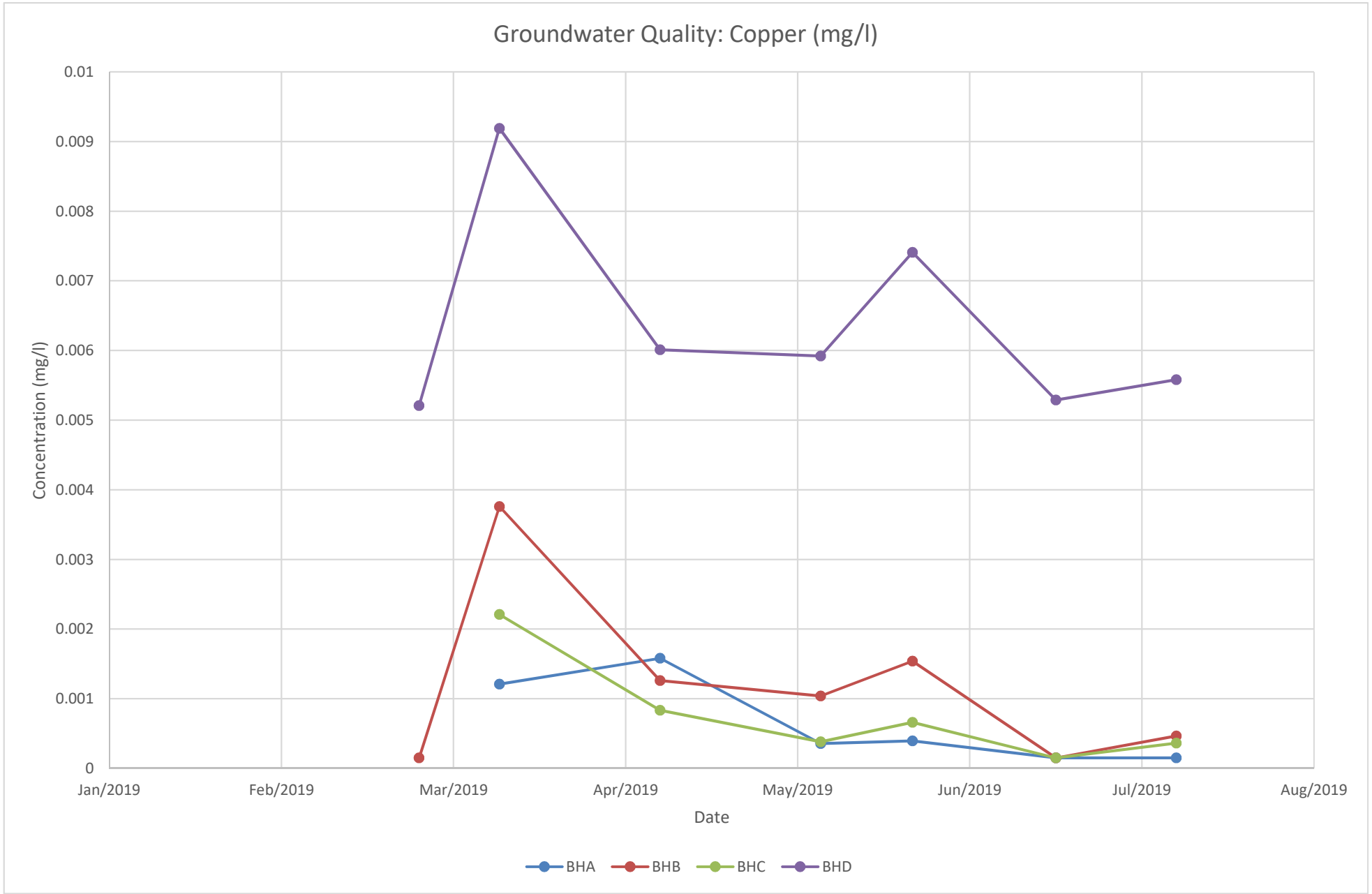

Groundwater Quality: pH
8.4
8.2
8
7.8
7.6
7.4
7.2
7
6.8
Concentration (pH)
Jan/2019
Feb/2019
Mar/2019
Apr/2019
May/2019
Jun/2019
Jul/2019
Aug/2019
Date
BHA
BHB
BHC
BHD

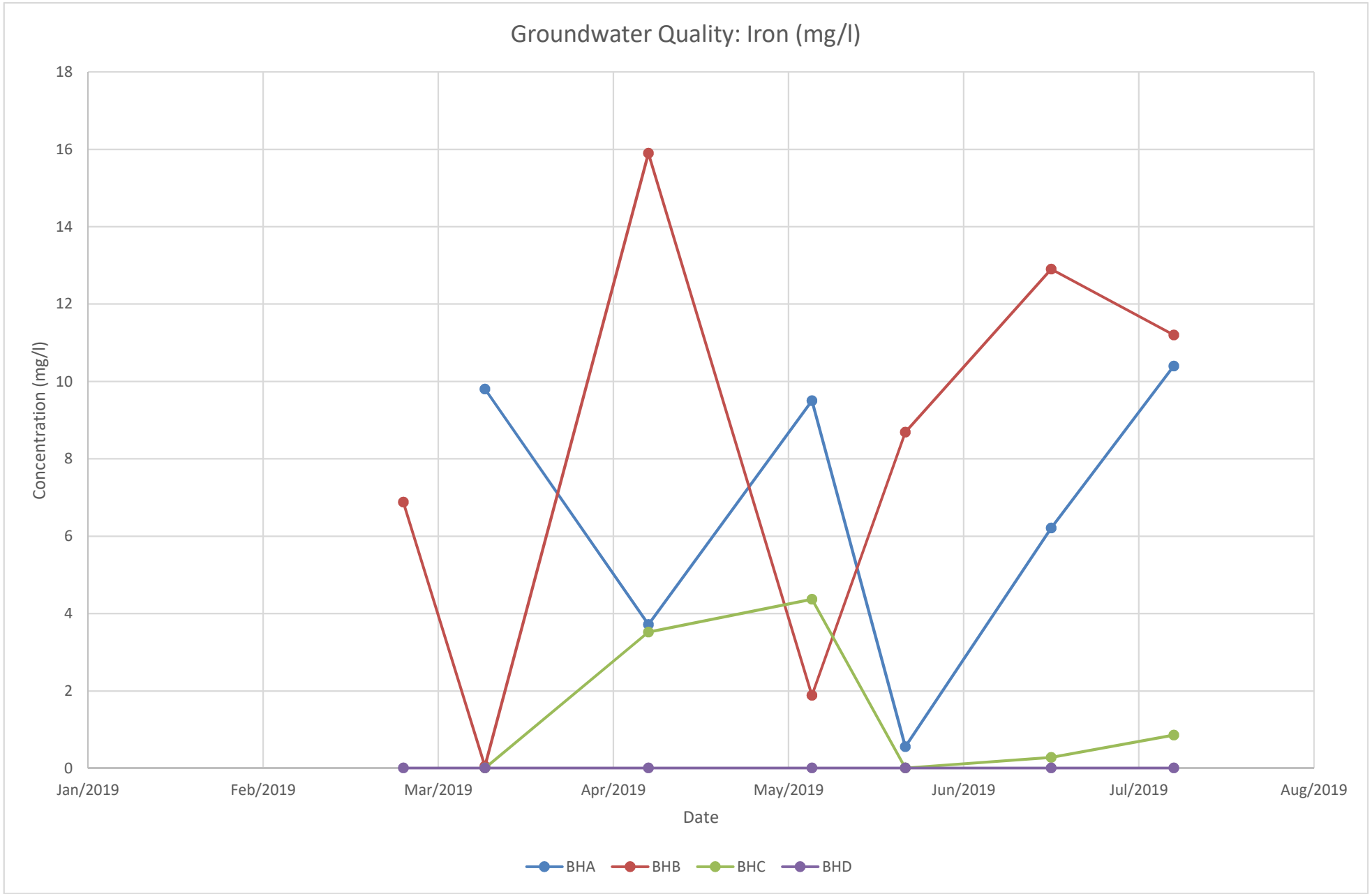

Groundwater Quality: Sulphate (mg/l)
Concentration (mg/l)
140
120
100
80
60
40
20
0
Jan/2019
Feb/2019
Mar/2019
Apr/2019
May/2019
Jun/2019
Jul/2019
Aug/2019
Date
BHA
BHB
BHC
BHD

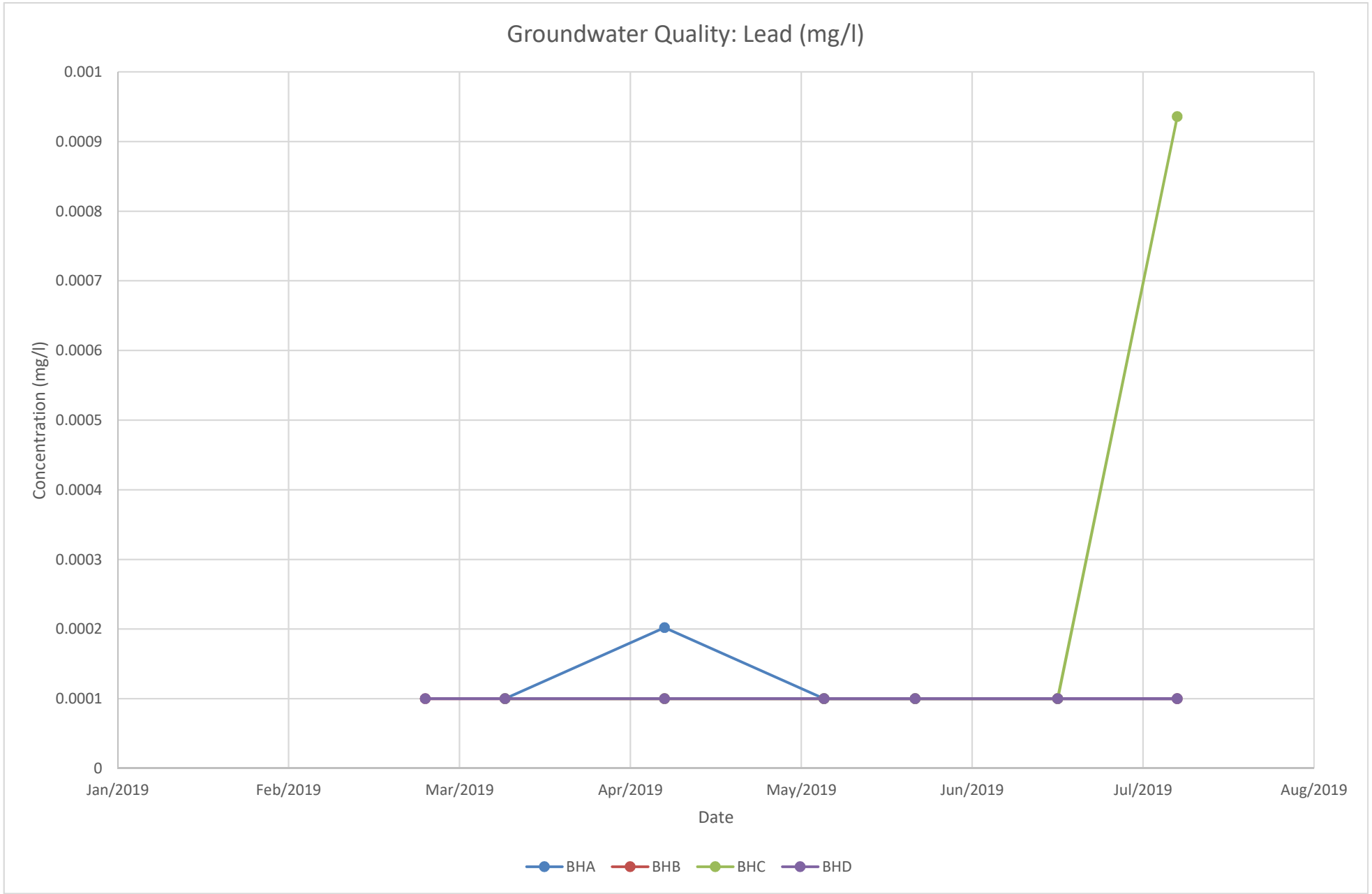

Groundwater Quality: Arsenic (mg/l)
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
Concentration (mg/l)
Jan/2019
Feb/2019
Mar/2019
Apr/2019
May/2019
Jun/2019
Jul/2019
Aug/2019
Date
BHA
BHB
BHC
BHD

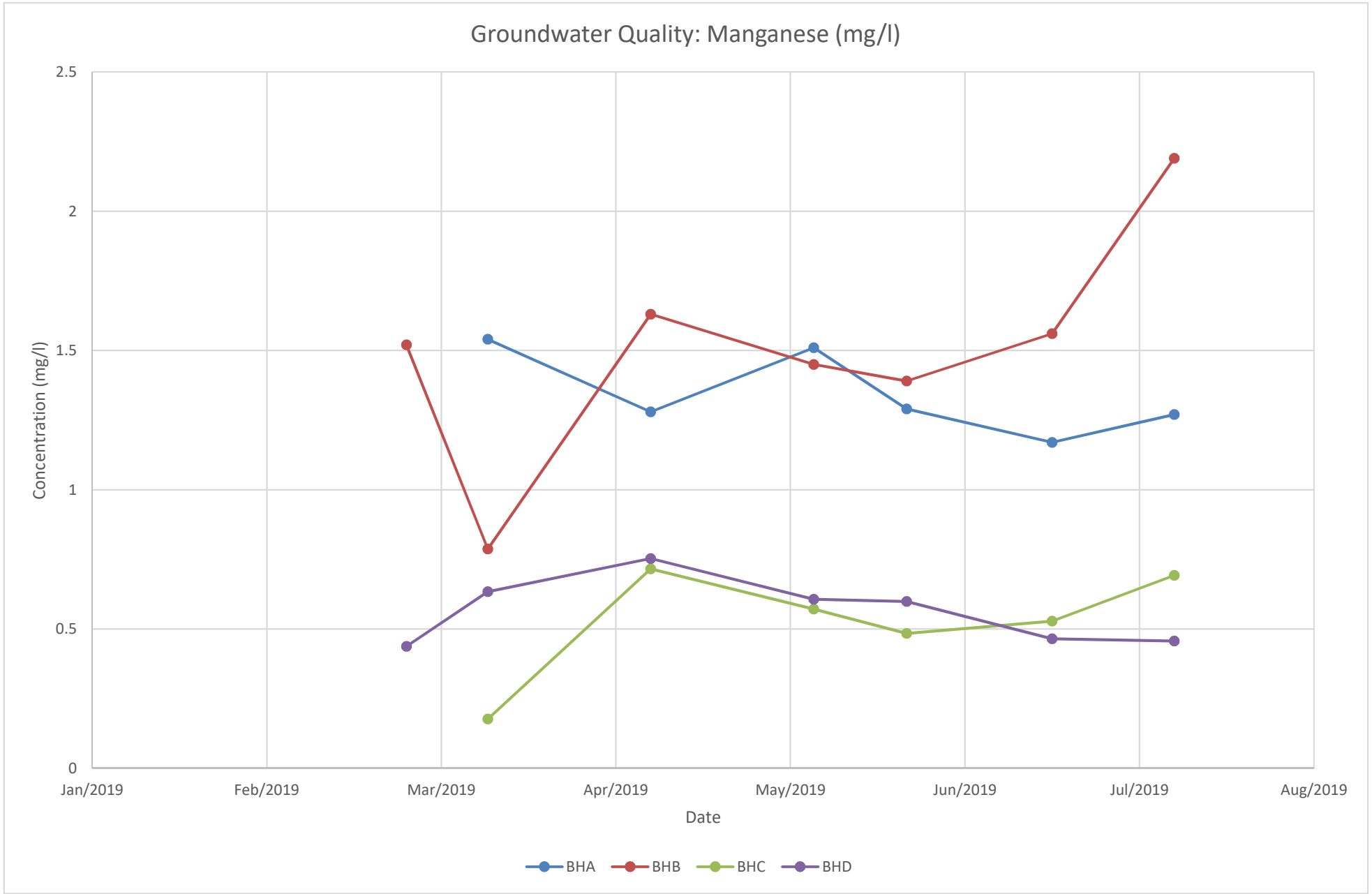
Groundwater Quality: Cadmium (mg/l)
0.00016
0.00014
0.00012
0.0001
0.00008
0.00006
0.00004
0.00002
0
Concentration (mg/l)
Jan/2019
Feb/2019
Mar/2019
Apr/2019
May/2019
Jun/2019
Jul/2019
Aug/2019
Date
BHA
BHB
BHC
BHD

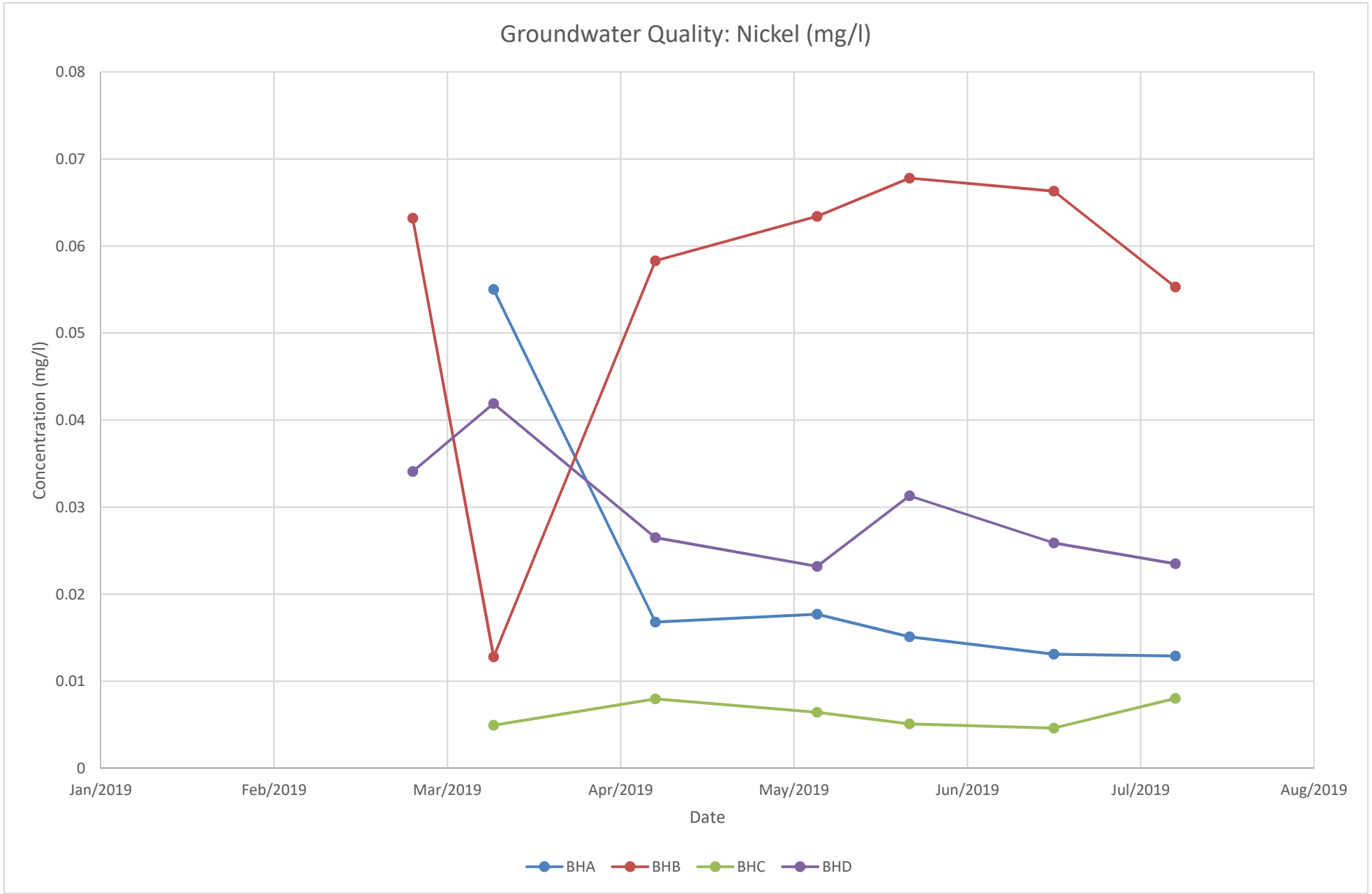

Groundwater Quality: Chromium (mg/l)
Concentration (mg/l)
0.0045
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
Jan/2019
Feb/2019
Mar/2019
Apr/2019
May/2019
Jun/2019
Jul/2019
Aug/2019
Date
BHA
BHB
BHC
BHD

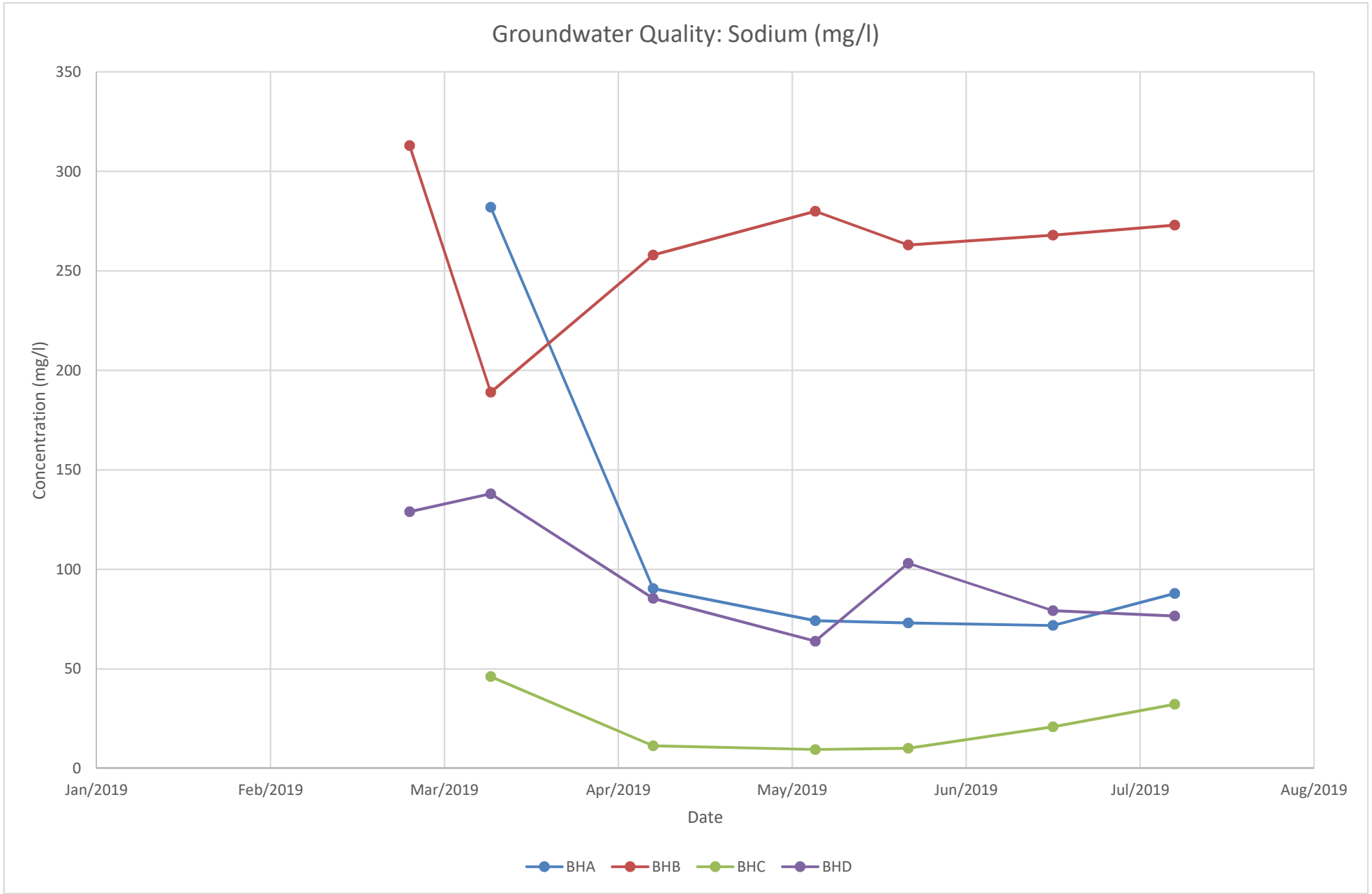

Groundwater Quality: Copper (mg/l)
Concentration (mg/l)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
Jan/2019
Feb/2019
Mar/2019
Apr/2019
May/2019
Jun/2019
Jul/2019
Aug/2019
Date
BHA
BHB
BHC
BHD

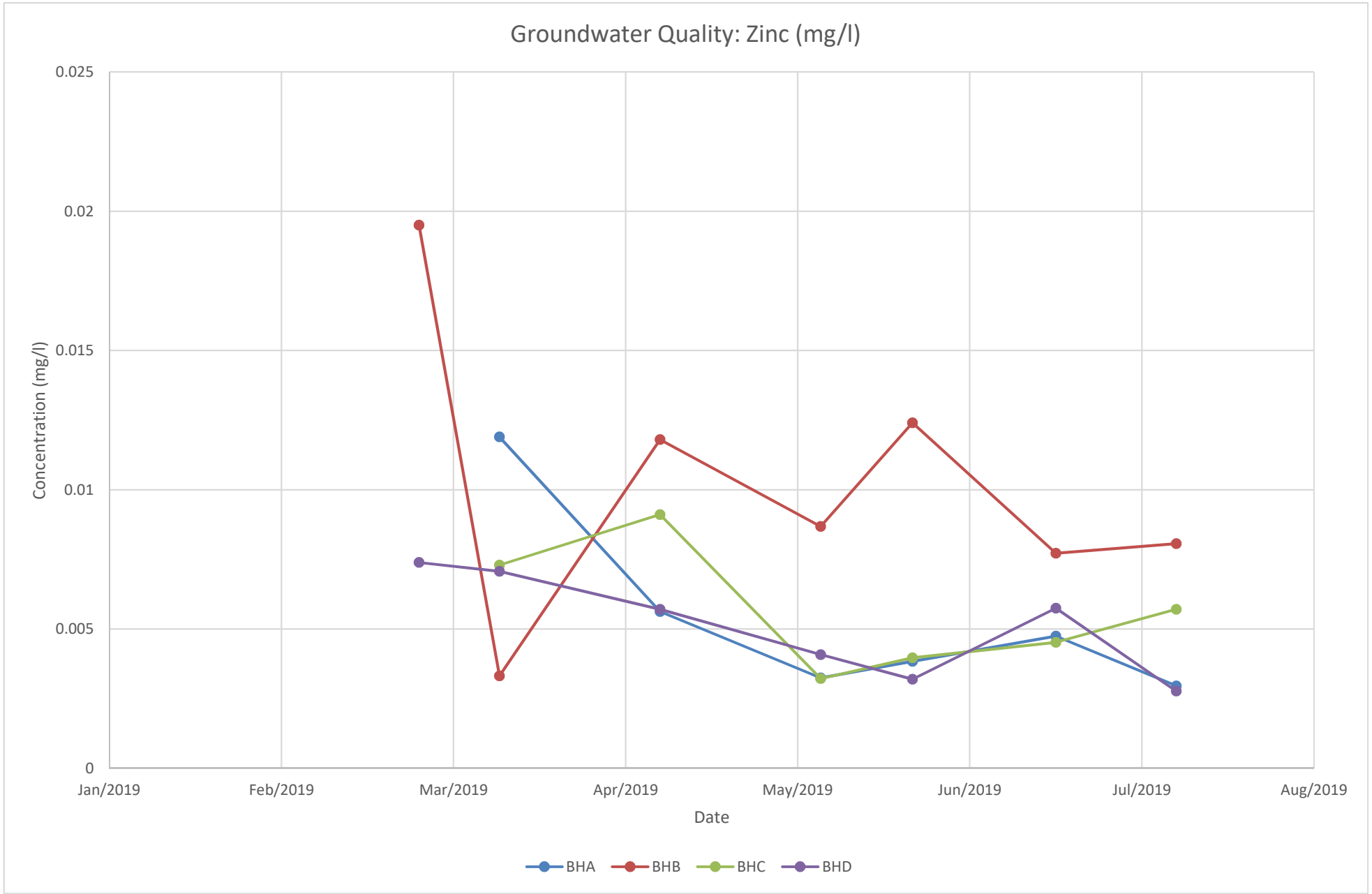

Groundwater Quality: Iron (mg/l)
Concentration (mg/l)
18
16
14
12
10
8
6
4
2
0
Jan/2019
Feb/2019
Mar/2019
Apr/2019
May/2019
Jun/2019
Jul/2019
Aug/2019
Date
BHA
BHB
BHC
BHD


Groundwater Quality: Lead (mg/l)
Concentration (mg/l)
0.001
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
Jan/2019
Feb/2019
Mar/2019
Apr/2019
May/2019
Jun/2019
Jul/2019
Aug/2019
Date
BHA
BHB
BHC
BHD


Groundwater Quality: Manganese (mg/l)
Concentration (mg/l)
2.5
2
1.5
1
0.5
0
Jan/2019
Feb/2019
Mar/2019
Apr/2019
May/2019
Jun/2019
Jul/2019
Aug/2019
Date
BHA
BHB
BHC
BHD


Groundwater Quality: Nickel (mg/l)
Concentration (mg/l)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Jan/2019
Feb/2019
Mar/2019
Apr/2019
May/2019
Jun/2019
Jul/2019
Aug/2019
Date
BHA
BHB
BHC
BHD


Groundwater Quality: Sodium (mg/l)
Concentration (mg/l)
350
300
250
200
150
100
50
0
Jan/2019
Feb/2019
Mar/2019
Apr/2019
May/2019
Jun/2019
Jul/2019
Aug/2019
Date
BHA
BHB
BHC
BHD


Groundwater Quality: Zinc (mg/l)
0.025
0.02
0.015
0.01
0.005
0
Concentration (mg/l)
Jan/2019
Feb/2019
Mar/2019
Apr/2019
May/2019
Jun/2019
Jul/2019
Aug/2019
Date
BHA
BHB
BHC
BHD

APPENDIX 06

Diffusion Model Parameterisation Table

Table 1
Landfill Source & Containment Lining System

PARAMETER	Modelled Values	Source of Data
Basal Width Perpendicular to Groundwater Flow (m)	130 Single	Based on site development plans.
Basal Length Parallel to Groundwater Flow (m)	150 Single	Based on site development plans.
Elevation of Base of Landfill (maOD)	13.2 Single	Minimum basal elevation from quarry design
Elevation of Base of Aquifer (maOD)	13.5 Single	Minimum elevation from borehole logs
Leachate Head Inside Landfill (maOD)	18.54 Single	Assumed leachate head close to groundwater head as worst case
Groundwater Head outside Landfill (maOD)	18.55 Single	Maximum Groundwater level across site (BHB)
Liner Thickness (m)	1.0 Single	Proposed minimum thickness in accordance with requirements of landfill directive for inert sites.
Liner Hydraulic Conductivity (m/s)	$1x10^{-7}$ Single	As per minimum requirement for Inert Landfill
Liner Average Pore Radius (m)	3.5×10^{-10} Single Value	Adapted from Bourke et al (1988) – London Clay aperture silt = 0.7nm.
Liner Effective Porosity (fraction)	0.4 Single Value	Mid-range from Tellam & Lloyd (1981).
Liner Dry Bulk Density (kg/m3)	2000 Single	average for clay.
Liner Tortuosity	2 Single	Minimum from typical distribution based on Freeze and Cherry (1979) (2-10).
Geomembrane Present	No	CQA reports for as-built lining system.

Table 2
Leachate Quality Data

Item	Value/Description	Source of Data
Cadmium (mg/l)	0.004 Single	Based on Inert WAC limits as outlined within the Landfill Directive council decision annex 2003/33/EC and outlined in Table 2-3 and Table 2-4 of the HRA
Copper(mg/l)	0.20 Single	
Sulphate (mg/l)	600 single	
Zinc (mg/l)	0.40 Single	

Item	Value/Description	Source of Data
Lead (mg/l)	0.05 Single	
Arsenic (mg/l)	0.05 Single	
Mercury (mg/l)	0.001 Single	
Benzene (mg/l)	1.89 Single	
Acenaphthylene (mg/l)	0.198 Single	
Aromatic C10 – C12 (mg/l)	2.28 Single	

Table 3
Free Solution Diffusion Coefficients, Retardation and Half Lives

Parameter	Value	Derivation
Diffusion Coefficient		
Cadmium (m^2/s)	7.17×10^{-10} Single	After EA 2004: Containment fluxes from hydraulic containment landfills – a review
Copper (m^2/s)	7.14×10^{-10} Single	Buffle et.al Metal flux and dynamic specification at (bio)interfaces
Sulphate (m^2/s)	1.07×10^{-9} Single	
Zinc (m^2/s)	7.03×10^{-10} Single	
Lead (m^2/s)	9.45×10^{-10} Single	
Arsenic (m^2/s)	9.05×10^{-10}	
Mercury (m^2/s)	3.01×10^{-9}	
Benzene (m^2/s)	6.64×10^{-10} Single	Compilation of Data for Priority Organic pollutants for Derivation of Soil Guideline Values Science report SC050021/SR7
Acenaphthylene (m^2/s)	5.16×10^{-10} Single	Compilation of Data for Priority Organic pollutants for Derivation of Soil Guideline Values Science report SC050021/SR7 – value for Naphthalene used as worst case
Aromatic C10 – C12 (m^2/s)	1.00×10^{-9} Single	Vito (2017) S-Risk Substance Data Sheets – Part 6: Total Petroleum Hydrocarbons
Partition Coefficent (Kd)		
Fraction of Organic Carbon (fraction)	0.01 Single	Minimum likely value for clay.
Cadmium (mg/l)	1.6	Minimum value from ConSim helpfiles used as worst case

	Single	
Copper(mg/l)	40 Single	
Lead (kd) (l/kg)	990 Single	
Arsenic (kd) (l/kg)	25 Single	
Mercury (kd) (l/kg)	450 Single	
Sulphate (kd) (l/kg)	0 Single	
Zinc (Kd) (l/kg)	11 Single	
Benzene (Kd) (l/kg)	0.676 Single	Calculated as KoC (as outlined in LandSim Parameterisation) X FoC
Acenaphthylene (Kd) (l/kg)	6.45 Single	
Aromatic C10 – C12 (Kd) (l/kg)	25.1 Single	
Half Life (days)		
Benzene (days)	113.1 Single	Howard et al (1991) Handbook of Environmental Degradation Rates
Acenaphthylene (days)	259.15 Single	
Aromatic C10 – C12 (days)	328.5 Single	EA R&D Report P2-228

Table 4
Geosphere Parameters

PARAMETER	Value	Derivation
Hydraulic Conductivity of Aquifer (m/s)	$4.1x10^{-4}$ Single	Estimated from site testing of Lynch Hill Gravels
Regional Gradient	0.015 Single Value	Minimum value estimated from monitoring data
Downgradient distance of compliance point from landfill (m)	10 Single Value	Average distance to down-gradient boreholes from landfill boundary

APPENDIX 07

Landsim Model Parameterisation Table

Table 1
Leachate Source

Item	Value/Description	Source of Data
Infiltration to Open Waste (mm/year)	213 ± 21.3 Normal	Annual Effective rainfall for Hertfordshire, South Essex and North Kent from MAFF technical Bulletin 34
Infiltration to Capped Areas (mm/year)	106 ± 10.6 Normal	50% of effective rainfall to account for run-off from low permeability waste, soils and drainage
Time Offset (years)	0 Single Value	Modelled as single cell
End of Filling (years from start of waste disposal)	2 Single Value	Based on proposed development timeframe
Duration of Management Control (years from start of waste disposal)	0 Single Value	No management assumed as worst case
Base Area (ha)	0.212 Single Value	Sidewall area (perimeter length (530m) x maximum sand & gravel thickness (c.4m))
Top Area (ha)	1.84 Single Value	Cap area of final landfill
Final Waste Thickness (m)	Min: 2.5 Max: 4.0 Uniform	Equal to estimated thickness of in-situ sand and gravel
Waste Porosity (fraction)	Min: 0.30 Max: 0.50 Uniform	Typical range for municipal waste used as worst case
Waste Density (kg/l)	Min: 1.10 Max: 1.80 Uniform	Typical range for inert wastes
Waste Field Capacity (fraction)	Min: 0.30 Max: 0.50 Uniform	Equal to waste porosity

Item	Value/Description	Source of Data
Head of Leachate when Surface Water Breakout Occurs (m)	Min: 2.5 Max: 4.0 Uniform	As per waste thickness
Specified Leachate Head (m)	Min: 2.5 Max: 4.0 Uniform	Assumes as worst case that leachate levels rise to ground level and outward gradient is developed. Head equal to waste thickness

Table 2
Leachate Quality

Item	Value/Description	Source of Data
Cadmium (mg/l)	Min: 0.00008 Max: 0.004	Maxima based on Inert WAC limits as outlined within the Landfill Directive council decision annex 2003/33/EC and outlined in Table 2-3 and Table 2-4 of the HRA Minima set at detection limit to reflect typically low levels recorded in inert waste
Copper(mg/l)	Min: 0.0003 Max: 0.20	
Sulphate (mg/l)	Min: 0.5 Max: 600	
Zinc (mg/l)	Min: 0.001 Max: 0.40	
Lead (mg/l)	Min: 0.0002 Max: 0.05	
Arsenic (mg/l)	Min: 0.0005 Max: 0.05	
Mercury (mg/l)	Min: 0.00001 Max: 0.001	
Benzene (mg/l)	Min: 0.001 Max: 1.26	
Acenaphthylene (mg/l)	Min: 0.000005 Max: 0.198	
Aromatic C10 – C12 (mg/l)	Min: 0.01 Max: 2.28	

Table 3
Leachate Source Term Kappa Values and Half Lives

Item	Value/Description	Source of Data
Values of m and c used to calculate the kappa value		
Cadmium	m = 0.0823 c = 0.1589	LandSim V2.5 Default
Copper	m = 0.0664 c = -0.0488	LandSim V2.5 Default
Sulphate	m = 0.0166 c = 0.1209	LandSim V2.5 Default
Zinc	m = 0.0403 c = 0.0561	LandSim V2.5 Default
Lead	m = 0.0443 c = 0.0171	LandSim V2.5 Default
Arsenic	m = 0.0415 c = -0.0862	LandSim V2.5 Default
Mercury	m = 0.0767 c = 0.1643	LandSim V2.5 Default
Benzene	m = 0.0298 c = 0.2919	Value for chloride used as worst case
Acenaphthylene	m = 0.0298 c = 0.2919	
Aromatic C10 – C12	m = 0.0298 c = 0.2919	

Table 4
Engineered Geological Barrier

Item	Value/Description	Source of Data
Engineered Lining System (1m Clay EBS)		
Thickness (m)	1m Single	Assumed
Hydraulic Conductivity (m/sec)	$1x10^{-7}$ Single Value	As per minimum requirement for Inert Landfill
Moisture Content/ Effective Porosity (fraction)	Min: 0.05 Max: 0.20 Uniform	Assumed
Longitudinal Dispersivity (m)	0.1 Single	10% of pathway length (liner thickness)

Item	Value/Description	Source of Data
Density (kg/l)	Min: 1.8 Max: 2.2 Uniform	Assumed
Fraction of organic Carbon (fraction)	Min: 0.01 Max: 0.1 Uniform	ConSim suggested input parameter for a clay
Retardation Co-efficient		
Cadmium (mg/l)	Min: 1.6 ML: 40 Max: 990 Triangular	ConSim suggested range for loam as representative of clay barrier
Copper(mg/l)	Min: 40 Max: 295 Uniform	Potential range from ConSim helpfile (excludes high Kd recorded at pH >8)
Lead (kd) (l/kg)	Min: 990 Most Likely: 16000 Max: 270000 Triangular	ConSim suggested range for loam as representative of clay barrier
Arsenic (kd) (l/kg)	Min: 25 Max: 250 Uniform	LandSim Default
Mercury (kd) (l/kg)	Min: 450 Max: 3835 Uniform	LandSim Default
Sulphate (kd) (l/kg)	0 Single	Assumes unretarded determinand
Zinc (Kd) (l/kg)	Min: 11 Most Likely: 1300 Max: 165000 Triangular	ConSim suggested range for loam as representative of clay barrier
Benzene (Koc) (l/kg)	67.61 Single	Compilation of Data for Priority Organic pollutants for Derivation of Soil Guideline Values Science report SC050021/SR7
Acenaphthylene (Koc) (l/kg)	645.65 Single	

Item	Value/Description	Source of Data
		Naphthalene value used of Acenaphthylene as worst case
Aromatic C10 – C12 (Koc) (l/kg)	2510 Single	EA R&D Report P2-228
Half Life		
Benzene	Minimum: 0.014 Maximum: 0.31 Uniform	Howard et al (1991) Handbook of Environmental Degradation Rates
Acenaphthylene	Min: 0.068 Max: 0.71 Uniform	
Aromatic C10 – C12	Min: 0.3 Max: 0.9 Uniform	EA R&D Report P2-228
All other parameters	0 Single Value	Assumes no degradation

Table 5
Unsaturated Path – Flow within the Lynch Hill Gravels

Item	Value/Description	Source of Data
Pathway Length (m)	Min: 0.1 Max: 1.5 Uniform	Based on the thickness of sidewall barrier above the groundwater table
Moisture Content (fraction)	Min: 0.15 Max: 0.22 Uniform	Typical range for silty sandy gravels from ConSIM help files
Hydraulic Conductivity (m/s)	Min: $1x10^{-5}$ Most Likely: $4.1x10^{-4}$ Max: $1x10^{-3}$ Log Triangular	Typical range from desk study, most likely based on laboratory testing of in-situ sands and gravels
Longitudinal Dispersivity (m)	Min: 0.001 Max: 0.15 Uniform	10% of pathway length
Density (kg/l)	Min: 1.5 Max: 2.0	Typical range for sand & gravel

Item	Value/Description	Source of Data
	Uniform	
Fraction of organic Carbon (fraction)	Min: 0.00049 Max: 0.0012 Uniform	Wang et.al (2013) *A practical measurement strategy to estimate nonlinear chlorinated solvent sorption in low FoC sediments*, Groundwater Monitoring and Remediation 33(1) pp87-96
Retardation Co-efficient		
Cadmium (mg/l)	Min: 3.7 ML: 74 Max: 1500 Triangular	ConSim suggested range for Sand
Copper(mg/l)	Min: 40 Max: 295 Uniform	Potential range from ConSim helpfile (excludes high Kd recorded at pH >8 & FOC 11%)
Lead (kd) (l/kg)	Min: 27 Most Likely: 270 Max: 27000 Triangular	ConSim suggested range for sand
Arsenic (kd) (l/kg)	Min: 25 Max: 250 Uniform	LandSim Default
Mercury (kd) (l/kg)	Min: 450 Max: 3835 Uniform	LandSim Default
Sulphate (kd) (l/kg)	0 Single	Assumes unretarded determinand
Zinc (Kd) (l/kg)	Min: 1.1 Most Likely: 200 Max: 36000 Triangular	ConSim suggested range for sand
Benzene (Koc) (l/kg)	67.61 Single	Compilation of Data for Priority Organic pollutants for Derivation of Soil Guideline Values Science report SC050021/SR7
Acenaphthylene (Koc) (l/kg)	645.65 Single	

Item	Value/Description	Source of Data
Aromatic C10 – C12 (Koc) (l/kg)	2510 Single	EA R&D Report P2-228
Half Life		
All Parameters	As per Geological Barrier	

Table 6
Aquifer Flow - Lateral flow within the Lynch Hill Gravels

Item	Value/Description	Source of Data
Pathway Length (m)	Min: 10 Max: 160 Uniform	Based on down-gradient receptor being site boundary (10m from western edge of landfill)
Pathway Width (m)	130 Single	Equal to aquifer width adjacent to down-stream boundary of landfill
Mixing Zone Thickness (m)	Min: 0.5 Max: 2.2 Uniform	Saturated Aquifer thickness of Lynch Hill gravels based on monitoring data
Hydraulic conductivity (m/s)	Min: $1x10^{-5}$ Most Likely: $4.1x10^{-4}$ Max: $1x10^{-3}$ Log Triangular	Typical range from desk study most likely based on laboratory testing of in-situ sands and gravels
Regional Gradient	Min: 0.015 Max: 0.025 Uniform	Regional flow gradient across the site based on site specific groundwater levels.
Density (kg/l)	Min: 1.5 Max: 2.0 Uniform	Typical range for sand & gravel
Fraction of organic Carbon (fraction)	Min: 0.00049 Max: 0.0012 Uniform	Wang et.al (2013) *A practical measurement strategy to estimate nonlinear chlorinated solvent sorption in low FoC sediments*, Groundwater Monitoring and Remediation 33(1) pp87-96
Pathway Porosity (fraction)	Min: 0.15 Max: 0.22 Uniform	Typical range for silty sandy gravels from ConSIM help files

Item	Value/Description	Source of Data
Longitudinal Dispersivity (m)	Min: 1.0 Max: 16 Uniform	10% of pathway length
Transverse Dispersivity (m)	Min: 0.1 Max: 1.6 Uniform	1% of pathway length
Retardation Coefficient		
All Parameters	As per unsaturated pathway (none assumed for Hazardous Substances)	
Half Live		
All Parameters	As per Geological Barrier (none assumed for Hazardous Substances)	

Table 7
Background Groundwater Quality

Item	Value/Description	Current Applicability to Site
Cadmium (mg/l)	Min: 0.00004 Most Likely: 0.000059 Max 0.000148 Log Triangular	Based on background groundwater monitoring boreholes
Copper(mg/l)	Min: 0.00015 Most Likely: 0.0024 Max: 0.00919 Log Triangular	
Sulphate (mg/l)	Min: 15.3 Most Likely: 61.53 Max: 119 Log Triangular	
Zinc (mg/l)	Min: 0.00277 Most Likely: 0.00667 Max: 0.0195 Log Triangular	
Lead (mg/l)	Min: 0.0001 Most Likely: 0.000136 Max: 0.000936 Log Triangular	
Arsenic (mg/l)	Min: 0.000588	

Item	Value/Description	Current Applicability to Site
	Most Likely: 0.0046 Max: 0.0138 Log Triangular	
	Min: 0.000005 Most Likely: 0.000006 Max: 0.000012 Log Triangular	
Benzene (mg/l)	-	Not detected in background groundwater
Acenaphthylene (mg/l)	-	
Aromatic C10 – C12 (mg/l)	-	Assumed not present in background groundwater

APPENDIX 08

Diffusion Model Results

Cockhide Farm

14 August 2019

Acenaphthylene

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	130	m
Basal length parallel to groundwater flow	Length_LF	150	m
Basal area	Base_Area	19500	m2
Elevation of base of landfill	LFbase_elev	13.2	maOD
Elevation of base of aquifer	Aqbound_elev	13.5	maOD
Leachate head inside landfill	Head_inLF	18.54	maOD
Groundwater head outside landfill	Head_outLF	18.55	maOD
Area of liner below the water table	Area_contact	2822.4	m2

CONTAMINANT PARAMETERS

Contaminant name	Cont_Nme	Acenaphthylene	-
Contaminant type	Cont_Type	Organic	-
Contaminant classification	Cont_Class	List I	-
Concentration in landfill leachate	Conc_LF	0.198	mg/l
Free water diffusion coefficient	Dw_cl	6.16E-10	m2/s
Partition coefficient in clay	Kd_cl	6.45	l/kg
Retardation factor in clay	R_cl	33.25	-
Half life in clay (0 for no decay)	thalf_cl	2.59E+02	days
Decay in sorbed phase?	Decay_sorb	No	-
Decay constant in clay	Decay_cl	9.31041E-10	1/s

MINERAL BARRIER / LINER

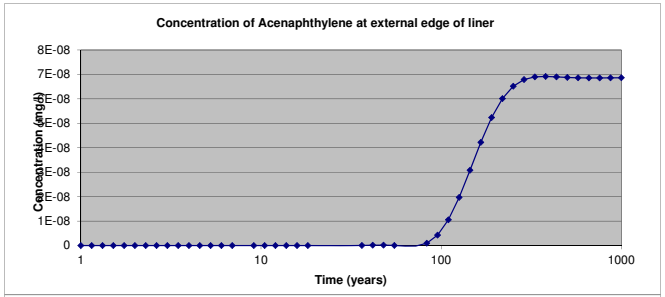
Thickness of mineral liner	thick_clbr	1	m
Hydraulic conductivity	k_cl	1.00E-07	m/s
Average pore radius	pore_radius	3.50E-10	m
Effective porosity	n	0.4	-
Dry bulk density	rho	2000	kg/m3
Tortuosity	tau_cl	2	-

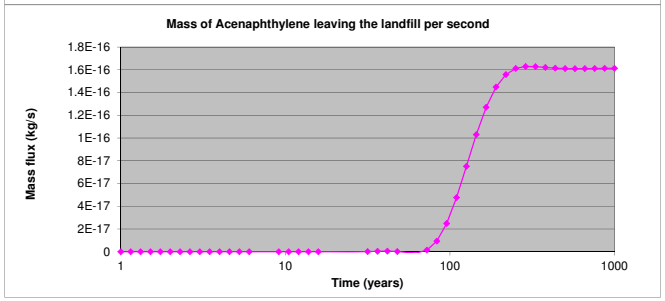
CONTAMINANT AND WATER FLUXES

Groundwater flux into landfill		5.6448E-06	m3/s
Maximum contaminant concentration at compliance point at tmax	C_comp	6.91772E-08	mg/l

CHART PARAMETERS

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





Time years	Concentration o	Mass of Acenaphtl
	Concentration	Mass flux (kg/s)
1	-1.21812E-26	-1.94158E-34
1.148153621	-2.89613E-25	-4.29708E-33
1.318256739	-5.51246E-24	-7.61426E-32
1.513561248	-8.51987E-23	-1.0957E-30
1.737800829	-1.08345E-21	-1.29751E-29
1.995262315	-1.14756E-20	-1.27993E-28
2.290867653	-1.02377E-19	-1.06358E-27
2.630267992	-7.77102E-19	-7.51908E-27
3.01995172	-5.06262E-18	-4.55977E-26
3.467368505	-2.84998E-17	-2.3858E-25
3.981071706	-1.39192E-16	-1.07936E-24
4.570881896	-5.89662E-16	-4.20665E-24
5.248074602	-2.15183E-15	-1.39329E-23
6.025595861	-6.63967E-15	-3.79344E-23
6.918309709	-1.65822E-14	-7.78878E-23
7.943282347	-2.96785E-14	-8.44188E-23
9.120108394	-1.83127E-14	1.54312E-22
10.47128548	1.11642E-13	1.12711E-21
12.02264435	5.41179E-13	3.3318E-21
13.80384265	1.37666E-12	5.85837E-21
15.84893192	2.06814E-12	3.72272E-21
18.19700859	5.53561E-13	-1.28138E-20
20.89296131	-6.48847E-12	-4.92724E-20
23.98832919	-1.9772E-11	-8.45433E-20
27.54228703	-2.97131E-11	-5.39738E-20
31.6227766	-1.28122E-11	1.15521E-19
36.30780548	5.26927E-11	3.92692E-19
41.68693835	1.47659E-10	5.3505E-19
47.86300923	1.83039E-10	1.92416E-19
54.95408739	4.99054E-11	-6.33525E-19
63.09573445	-2.1097E-10	-9.59503E-19
72.44359601	-1.92881E-10	1.42954E-18
83.17637711	9.51212E-10	9.34869E-18
95.4992586	4.27537E-09	2.48041E-17
109.6478196	1.05377E-08	4.76269E-17
125.8925412	1.97057E-08	7.5111E-17
144.5439771	3.08033E-08	1.02975E-16
165.9586907	4.22274E-08	1.27071E-16
190.5460718	5.23561E-08	1.4484E-16
218.7761624	6.01049E-08	1.55826E-16
251.1886432	6.51664E-08	1.61218E-16
288.4031503	6.78957E-08	1.62941E-16
331.1311215	6.8992E-08	1.62813E-16
380.1893963	6.91772E-08	1.62105E-16
436.5158322	6.89968E-08	1.61474E-16
501.1872336	6.87668E-08	1.61127E-16
575.4399373	6.86151E-08	1.61034E-16
660.693448	6.85577E-08	1.61088E-16
758.577575	6.85647E-08	1.61194E-16
870.96359	6.86E-08	1.61293E-16
1000	6.86388E-08	1.61363E-16

Cockhide Farm 14 August 2019

Aromatic C10-C12

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	130	m
Basal length parallel to groundwater flow	Length_LF	150	m
Basal area	Base_Area	19500	m2
Elevation of base of landfill	LFbase_elev	13.2	maOD
Elevation of base of aquifer	Aqbound_elev	13.5	maOD
Leachate head inside landfill	Head_inLF	18.54	maOD
Groundwater head outside landfill	Head_outLF	18.55	maOD
Area of liner below the water table	Area_contact	2822.4	m2

CONTAMINANT PARAMETERS

Contaminant name	Cont_Nme	Aromatic C10-C12	-
Contaminant type	Cont_Type	Organic	-
Contaminant classification	Cont_Class	List I	-
Concentration in landfill leachate	Conc_LF	2.28	mg/l
Free water diffusion coefficient	Dw_cl	1.00E-09	m2/s
Partition coefficient in clay	Kd_cl	25.1	l/kg
Retardation factor in clay	R_cl	126.5	-
Half life in clay (0 for no decay)	thalf_cl	3.29E+02	days
Decay in sorbed phase?	Decay_sorb	No	-
Decay constant in clay	Decay_cl	1.93057E-10	1/s

MINERAL BARRIER / LINER

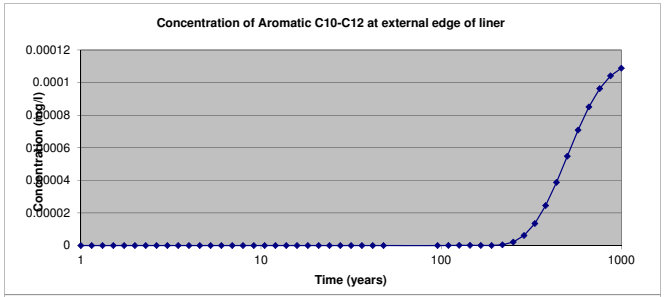
Thickness of mineral liner	thick_clbr	1	m
Hydraulic conductivity	k_cl	1.00E-07	m/s
Average pore radius	pore_radius	3.50E-10	m
Effective porosity	n	0.4	-
Dry bulk density	rho	2000	kg/m3
Tortuosity	tau_cl	2	-

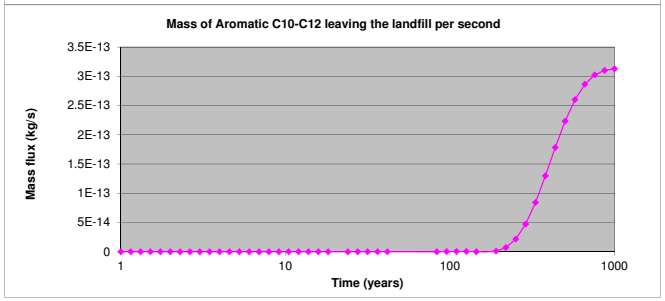
CONTAMINANT AND WATER FLUXES

Groundwater flux into landfill		5.6448E-06	m3/s
Maximum contaminant concentration at compliance point at tmax	C_comp	0.000108812	mg/l

CHART PARAMETERS

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





Time years	Concentration o	Mass of Aromatic C10-C12 flux (kg/s)
1	-8.87688E-36	-3.62981E-43
1.148153621	-1.25455E-33	-4.7793E-41
1.318256739	-1.26951E-31	-4.50543E-39
1.513561248	-9.40334E-30	-3.1087E-37
1.737800829	-5.20423E-28	-1.60259E-35
1.995262315	-2.19374E-26	-6.29211E-34
2.290867653	-7.17025E-25	-1.91544E-32
2.630267992	-1.84773E-23	-4.59709E-31
3.01995172	-3.81283E-22	-8.83464E-30
3.467368505	-6.39206E-21	-1.37935E-28
3.981071706	-8.82407E-20	-1.77335E-27
4.570881896	-1.01568E-18	-1.90094E-26
5.248074602	-9.86093E-18	-1.71863E-25
6.025595861	-8.16033E-17	-1.32415E-24
6.918309709	-5.81002E-16	-8.77286E-24
7.943282347	-3.58702E-15	-5.0341E-23
9.120108394	-1.93162E-14	-2.51363E-22
10.47128548	-9.10108E-14	-1.09319E-21
12.02264435	-3.74868E-13	-4.12183E-21
13.80384265	-1.34071E-12	-1.32884E-20
15.84893192	-4.09464E-12	-3.5489E-20
18.19700859	-1.0292E-11	-7.25821E-20
20.89296131	-1.937E-11	-8.4192E-20
23.98832919	-1.78704E-11	1.03622E-19
27.54228703	4.36237E-11	9.01228E-19
31.6227766	2.70351E-10	2.79525E-18
36.30780548	7.67935E-10	5.34963E-18
41.68693835	1.3815E-09	5.11596E-18
47.86300923	1.20543E-09	-5.7083E-18
54.95408739	-1.66335E-09	-3.46437E-17
63.09573445	-8.94182E-09	-7.35823E-17
72.44359601	-1.85833E-08	-8.02995E-17
83.17637711	-2.05946E-08	1.41855E-17
95.4992586	1.38742E-09	2.40496E-16
109.6478196	5.57943E-08	4.89382E-16
125.8925412	1.20461E-07	4.95866E-16
144.5439771	1.38296E-07	8.15172E-17
165.9586907	7.2015E-08	-2.99447E-16
190.5460718	3.6029E-08	1.03373E-15
218.7761624	4.57806E-07	7.12011E-15
251.1886432	2.15198E-06	2.16115E-14
288.4031503	6.18681E-06	4.72495E-14
331.1311215	1.35213E-05	8.42803E-14
380.1893963	2.45463E-05	1.29743E-13
436.5158322	3.87666E-05	1.78147E-13
501.1872336	5.48183E-05	2.2327E-13
575.4399373	7.08467E-05	2.60159E-13
660.693448	8.50735E-05	2.86427E-13
758.577575	9.62931E-05	3.02382E-13
870.96359	0.000104101	3.10211E-13
1000	0.000108812	3.12796E-13

Cockhide Farm

14 August 2019

Arsenic

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	130	m
Basal length parallel to groundwater flow	Length_LF	150	m
Basal area	Base_Area	19500	m2
Elevation of base of landfill	LFbase_elev	13.2	maOD
Elevation of base of aquifer	Aqbound_elev	13.5	maOD
Leachate head inside landfill	Head_inLF	18.54	maOD
Groundwater head outside landfill	Head_outLF	18.55	maOD
Area of liner below the water table	Area_contact	2822.4	m2

CONTAMINANT PARAMETERS

Contaminant name	Cont_Nme	Arsenic	-
Contaminant type	Cont_Type	Inorganic	-
Contaminant classification	Cont_Class	List I	-
Concentration in landfill leachate	Conc_LF	0.05	mg/l
Free water diffusion coefficient	Dw_cl	9.05E-10	m2/s
Partition coefficient in clay	Kd_cl	25	l/kg
Retardation factor in clay	R_cl	126	-
Half life in clay (0 for no decay)	thalf_cl	1.00E+09	days
Decay in sorbed phase?	Decay_sorb	No	-
Decay constant in clay	Decay_cl	6.36709E-17	1/s

MINERAL BARRIER / LINER

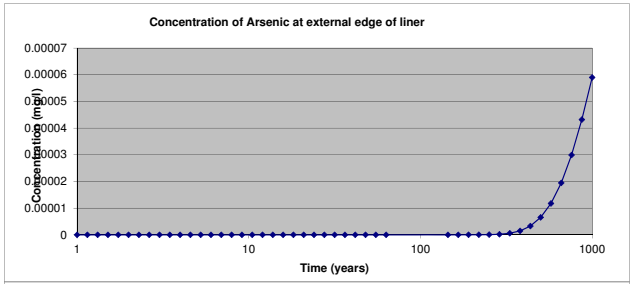
Thickness of mineral liner	thick_clbr	1	m
Hydraulic conductivity	k_cl	1.00E-07	m/s
Average pore radius	pore_radius	3.50E-10	m
Effective porosity	n	0.4	-
Dry bulk density	rho	2000	kg/m3
Tortuosity	tau_cl	2	-

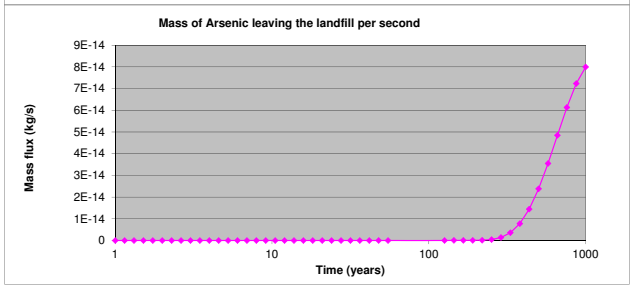
CONTAMINANT AND WATER FLUXES

Groundwater flux into landfill		5.6448E-06	m3/s
Maximum contaminant concentration at compliance point at tmax	C_comp	5.89951E-05	mg/l

CHART PARAMETERS

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





Concentration o Mass of Arsenic leaving the landfill

Time years	Concentration	Mass flux (kg/s)
1	-5.29826E-39	-2.04401E-46
1.148153621	-9.78045E-37	-3.51247E-44
1.318256739	-1.27384E-34	-4.25789E-42
1.513561248	-1.19811E-32	-3.72664E-40
1.737800829	-8.31613E-31	-2.40655E-38
1.995262315	-4.34694E-29	-1.17007E-36
2.290867653	-1.74375E-27	-4.36482E-35
2.630267992	-5.46356E-26	-1.27146E-33
3.01995172	-1.35925E-24	-2.94002E-32
3.467368505	-2.72659E-23	-5.47979E-31
3.981071706	-4.47345E-22	-8.35112E-30
4.570881896	-6.08355E-21	-1.05453E-28
5.248074602	-6.94281E-20	-1.11701E-27
6.025595861	-6.72579E-19	-1.00381E-26
6.918309709	-5.58874E-18	-7.73184E-26
7.943282347	-4.02066E-17	-5.15029E-25
9.120108394	-2.52438E-16	-2.98849E-24
10.47128548	-1.39191E-15	-1.51818E-23
12.02264435	-6.76732E-15	-6.7655E-23
13.80384265	-2.90438E-14	-2.6384E-22
15.84893192	-1.09716E-13	-8.92448E-22
18.19700859	-3.61669E-13	-2.5664E-21
20.89296131	-1.02153E-12	-6.0035E-21
23.98832919	-2.37915E-12	-1.0129E-20
27.54228703	-4.14232E-12	-6.01648E-21
31.6227766	-3.40567E-12	3.41425E-20
36.30780548	9.17732E-12	1.62155E-19
41.68693835	5.20993E-11	4.16593E-19
47.86300923	1.44117E-10	6.91561E-19
54.95408739	2.6726E-10	5.28589E-19
63.09573445	2.99439E-10	-9.32292E-19
72.44359601	-3.05996E-11	-4.36573E-18
83.17637711	-1.03776E-09	-8.76714E-18
95.4992586	-2.7042E-09	-9.90059E-18
109.6478196	-4.13921E-09	-1.07466E-18
125.8925412	-3.39297E-09	2.1539E-17
144.5439771	1.68773E-09	5.1171E-17
165.9586907	1.16387E-08	7.03244E-17
190.5460718	2.4688E-08	7.36177E-17
218.7761624	4.17252E-08	1.22975E-16
251.1886432	8.22397E-08	4.23864E-16
288.4031503	2.13577E-07	1.3848E-15
331.1311215	5.88924E-07	3.60876E-15
380.1893963	1.48117E-06	7.78046E-15
436.5158322	3.29488E-06	1.44571E-14
501.1872336	6.54074E-06	2.38229E-14
575.4399373	1.17673E-05	3.54986E-14
660.693448	1.94591E-05	4.84925E-14
758.577575	2.99239E-05	6.13288E-14
870.96359	4.31978E-05	7.23303E-14
1000	5.89951E-05	7.99731E-14

Cockhide Farm

14 August 2019

Benzene

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	130	m
Basal length parallel to groundwater flow	Length_LF	150	m
Basal area	Base_Area	19500	m2
Elevation of base of landfill	LFbase_elev	13.2	maOD
Elevation of base of aquifer	Aqbound_elev	13.5	maOD
Leachate head inside landfill	Head_inLF	18.54	maOD
Groundwater head outside landfill	Head_outLF	18.55	maOD
Area of liner below the water table	Area_contact	2822.4	m2

CONTAMINANT PARAMETERS

Contaminant name	Cont_Nme	Benzene	-
Contaminant type	Cont_Type	Organic	-
Contaminant classification	Cont_Class	List I	-
Concentration in landfill leachate	Conc_LF	1.89	mg/l
Free water diffusion coefficient	Dw_cl	6.64E-10	m2/s
Partition coefficient in clay	Kd_cl	0.676	l/kg
Retardation factor in clay	R_cl	4.38	-
Half life in clay (0 for no decay)	thalf_cl	1.13E+02	days
Decay in sorbed phase?	Decay_sorb	No	-
Decay constant in clay	Decay_cl	1.61948E-08	1/s

MINERAL BARRIER / LINER

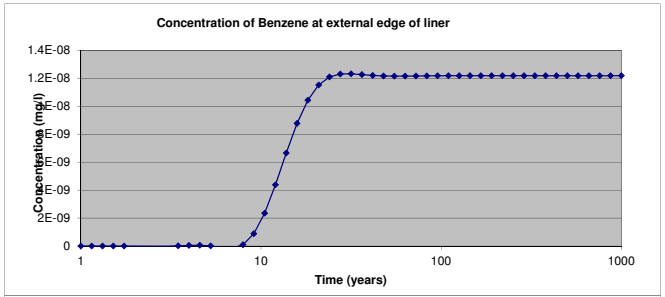
Thickness of mineral liner	thick_clbr	1	m
Hydraulic conductivity	k_cl	1.00E-07	m/s
Average pore radius	pore_radius	3.50E-10	m
Effective porosity	n	0.4	-
Dry bulk density	rho	2000	kg/m3
Tortuosity	tau_cl	2	-

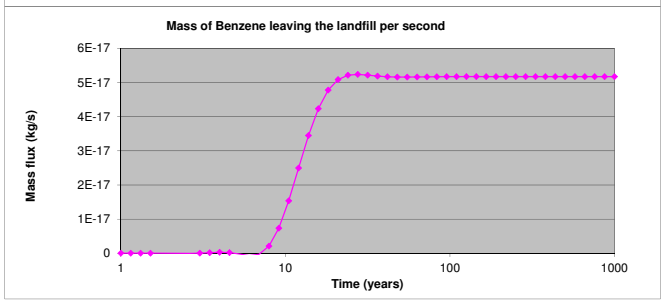
CONTAMINANT AND WATER FLUXES

Groundwater flux into landfill		5.6448E-06	m3/s
Maximum contaminant concentration at compliance point at tmax	C_comp	1.23295E-08	mg/l

CHART PARAMETERS

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





Time years	Concentration o	Mass flux (kg/s)
	Mass of Benzene l	
1	5.86953E-15	1.77554E-22
1.148153621	9.33793E-14	9.01196E-22
1.318256739	3.19987E-13	2.29026E-21
1.513561248	6.30069E-13	3.16296E-21
1.737800829	5.21133E-13	-5.52529E-22
1.995262315	-1.1359E-12	-1.44473E-20
2.290867653	-5.16386E-12	-3.62874E-20
2.630267992	-9.3448E-12	-4.15049E-20
3.01995172	-6.07863E-12	1.41243E-20
3.467368505	1.34394E-11	1.45948E-19
3.981071706	4.49456E-11	2.64272E-19
4.570881896	5.79438E-11	1.73558E-19
5.248074602	1.00796E-11	-2.40961E-19
6.025595861	-9.62433E-11	-6.91724E-19
6.918309709	-1.46507E-10	-3.12957E-19
7.943282347	9.38852E-11	2.08032E-18
9.120108394	8.841E-10	7.33842E-18
10.47128548	2.35161E-09	1.53598E-17
12.02264435	4.38485E-09	2.49847E-17
13.80384265	6.6587E-09	3.44945E-17
15.84893192	8.77759E-09	4.23685E-17
18.19700859	1.044E-08	4.78244E-17
20.89296131	1.15296E-08	5.0903E-17
23.98832919	1.21035E-08	5.21886E-17
27.54228703	1.2315E-08	5.24205E-17
31.6227766	1.23295E-08	5.2209E-17
36.30780548	1.22719E-08	5.19263E-17
41.68693835	1.22118E-08	5.17307E-17
47.86300923	1.2175E-08	5.16466E-17
54.95408739	1.21619E-08	5.16415E-17
63.09573445	1.21641E-08	5.16737E-17
72.44359601	1.21724E-08	5.17133E-17
83.17637711	1.21812E-08	5.17454E-17
95.4992586	1.21879E-08	5.17659E-17
109.6478196	1.21918E-08	5.17762E-17
125.8925412	1.21937E-08	5.17797E-17
144.5439771	1.21942E-08	5.17793E-17
165.9586907	1.21939E-08	5.17773E-17
190.5460718	1.21934E-08	5.17751E-17
218.7761624	1.21929E-08	5.17731E-17
251.1886432	1.21925E-08	5.17717E-17
288.4031503	1.21922E-08	5.17707E-17
331.1311215	1.2192E-08	5.17701E-17
380.1893963	1.21919E-08	5.17697E-17
436.5158322	1.21918E-08	5.17696E-17
501.1872336	1.21918E-08	5.17695E-17
575.4399373	1.21918E-08	5.17695E-17
660.693448	1.21918E-08	5.17696E-17
758.577575	1.21918E-08	5.17696E-17
870.96359	1.21918E-08	5.17696E-17
1000	1.21918E-08	5.17696E-17

Cockhide Farm

14 August 2019

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	130	m
Basal length parallel to groundwater flow	Length_LF	150	m
Basal area	Base_Area	19500	m2
Elevation of base of landfill	LFbase_elev	13.2	maOD
Elevation of base of aquifer	Aqbound_elev	13.5	maOD
Leachate head inside landfill	Head_inLF	18.54	maOD
Groundwater head outside landfill	Head_outLF	18.55	maOD
Area of liner below the water table	Area_contact	2822.4	m2

CONTAMINANT PARAMETERS

Contaminant name	Cont_Nme	Cadmium	-
Contaminant type	Cont_Type	Inorganic	-
Contaminant classification	Cont_Class	List II	-
Concentration in landfill leachate	Conc_LF	0.004	mg/l
Free water diffusion coefficient	Dw_cl	7.17E-10	m2/s
Partition coefficient in clay	Kd_cl	1.6	l/kg
Retardation factor in clay	R_cl	9	-
Half life in clay (0 for no decay)	thalf_cl	1.00E+09	days
Decay in sorbed phase?	Decay_sorb	No	-
Decay constant in clay	Decay_cl	8.91393E-16	1/s

MINERAL BARRIER / LINER

Thickness of mineral liner	thick_clbr	1	m
Hydraulic conductivity	k_cl	1.00E-07	m/s
Average pore radius	pore_radius	3.50E-10	m
Effective porosity	n	0.4	-
Dry bulk density	rho	2000	kg/m3
Tortuosity	tau_cl	2	-

Cadmium

STEADY STATE DILUTION

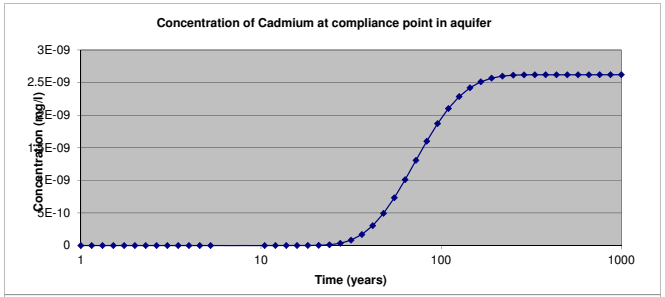
Hydraulic gradient in the aquifer	aq_I	0.015	-
Hydraulic conductivity of the aquifer	k_aq	4.10E-04	m/s
Downgradient distance of compliance point from landfill	dist_cp	10	m
Mixing width	Mix_W	130	m
Mixing depth	Mix_D	5.05	m
Dilution flow in aquifer downstream to the landfill	aq_Q	0.004037475	m3/s

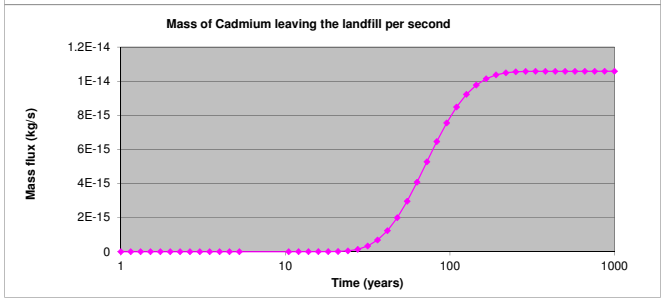
CONTAMINANT AND WATER FLUXES

Groundwater flux into landfill		5.6448E-06	m3/s
Maximum contaminant concentration at compliance point at tmax	C_comp	2.62085E-09	mg/l

CHART PARAMETERS

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





Time years	Concentration o	Mass of Cadmium Mass flux (kg/s)
1	-4.52265E-19	-1.82601E-24
1.148153621	-1.91496E-18	-7.7316E-24
1.318256739	-7.08325E-18	-2.85984E-23
1.513561248	-2.26144E-17	-9.1305E-23
1.737800829	-6.07208E-17	-2.45159E-22
1.995262315	-1.29192E-16	-5.21611E-22
2.290867653	-1.80385E-16	-7.28299E-22
2.630267992	2.20641E-17	8.90832E-23
3.01995172	1.08945E-15	4.39864E-21
3.467368505	3.94155E-15	1.59139E-20
3.981071706	8.74473E-15	3.53066E-20
4.570881896	1.21835E-14	4.91906E-20
5.248074602	4.31614E-15	1.74263E-20
6.025595861	-2.96258E-14	-1.19613E-19
6.918309709	-9.47888E-14	-3.82707E-19
7.943282347	-1.59854E-13	-6.45406E-19
9.120108394	-1.40108E-13	-5.65681E-19
10.47128548	6.80338E-14	2.74685E-19
12.02264435	4.82533E-13	1.94821E-18
13.80384265	9.3584E-13	3.77843E-18
15.84893192	1.17904E-12	4.76036E-18
18.19700859	1.42814E-12	5.76607E-18
20.89296131	3.42222E-12	1.38171E-17
23.98832919	1.16948E-11	4.72176E-17
27.54228703	3.43874E-11	1.38838E-16
31.6227766	8.28461E-11	3.34489E-16
36.30780548	1.69611E-10	6.84799E-16
41.68693835	3.05114E-10	1.23189E-15
47.86300923	4.94116E-10	1.99498E-15
54.95408739	7.33178E-10	2.96019E-15
63.09573445	1.01022E-09	4.07873E-15
72.44359601	1.30642E-09	5.27464E-15
83.17637711	1.59992E-09	6.45963E-15
95.4992586	1.87012E-09	7.55058E-15
109.6478196	2.10141E-09	8.4844E-15
125.8925412	2.28526E-09	9.22666E-15
144.5439771	2.42047E-09	9.7726E-15
165.9586907	2.5119E-09	1.01417E-14
190.5460718	2.5681E-09	1.03686E-14
218.7761624	2.59888E-09	1.04929E-14
251.1886432	2.61337E-09	1.05514E-14
288.4031503	2.61875E-09	1.05731E-14
331.1311215	2.61991E-09	1.05778E-14
380.1893963	2.61967E-09	1.05769E-14
436.5158322	2.61937E-09	1.05756E-14
501.1872336	2.61937E-09	1.05757E-14
575.4399373	2.61966E-09	1.05768E-14
660.693448	2.62006E-09	1.05784E-14
758.577575	2.62043E-09	1.05799E-14
870.96359	2.6207E-09	1.0581E-14
1000	2.62085E-09	1.05816E-14

Cockhide Farm

14 August 2019

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	130	m
Basal length parallel to groundwater flow	Length_LF	150	m
Basal area	Base_Area	19500	m2
Elevation of base of landfill	LFbase_elev	13.2	maOD
Elevation of base of aquifer	Aqbound_elev	13.5	maOD
Leachate head inside landfill	Head_inLF	18.54	maOD
Groundwater head outside landfill	Head_outLF	18.55	maOD
Area of liner below the water table	Area_contact	2822.4	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	0.2	mg/l
Free water diffusion coefficient	Dw_cl	7.14E-10	m2/s
Partition coefficient in clay	Kd_cl	40	l/kg
Retardation factor in clay	R_cl	201	-
Half life in clay (0 for no decay)	thalf_cl	1.00E+09	days
Decay in sorbed phase?	Decay_sorb	No	-
Decay constant in clay	Decay_cl	3.99131E-17	1/s

MINERAL BARRIER / LINER

Thickness of mineral liner	thick_clbr	1	m
Hydraulic conductivity	k_cl	1.00E-07	m/s
Average pore radius	pore_radius	3.50E-10	m
Effective porosity	n	0.4	-
Dry bulk density	rho	2000	kg/m3
Tortuosity	tau_cl	2	-

Copper

STEADY STATE DILUTION

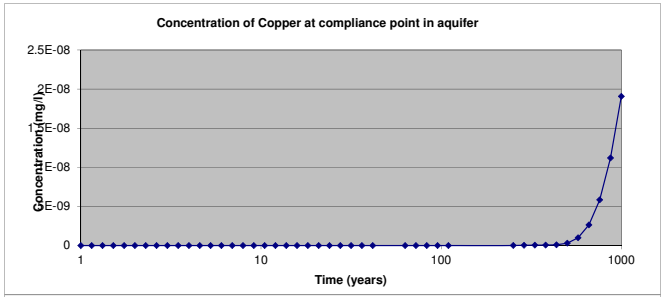
Hydraulic gradient in the aquifer	aq_I	0.015	-
Hydraulic conductivity of the aquifer	k_aq	4.10E-04	m/s
Downgradient distance of compliance point from landfill	dist_cp	10	m
Mixing width	Mix_W	130	m
Mixing depth	Mix_D	5.05	m
Dilution flow in aquifer downstream to the landfill	aq_Q	0.004037475	m3/s

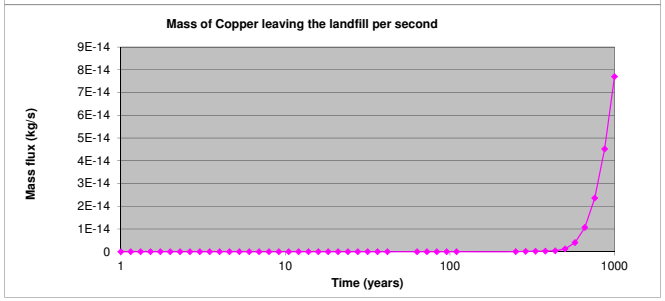
CONTAMINANT AND WATER FLUXES

Groundwater flux into landfill		5.6448E-06	m3/s
Maximum contaminant concentration at compliance point at tmax	C_comp	1.9072E-08	mg/l

CHART PARAMETERS

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





Time years	Concentration (mg/l)	Mass flux (kg/s)
1	-1.02985E-54	-4.15801E-60
1.148153621	-1.60596E-51	-6.48403E-57
1.318256739	-1.52527E-48	-6.15824E-54
1.513561248	-9.11943E-46	-3.68195E-51
1.737800829	-3.53995E-43	-1.42925E-48
1.995262315	-9.18199E-41	-3.70721E-46
2.290867653	-1.63477E-38	-6.60032E-44
2.630267992	-2.04852E-36	-8.27084E-42
3.01995172	-1.84948E-34	-7.46721E-40
3.467368505	-1.2296E-32	-4.96447E-38
3.981071706	-6.14367E-31	-2.48049E-36
4.570881896	-2.35124E-29	-9.49308E-35
5.248074602	-7.01572E-28	-2.83258E-33
6.025595861	-1.65935E-26	-6.69958E-32
6.918309709	-3.15934E-25	-1.27557E-30
7.943282347	-4.9124E-24	-1.98337E-29
9.120108394	-6.3219E-23	-2.55245E-28
10.47128548	-6.81792E-22	-2.75272E-27
12.02264435	-6.23268E-21	-2.51643E-26
13.80384265	-4.87998E-20	-1.97028E-25
15.84893192	-3.30242E-19	-1.33335E-24
18.19700859	-1.94615E-18	-7.85752E-24
20.89296131	-1.00409E-17	-4.05399E-23
23.98832919	-4.54656E-17	-1.83566E-22
27.54228703	-1.80381E-16	-7.28283E-22
31.6227766	-6.22249E-16	-2.51232E-21
36.30780548	-1.83377E-15	-7.40378E-21
41.68693835	-4.4437E-15	-1.79413E-20
47.86300923	-8.02734E-15	-3.24102E-20
54.95408739	-6.84894E-15	-2.76524E-20
63.09573445	1.86336E-14	7.52329E-20
72.44359601	1.08003E-13	4.36059E-19
83.17637711	2.99402E-13	1.20883E-18
95.4992586	5.38961E-13	2.17604E-18
109.6478196	5.19086E-13	2.0958E-18
125.8925412	-4.02928E-13	-1.62681E-18
144.5439771	-2.85393E-12	-1.15227E-17
165.9586907	-6.38645E-12	-2.57851E-17
190.5460718	-8.18729E-12	-3.3056E-17
218.7761624	-3.22607E-12	-1.30252E-17
251.1886432	1.2289E-11	4.96167E-17
288.4031503	3.50591E-11	1.4155E-16
331.1311215	5.31786E-11	2.14707E-16
380.1893963	6.05928E-11	2.44642E-16
436.5158322	9.6581E-11	3.89943E-16
501.1872336	3.05644E-10	1.23403E-15
575.4399373	9.93378E-10	4.01074E-15
660.693448	2.64091E-09	1.06626E-14
758.577575	5.84683E-09	2.36064E-14
870.96359	1.11936E-08	4.51938E-14
1000	1.9072E-08	7.70027E-14

Cockhide Farm 14 August 2019

Mercury

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	130	m
Basal length parallel to groundwater flow	Length_LF	150	m
Basal area	Base_Area	19500	m2
Elevation of base of landfill	LFbase_elev	13.2	maOD
Elevation of base of aquifer	Aqbound_elev	13.5	maOD
Leachate head inside landfill	Head_inLF	18.54	maOD
Groundwater head outside landfill	Head_outLF	18.55	maOD
Area of liner below the water table	Area_contact	2822.4	m2

CONTAMINANT PARAMETERS

Contaminant name	Cont_Nme	Mercury	-
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	3.01E-09	m2/s
Partition coefficient in clay	Kd_cl	450	l/kg
Retardation factor in clay	R_cl	2251	-
Half life in clay (0 for no decay)	thalf_cl	1.00E+09	days
Decay in sorbed phase?	Decay_sorb	No	-
Decay constant in clay	Decay_cl	3.56399E-18	1/s

MINERAL BARRIER / LINER

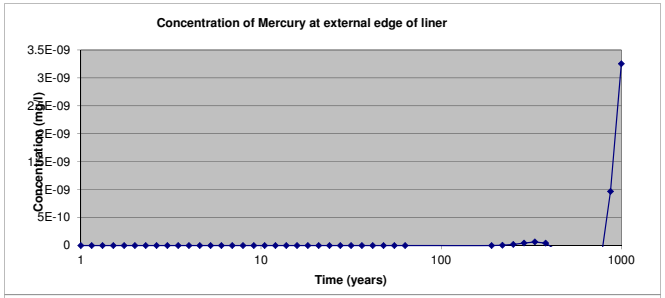
Thickness of mineral liner	thick_clbr	1	m
Hydraulic conductivity	k_cl	1.00E-07	m/s
Average pore radius	pore_radius	3.50E-10	m
Effective porosity	n	0.4	-
Dry bulk density	rho	2000	kg/m3
Tortuosity	tau_cl	2	-

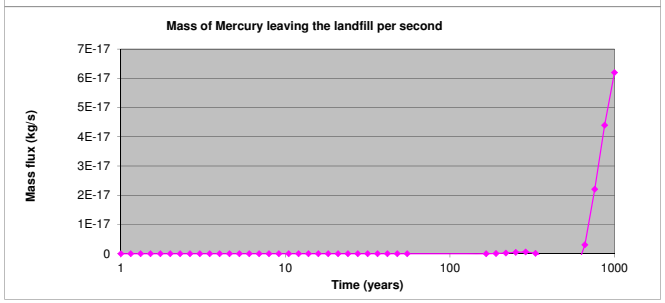
CONTAMINANT AND WATER FLUXES

Groundwater flux into landfill		5.6448E-06	m3/s
Maximum contaminant concentration at compliance point at tmax	C_comp	3.25284E-09	mg/l

CHART PARAMETERS

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





Concentration o Mass of Mercury le

Time years	Concentration	Mass flux (kg/s)
1	-1.30943E-84	-4.01546E-91
1.148153621	-2.35936E-79	-6.75004E-86
1.318256739	-1.89541E-74	-5.05897E-81
1.513561248	-7.16508E-70	-1.78409E-76
1.737800829	-1.34029E-65	-3.1133E-72
1.995262315	-1.30027E-61	-2.81752E-68
2.290867653	-6.8352E-58	-1.38161E-64
2.630267992	-2.02822E-54	-3.82414E-61
3.01995172	-3.52942E-51	-6.20711E-58
3.467368505	-3.73234E-48	-6.12239E-55
3.981071706	-2.47964E-45	-3.7937E-52
4.570881896	-1.06757E-42	-1.5233E-49
5.248074602	-3.06605E-40	-4.08005E-47
6.025595861	-6.03492E-38	-7.48914E-45
6.918309709	-8.3488E-36	-9.6613E-43
7.943282347	-8.31108E-34	-8.96798E-41
9.120108394	-6.08568E-32	-6.12274E-39
10.47128548	-3.34565E-30	-3.13825E-37
12.02264435	-1.4076E-28	-1.2309E-35
13.80384265	-4.61375E-27	-3.76103E-34
15.84893192	-1.19796E-25	-9.10263E-33
18.19700859	-2.50262E-24	-1.77236E-31
20.89296131	-4.26782E-23	-2.81676E-30
23.98832919	-6.02203E-22	-3.7036E-29
27.54228703	-7.11972E-21	-4.07956E-28
31.6227766	-7.13536E-20	-3.80832E-27
36.30780548	-6.12677E-19	-3.04471E-26
41.68693835	-4.55064E-18	-2.1042E-25
47.86300923	-2.94818E-17	-1.26686E-24
54.95408739	-1.67727E-16	-6.68314E-24
63.09573445	-8.41908E-16	-3.0988E-23
72.44359601	-3.73634E-15	-1.26219E-22
83.17637711	-1.46401E-14	-4.4902E-22
95.4992586	-5.03345E-14	-1.37575E-21
109.6478196	-1.49791E-13	-3.52448E-21
125.8925412	-3.75303E-13	-7.04193E-21
144.5439771	-7.43332E-13	-8.60183E-21
165.9586907	-9.4606E-13	5.58552E-21
190.5460718	2.85792E-13	6.78845E-20
218.7761624	5.95679E-12	2.21307E-19
251.1886432	2.03604E-11	4.60079E-19
288.4031503	4.45571E-11	5.96273E-19
331.1311215	6.55417E-11	1.31022E-19
380.1893963	4.37036E-11	-1.6107E-18
436.5158322	-8.34975E-11	-4.7662E-18
501.1872336	-3.56069E-10	-7.74812E-18
575.4399373	-7.00489E-10	-6.64895E-18
660.693448	-8.51066E-10	3.04989E-18
758.577575	-3.9913E-10	2.20601E-17
870.96359	9.69057E-10	4.3955E-17
1000	3.25284E-09	6.19759E-17

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Lead

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	130	m
Basal length parallel to groundwater flow	Length_LF	150	m
Basal area	Base_Area	19500	m2
Elevation of base of landfill	LFbase_elev	13.2	maOD
Elevation of base of aquifer	Aqbound_elev	13.5	maOD
Leachate head inside landfill	Head_inLF	18.54	maOD
Groundwater head outside landfill	Head_outLF	18.55	maOD
Area of liner below the water table	Area_contact	2822.4	m2

CONTAMINANT PARAMETERS

Contaminant name	Cont_Nme	Lead	-
Contaminant type	Cont_Type	Inorganic	-
Contaminant classification	Cont_Class	List I	-
Concentration in landfill leachate	Conc_LF	0.05	mg/l
Free water diffusion coefficient	Dw_cl	9.45E-10	m2/s
Partition coefficient in clay	Kd_cl	990	l/kg
Retardation factor in clay	R_cl	4951	-
Half life in clay (0 for no decay)	thalf_cl	1.00E+09	days
Decay in sorbed phase?	Decay_sorb	No	-
Decay constant in clay	Decay_cl	1.62039E-18	1/s

MINERAL BARRIER / LINER

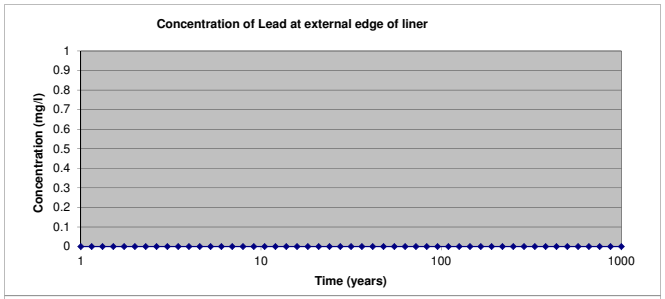
Thickness of mineral liner	thick_clbr	1	m
Hydraulic conductivity	k_cl	1.00E-07	m/s
Average pore radius	pore_radius	3.50E-10	m
Effective porosity	n	0.4	-
Dry bulk density	rho	2000	kg/m3
Tortuosity	tau_cl	2	-

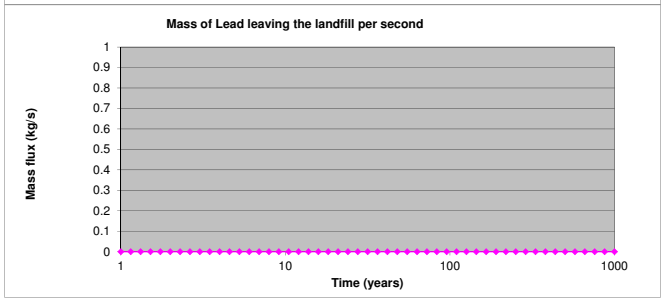
CONTAMINANT AND WATER FLUXES

Groundwater flux into landfill		5.6448E-06	m3/s
Maximum contaminant concentration at compliance point at tmax	C_comp	-2.2324E-213	mg/l

CHART PARAMETERS

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





Time years	Concentration o	Mass of Lead leav
	Concentration	Mass flux (kg/s)
1	-2.2324E-213	-5.6835E-220
1.148153621	-1.8184E-199	-4.3187E-206
1.318256739	-1.7461E-186	-3.8686E-193
1.513561248	-2.2798E-174	-4.7118E-181
1.737800829	-4.624E-163	-8.9144E-170
1.995262315	-1.6496E-152	-2.9665E-159
2.290867653	-1.1625E-142	-1.9499E-149
2.630267992	-1.8032E-133	-2.821E-140
3.01995172	-6.8112E-125	-9.938E-132
3.467368505	-6.8842E-117	-9.3676E-124
3.981071706	-2.0331E-109	-2.58E-116
4.570881896	-1.9045E-102	-2.2537E-109
5.248074602	-6.10981E-96	-6.7418E-103
6.025595861	-7.21007E-90	-7.4182E-97
6.918309709	-3.34585E-84	-3.20955E-91
7.943282347	-6.49796E-79	-5.81119E-86
9.120108394	-5.59752E-74	-4.66661E-81
10.47128548	-2.25799E-69	-1.75473E-76
12.02264435	-4.48684E-65	-3.24994E-72
13.80384265	-4.60438E-61	-3.10822E-68
15.84893192	-2.55012E-57	-1.60423E-64
18.19700859	-7.94289E-54	-4.65588E-61
20.89296131	-1.44578E-50	-7.89577E-58
23.98832919	-1.59401E-47	-8.10966E-55
27.54228703	-1.10071E-44	-5.21609E-52
31.6227766	-4.9113E-42	-2.16756E-49
36.30780548	-1.45785E-39	-5.99135E-47
41.68693835	-2.95817E-37	-1.13189E-44
47.86300923	-4.20864E-35	-1.49906E-42
54.95408739	-4.2988E-33	-1.42508E-40
63.09573445	-3.22279E-31	-9.94159E-39
72.44359601	-1.81027E-29	-5.19528E-37
83.17637711	-7.76667E-28	-2.07322E-35
95.4992586	-2.59119E-26	-6.43205E-34
109.6478196	-6.83607E-25	-1.57756E-32
125.8925412	-1.44858E-23	-3.10692E-31
144.5439771	-2.50167E-22	-4.98536E-30
165.9586907	-3.56916E-21	-6.60642E-29
190.5460718	-4.2602E-20	-7.32145E-28
218.7761624	-4.30425E-19	-6.86469E-27
251.1886432	-3.72064E-18	-5.50316E-26
288.4031503	-2.77828E-17	-3.80723E-25
331.1311215	-1.80718E-16	-2.29076E-24
380.1893963	-1.03094E-15	-1.20559E-23
436.5158322	-5.18222E-15	-5.56578E-23
501.1872336	-2.29988E-14	-2.2517E-22
575.4399373	-8.99673E-14	-7.92893E-22
660.693448	-3.08108E-13	-2.39125E-21
758.577575	-9.10064E-13	-5.96468E-21
870.96359	-2.24807E-12	-1.12805E-20
1000	-4.31832E-12	-1.12698E-20

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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	130	m
Basal length parallel to groundwater flow	Length_LF	150	m
Basal area	Base_Area	19500	m2
Elevation of base of landfill	LFbase_elev	13.2	maOD
Elevation of base of aquifer	Aqbound_elev	13.5	maOD
Leachate head inside landfill	Head_inLF	18.54	maOD
Groundwater head outside landfill	Head_outLF	18.55	maOD
Area of liner below the water table	Area_contact	2822.4	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	600	mg/l
Free water diffusion coefficient	Dw_cl	1.07E-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	1.00E+09	days
Decay in sorbed phase?	Decay_sorb	No	-
Decay constant in clay	Decay_cl	8.02254E-15	1/s

MINERAL BARRIER / LINER

Thickness of mineral liner	thick_clbr	1	m
Hydraulic conductivity	k_cl	1.00E-07	m/s
Average pore radius	pore_radius	3.50E-10	m
Effective porosity	n	0.4	-
Dry bulk density	rho	2000	kg/m3
Tortuosity	tau_cl	2	-

Sulphate

STEADY STATE DILUTION

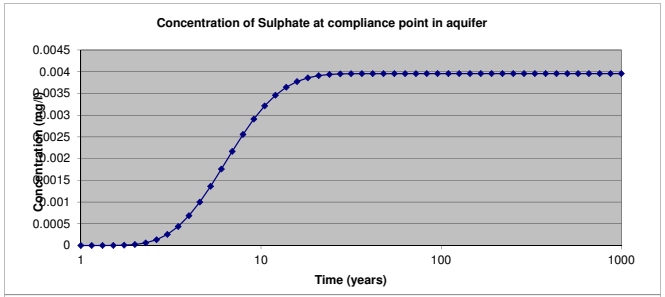
Hydraulic gradient in the aquifer	aq_I	0.015	-
Hydraulic conductivity of the aquifer	k_aq	4.10E-04	m/s
Downgradient distance of compliance point from landfill	dist_cp	10	m
Mixing width	Mix_W	130	m
Mixing depth	Mix_D	5.05	m
Dilution flow in aquifer downstream to the landfill	aq_Q	0.004037475	m3/s

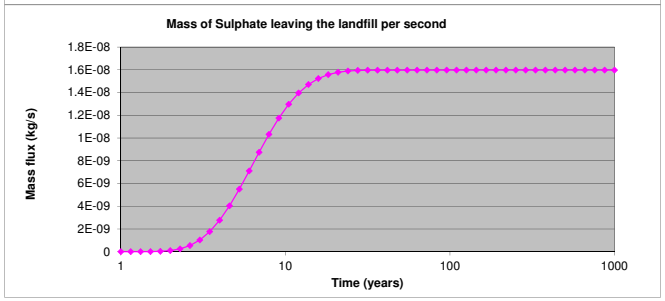
CONTAMINANT AND WATER FLUXES

Groundwater flux into landfill		5.6448E-06	m3/s
Maximum contaminant concentration at compliance point at tmax	C_comp	0.003956849	mg/l

CHART PARAMETERS

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





Time years	Concentration o	Mass of Sulphate l	Mass flux (kg/s)
1	6.88131E-07	2.77831E-12	
1.148153621	1.07566E-06	4.34295E-12	
1.318256739	1.40407E-06	5.66889E-12	
1.513561248	2.67064E-06	1.07826E-11	
1.737800829	8.09396E-06	3.26791E-11	
1.995262315	2.43071E-05	9.81392E-11	
2.290867653	6.18384E-05	2.49671E-10	
2.630267992	0.000134269	5.42107E-10	
3.01995172	0.000255896	1.03318E-09	
3.467368505	0.00043837	1.76991E-09	
3.981071706	0.000687265	2.77482E-09	
4.570881896	0.000999719	4.03634E-09	
5.248074602	0.001363901	5.50672E-09	
6.025595861	0.001760539	7.10813E-09	
6.918309709	0.002166035	8.74531E-09	
7.943282347	0.00255633	1.03211E-08	
9.120108394	0.002910558	1.17513E-08	
10.47128548	0.003213731	1.29754E-08	
12.02264435	0.003458064	1.39618E-08	
13.80384265	0.00364288	1.4708E-08	
15.84893192	0.003773384	1.52349E-08	
18.19700859	0.003858695	1.55794E-08	
20.89296131	0.003909668	1.57852E-08	
23.98832919	0.003936939	1.58953E-08	
27.54228703	0.003949537	1.59462E-08	
31.6227766	0.003954191	1.59649E-08	
36.30780548	0.003955287	1.59694E-08	
41.68693835	0.00395526	1.59693E-08	
47.86300923	0.003955188	1.5969E-08	
54.95408739	0.003955362	1.59697E-08	
63.09573445	0.003955725	1.59711E-08	
72.44359601	0.003956131	1.59728E-08	
83.17637711	0.003956471	1.59742E-08	
95.4992586	0.003956698	1.59751E-08	
109.6478196	0.003956815	1.59755E-08	
125.8925412	0.003956849	1.59757E-08	
144.5439771	0.003956834	1.59756E-08	
165.9586907	0.003956797	1.59755E-08	
190.5460718	0.003956755	1.59753E-08	
218.7761624	0.003956718	1.59752E-08	
251.1886432	0.003956691	1.5975E-08	
288.4031503	0.003956672	1.5975E-08	
331.1311215	0.00395666	1.59749E-08	
380.1893963	0.003956654	1.59749E-08	
436.5158322	0.003956651	1.59749E-08	
501.1872336	0.00395665	1.59749E-08	
575.4399373	0.003956651	1.59749E-08	
660.693448	0.003956652	1.59749E-08	
758.577575	0.003956653	1.59749E-08	
870.96359	0.003956654	1.59749E-08	
1000	0.003956655	1.59749E-08	

Cockhide Farm

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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	130	m
Basal length parallel to groundwater flow	Length_LF	150	m
Basal area	Base_Area	19500	m2
Elevation of base of landfill	LFbase_elev	13.2	maOD
Elevation of base of aquifer	Aqbound_elev	13.5	maOD
Leachate head inside landfill	Head_inLF	18.54	maOD
Groundwater head outside landfill	Head_outLF	18.55	maOD
Area of liner below the water table	Area_contact	2822.4	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	0.4	mg/l
Free water diffusion coefficient	Dw_cl	7.03E-10	m2/s
Partition coefficient in clay	Kd_cl	11	l/kg
Retardation factor in clay	R_cl	56	-
Half life in clay (0 for no decay)	thalf_cl	1.00E+09	days
Decay in sorbed phase?	Decay_sorb	No	-
Decay constant in clay	Decay_cl	1.4326E-16	1/s

MINERAL BARRIER / LINER

Thickness of mineral liner	thick_clbr	1	m
Hydraulic conductivity	k_cl	1.00E-07	m/s
Average pore radius	pore_radius	3.50E-10	m
Effective porosity	n	0.4	-
Dry bulk density	rho	2000	kg/m3
Tortuosity	tau_cl	2	-

Zinc

STEADY STATE DILUTION

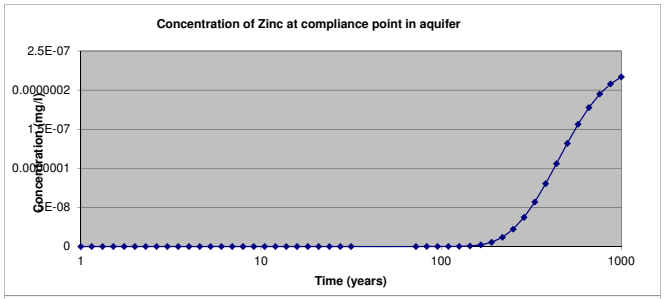
Hydraulic gradient in the aquifer	aq_I	0.015	-
Hydraulic conductivity of the aquifer	k_aq	4.10E-04	m/s
Downgradient distance of compliance point from landfill	dist_cp	10	m
Mixing width	Mix_W	130	m
Mixing depth	Mix_D	5.05	m
Dilution flow in aquifer downstream to the landfill	aq_Q	0.004037475	m3/s

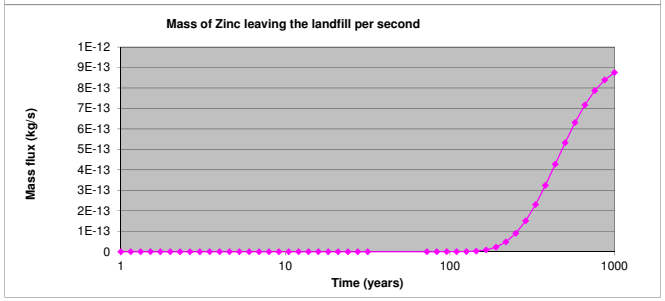
CONTAMINANT AND WATER FLUXES

Groundwater flux into landfill		5.6448E-06	m3/s
Maximum contaminant concentration at compliance point at tmax	C_comp	2.16847E-07	mg/l

CHART PARAMETERS

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



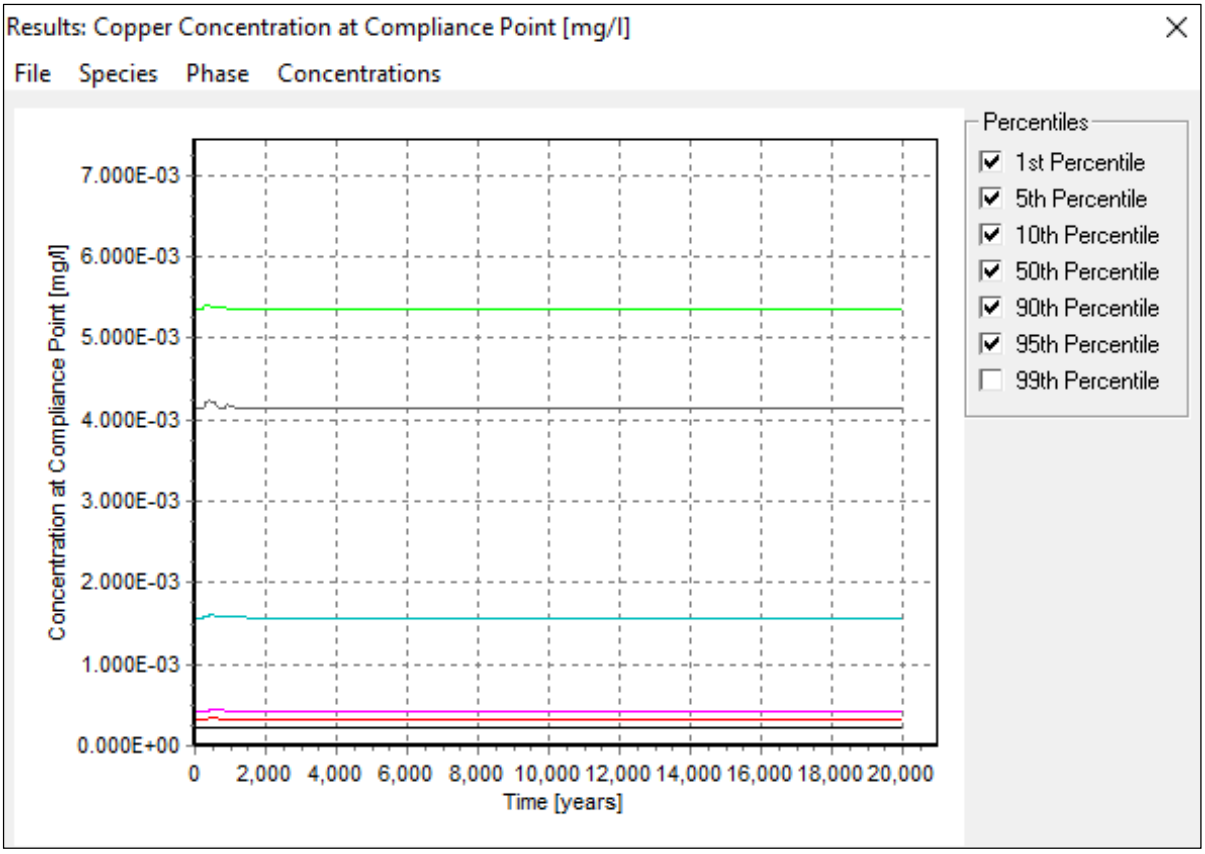


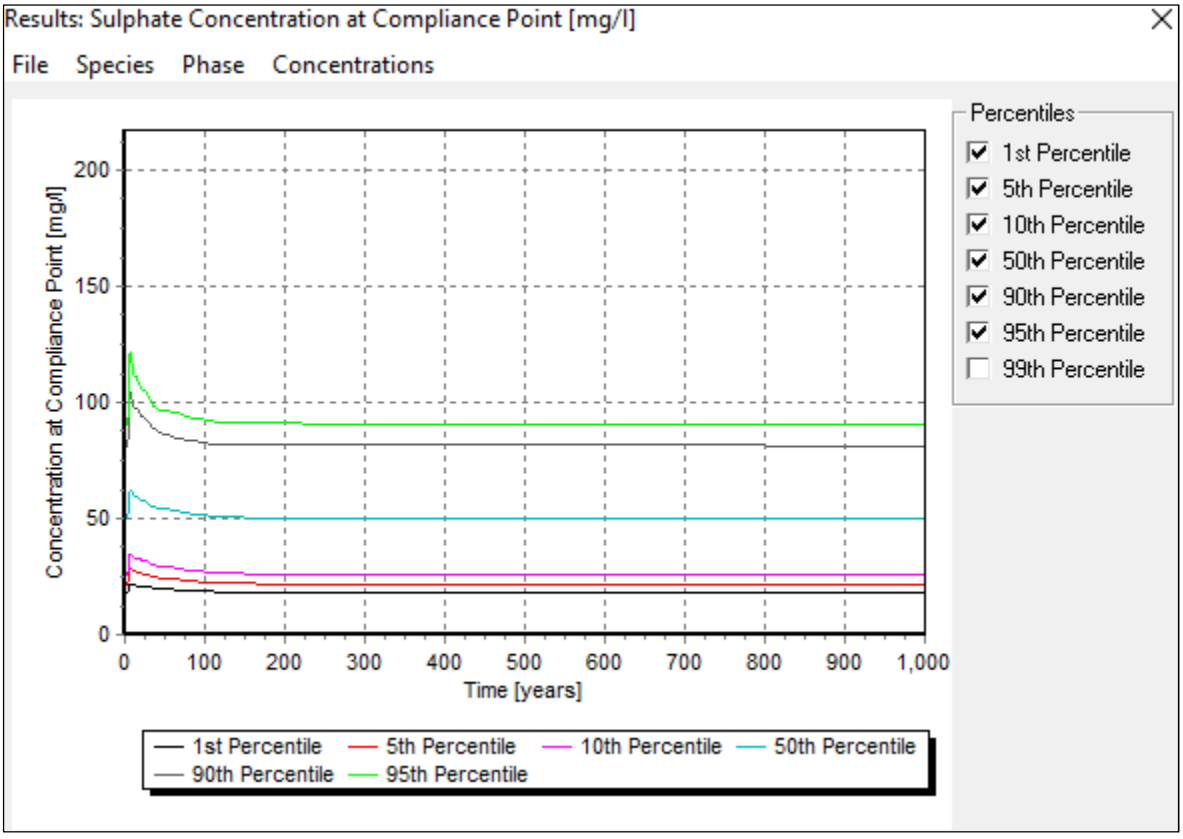
Time years	Concentration o	Mass of Zinc leavi
	Concentration	Mass flux (kg/s)
1	-3.98138E-32	-1.60747E-37
1.148153621	-1.91502E-30	-7.73184E-36
1.318256739	-7.07299E-29	-2.8557E-34
1.513561248	-2.04151E-27	-8.24253E-33
1.737800829	-4.68094E-26	-1.88992E-31
1.995262315	-8.65739E-25	-3.4954E-30
2.290867653	-1.31008E-23	-5.28943E-29
2.630267992	-1.64371E-22	-6.63644E-28
3.01995172	-1.73103E-21	-6.98898E-27
3.467368505	-1.54753E-20	-6.24811E-26
3.981071706	-1.18649E-19	-4.79041E-25
4.570881896	-7.87117E-19	-3.17797E-24
5.248074602	-4.55104E-18	-1.83747E-23
6.025595861	-2.30486E-17	-9.30583E-23
6.918309709	-1.02444E-16	-4.13614E-22
7.943282347	-3.98657E-16	-1.60957E-21
9.120108394	-1.34638E-15	-5.43598E-21
10.47128548	-3.86925E-15	-1.5622E-20
12.02264435	-9.06215E-15	-3.65882E-20
13.80384265	-1.53965E-14	-6.21631E-20
15.84893192	-9.78379E-15	-3.95018E-20
18.19700859	4.8737E-14	1.96775E-19
20.89296131	2.36925E-13	9.56581E-19
23.98832919	6.14071E-13	2.4793E-18
27.54228703	1.03262E-12	4.16919E-18
31.6227766	8.36145E-13	3.37592E-18
36.30780548	-1.21941E-12	-4.92334E-18
41.68693835	-6.14243E-12	-2.47999E-17
47.86300923	-1.25903E-11	-5.08329E-17
54.95408739	-1.46486E-11	-5.91432E-17
63.09573445	-2.8481E-12	-1.14991E-17
72.44359601	2.84873E-11	1.15017E-16
83.17637711	7.05662E-11	2.84909E-16
95.4992586	1.00242E-10	4.04725E-16
109.6478196	1.12742E-10	4.55194E-16
125.8925412	2.01072E-10	8.11823E-16
144.5439771	6.68192E-10	2.69781E-15
165.9586907	2.12181E-09	8.56674E-15
190.5460718	5.48207E-09	2.21337E-14
218.7761624	1.18511E-08	4.78485E-14
251.1886432	2.22495E-08	8.98319E-14
288.4031503	3.72929E-08	1.50569E-13
331.1311215	5.69236E-08	2.29828E-13
380.1893963	8.03043E-08	3.24227E-13
436.5158322	1.05924E-07	4.27666E-13
501.1872336	1.31889E-07	5.32497E-13
575.4399373	1.56302E-07	6.31065E-13
660.693448	1.77625E-07	7.17156E-13
758.577575	1.94913E-07	7.86956E-13
870.96359	2.07887E-07	8.39338E-13
1000	2.16847E-07	8.75516E-13

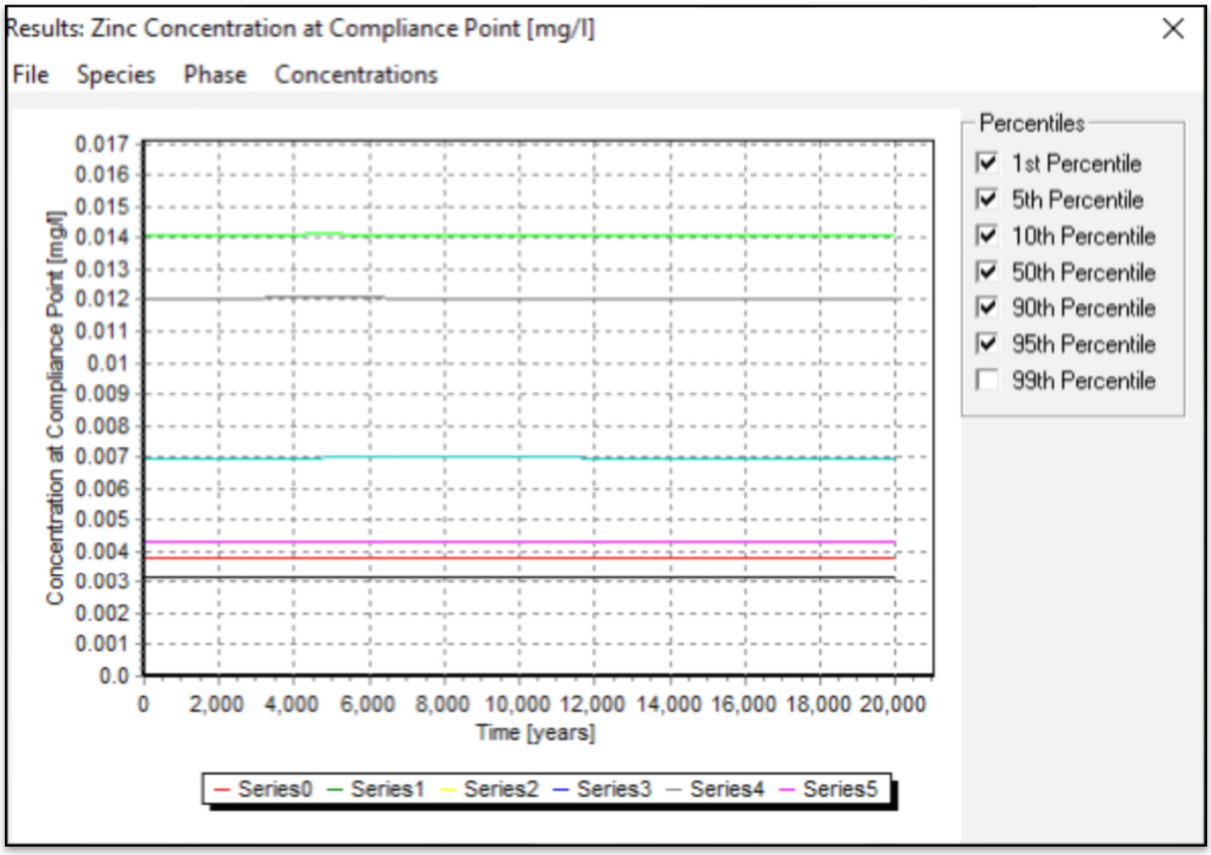
APPENDIX 09

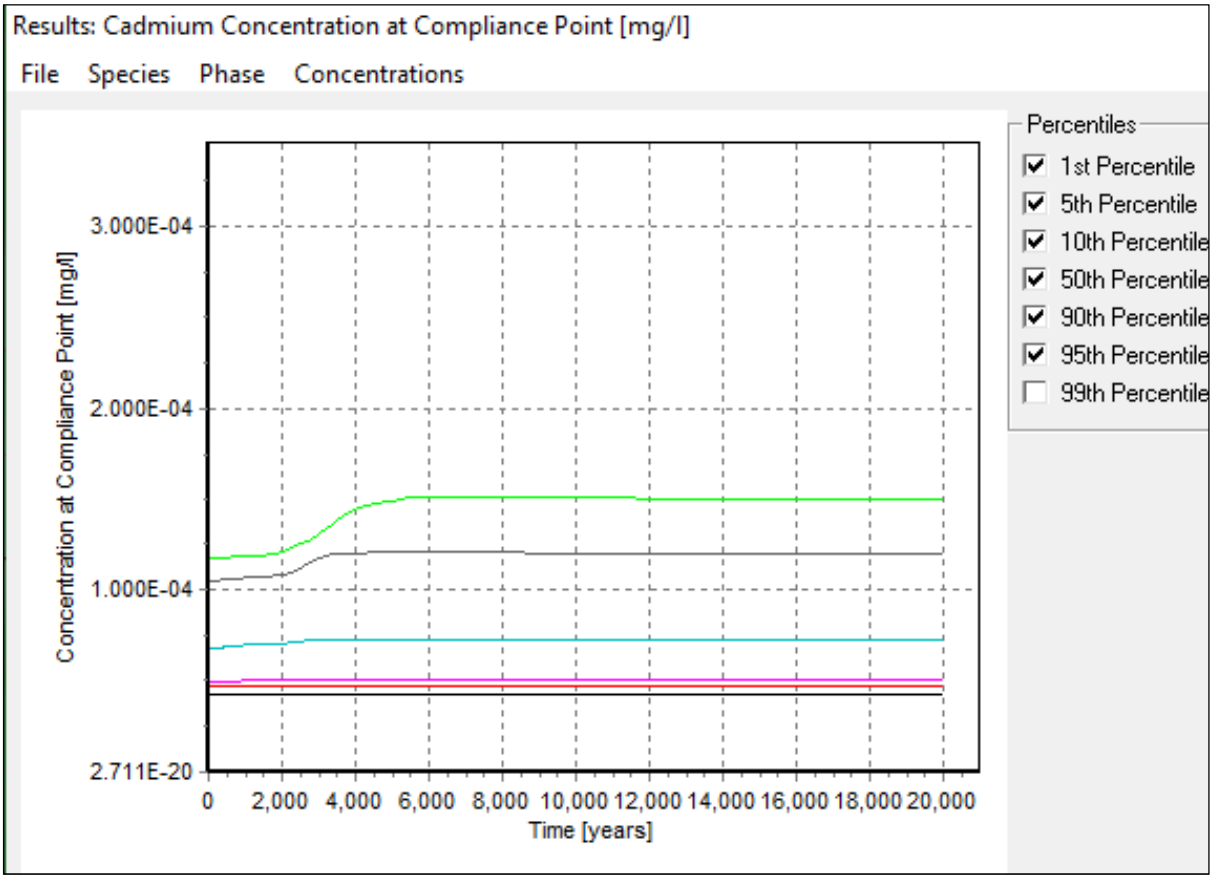
Landsim Model Results

Non-Hazardous Substances

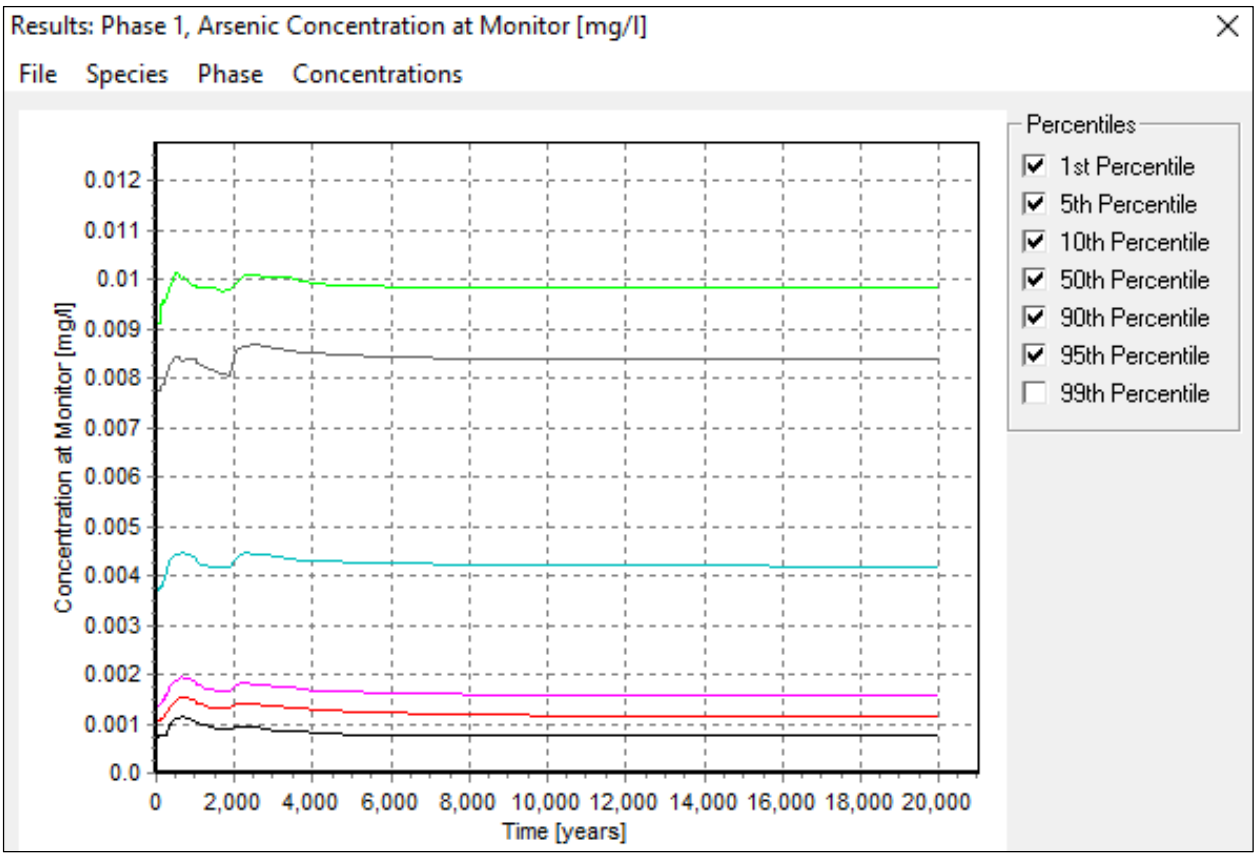


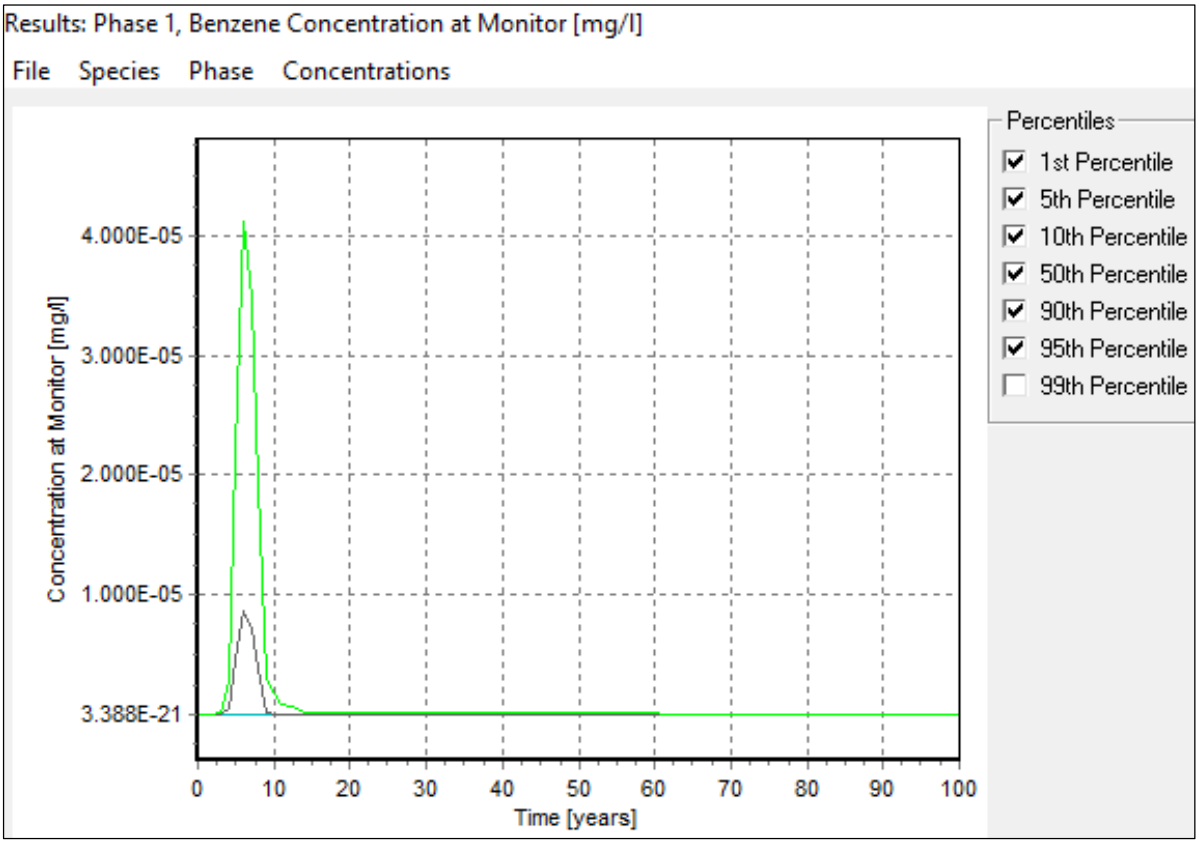


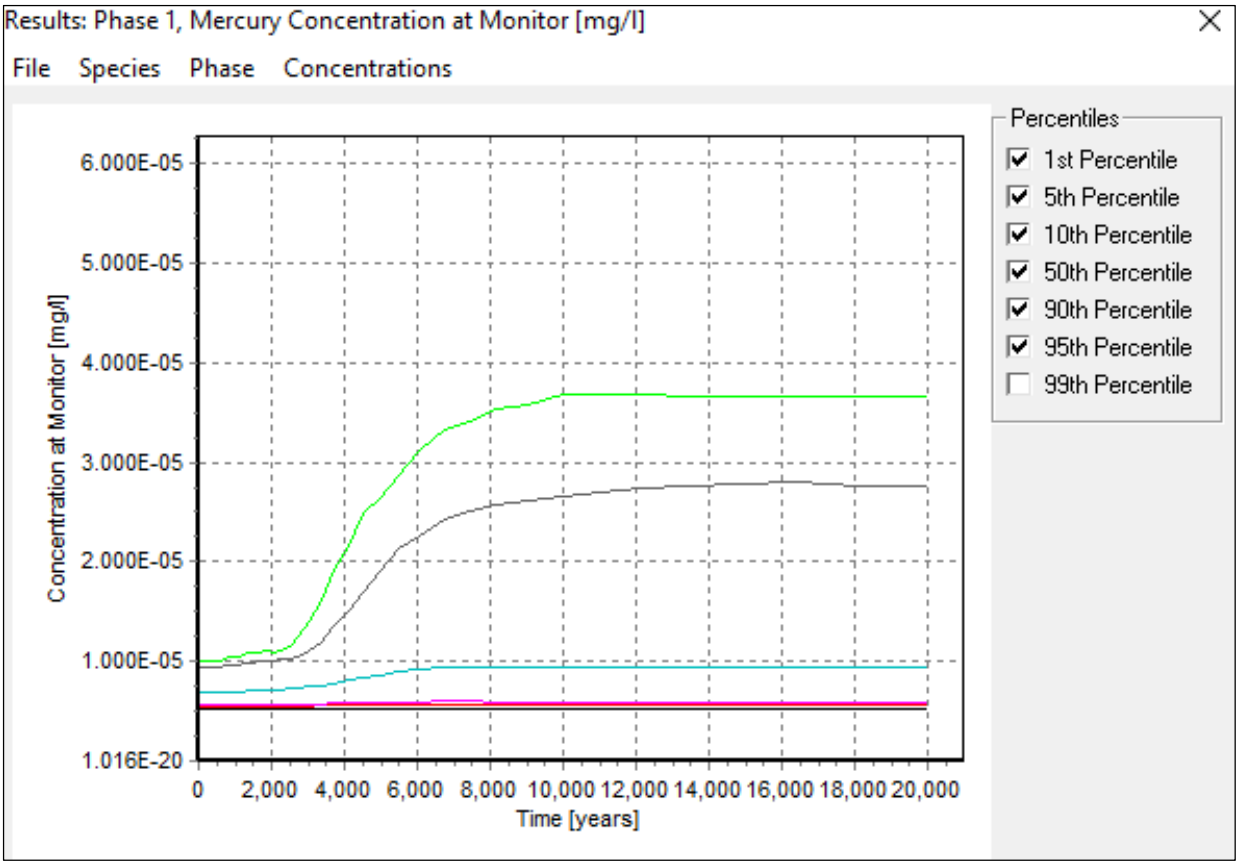

Results: Zinc Concentration at Compliance Point [mg/l]
File
Species
Phase
Concentrations
Concentration at Compliance Point [mg/l]
0.017
0.016
0.015
0.014
0.013
0.012
0.011
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.0
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000
18,000
20,000
Time [years]
Series0
Series1
Series2
Series3
Series4
Series5
Percentiles
1st Percentile
5th Percentile
10th Percentile
50th Percentile
90th Percentile
95th Percentile
99th Percentile

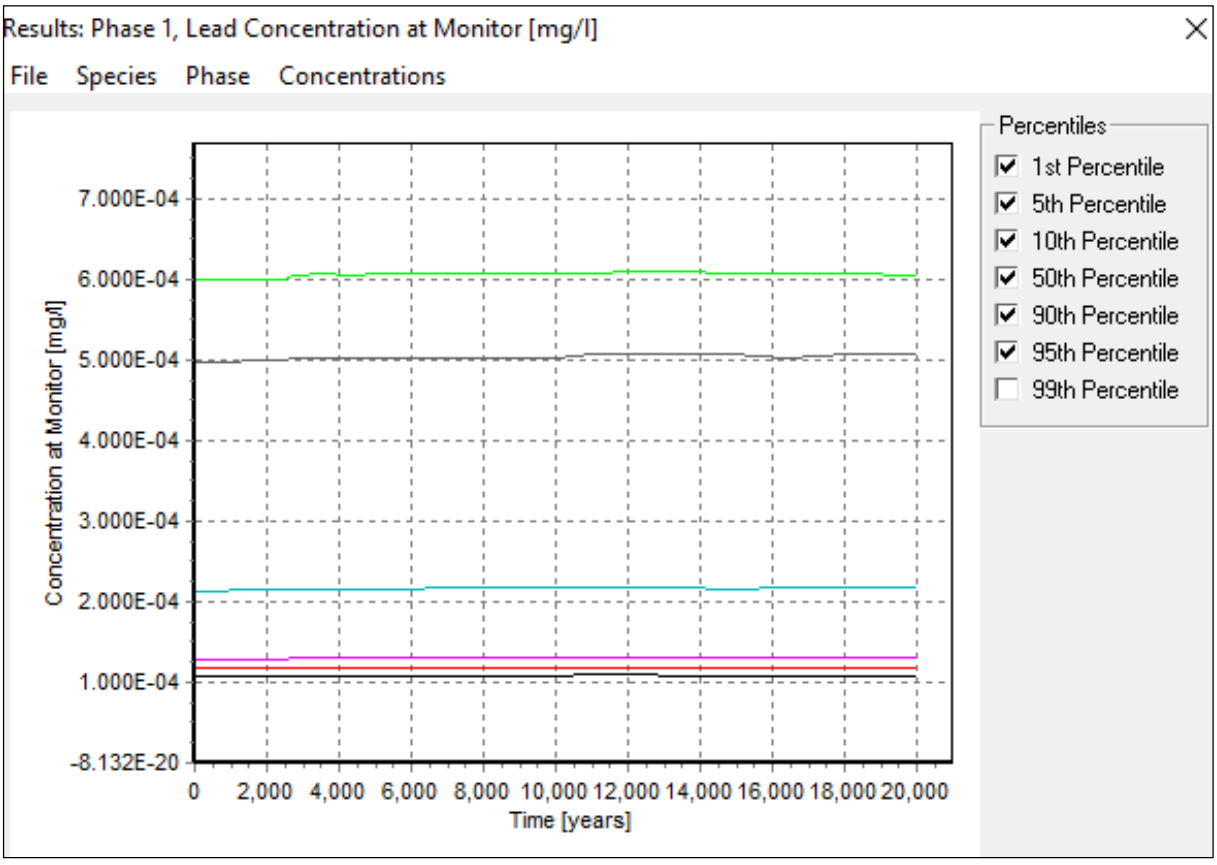

Results: Cadmium Concentration at Compliance Point [mg/l]
File
Species
Phase
Concentrations
Concentration at Compliance Point [mg/l]
3.000E-04
2.000E-04
1.000E-04
2.711E-20
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000
18,000
20,000
Time [years]
Percentiles
1st Percentile
5th Percentile
10th Percentile
50th Percentile
90th Percentile
95th Percentile
99th Percentile

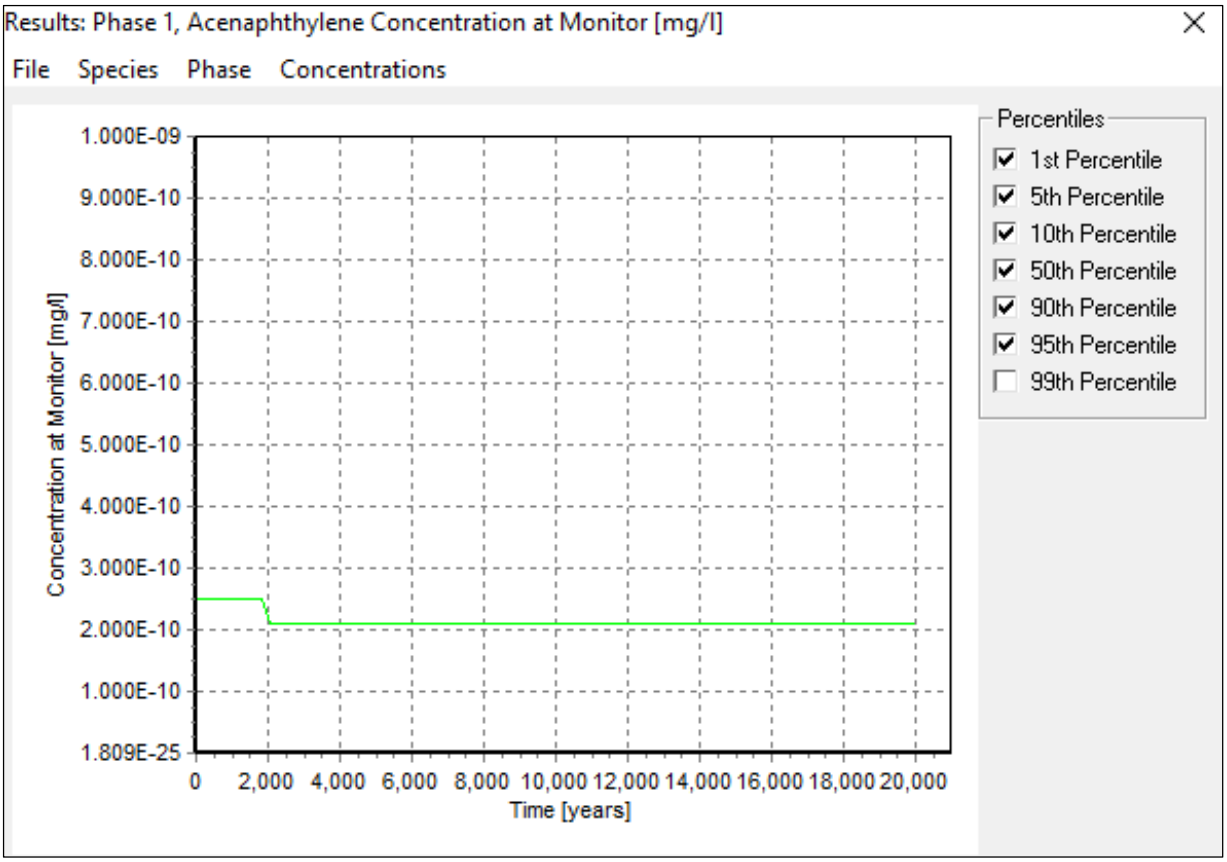
Hazardous Substances

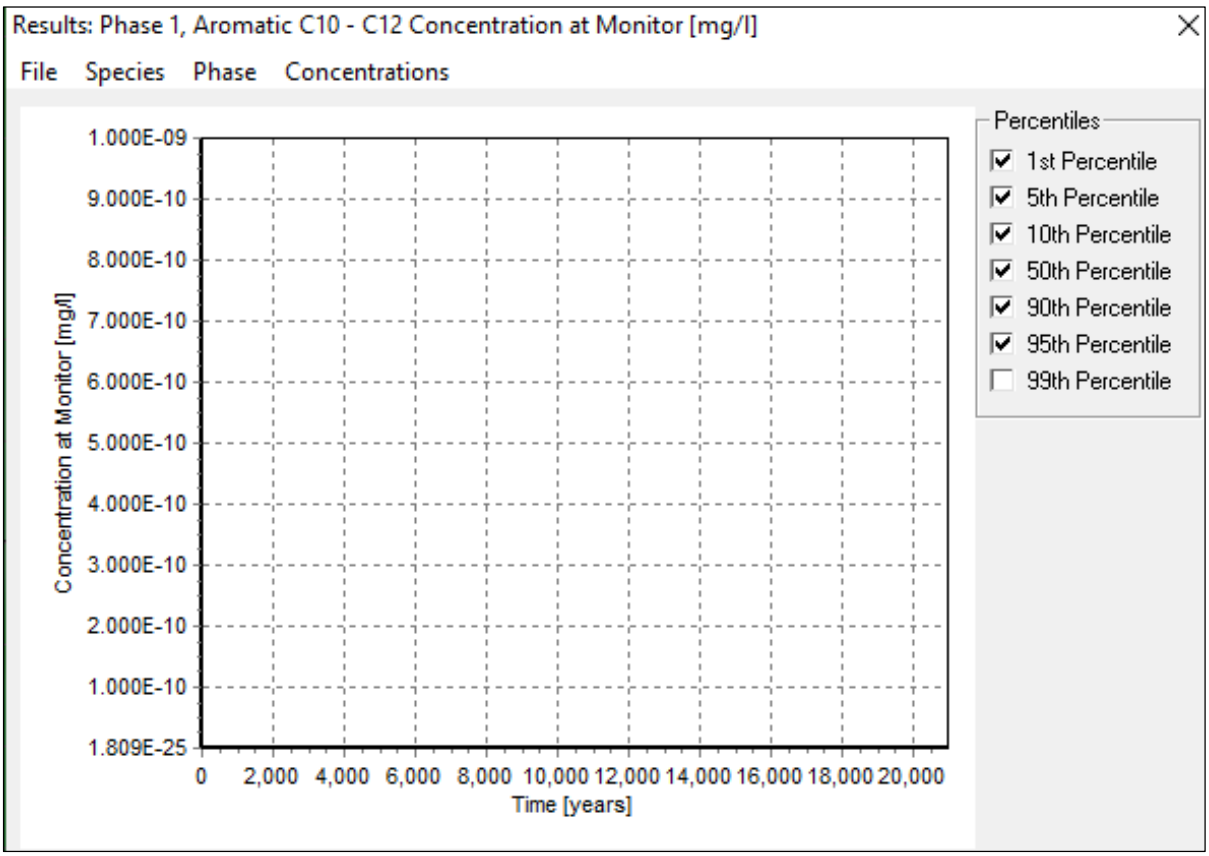





Results: Phase 1, Mercury Concentration at Monitor [mg/l]
File
Species
Phase
Concentrations
Percentiles
1st Percentile
5th Percentile
10th Percentile
50th Percentile
90th Percentile
95th Percentile
99th Percentile
Concentration at Monitor [mg/l]
6.000E-05
5.000E-05
4.000E-05
3.000E-05
2.000E-05
1.000E-05
1.016E-20
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000
18,000
20,000
Time [years]


Results: Phase 1, Lead Concentration at Monitor [mg/l]
File
Species
Phase
Concentrations
Percentiles
1st Percentile
5th Percentile
10th Percentile
50th Percentile
90th Percentile
95th Percentile
99th Percentile
Concentration at Monitor [mg/l]
7.000E-04
6.000E-04
5.000E-04
4.000E-04
3.000E-04
2.000E-04
1.000E-04
-8.132E-20
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000
18,000
20,000
Time [years]


Results: Phase 1, Acenaphthylene Concentration at Monitor [mg/l]
File
Species
Phase
Concentrations
Percentiles
1st Percentile
5th Percentile
10th Percentile
50th Percentile
90th Percentile
95th Percentile
99th Percentile
Concentration at Monitor [mg/l]
1.000E-09
9.000E-10
8.000E-10
7.000E-10
6.000E-10
5.000E-10
4.000E-10
3.000E-10
2.000E-10
1.000E-10
1.809E-25
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000
18,000
20,000
Time [years]


Results: Phase 1, Aromatic C10 - C12 Concentration at Monitor [mg/l]
File
Species
Phase
Concentrations
Percentiles
1st Percentile
5th Percentile
10th Percentile
50th Percentile
90th Percentile
95th Percentile
99th Percentile
Concentration at Monitor [mg/l]
1.000E-09
9.000E-10
8.000E-10
7.000E-10
6.000E-10
5.000E-10
4.000E-10
3.000E-10
2.000E-10
1.000E-10
1.809E-25
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000
18,000
20,000
Time [years]

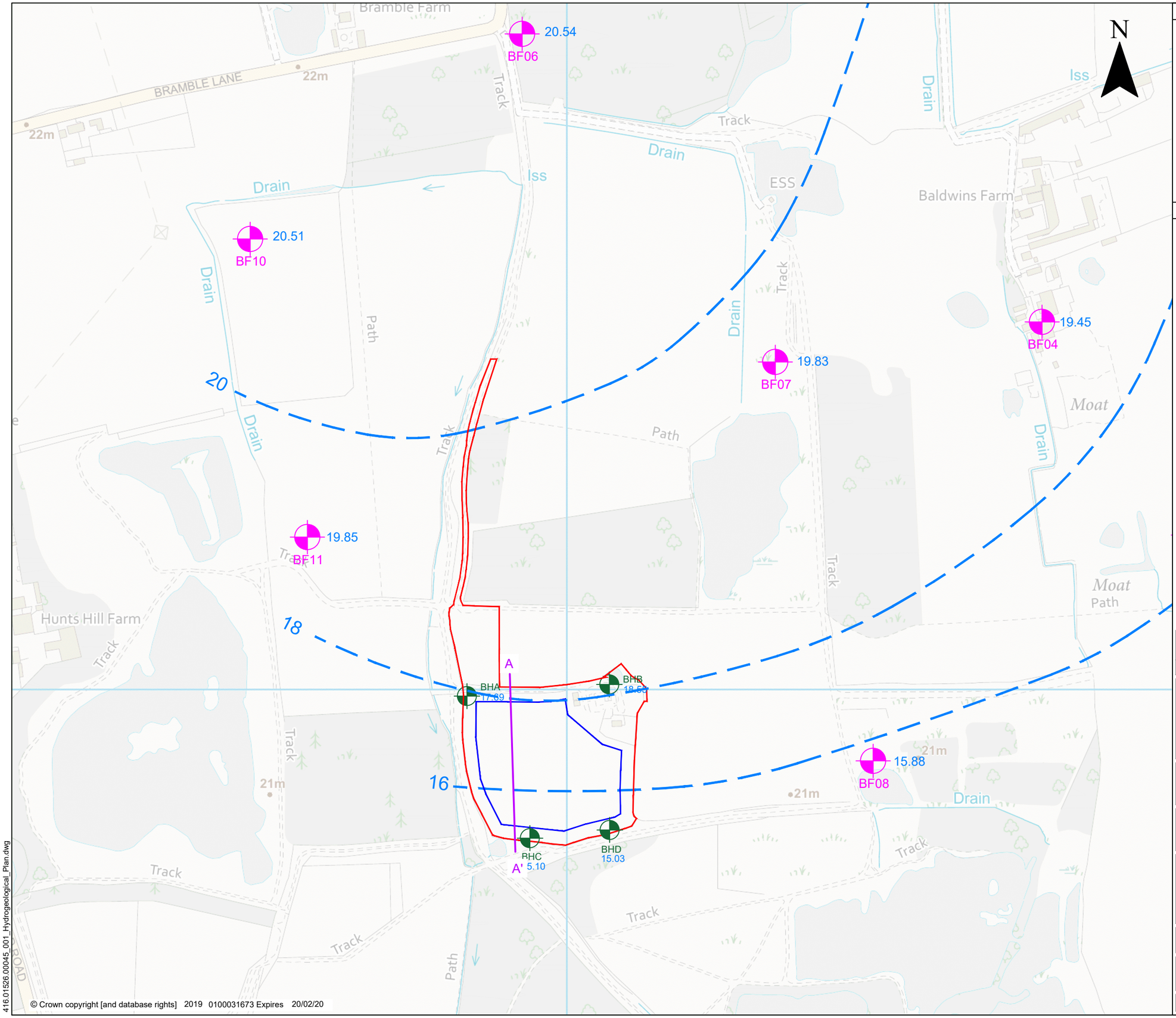
APPENDIX 10

Electronic Copies of Diffusion & Landsim Models (Available on Request)

DRAWINGS

DRAWING HRA1

Groundwater Monitoring Plan and Groundwater Contours



NOTES

LYNCH HILL GRAVEL HAS BEEN EXTENSIVELY WORKED AND BACKFILLED. THE CONTINUITY OF THE WATER TABLE IS THEREFORE UNCERTAIN

LEGEND

- SITE BOUNDARY
- LANDFILL BOUNDARY
- BALDWINS FARM GROUNDWATER MONITORING BOREHOLES
- COCKHIDE FARM GROUNDWATER MONITORING BOREHOLES
- 15.42 — GROUNDWATER LEVEL (MARCH 2019)
- INDICATIVE GROUNDWATER CONTOURS (MARCH 2019) (mAOD)

Revision	By	Chk'd By	Date	Comments
V1	SM	PS	21.08.19	

SLR global environmental solutions
LANGFORD LODGE
109 PEMBROKE ROAD
CLIFTON, BRISTOL
BS8 3EU
T: 01179 064280
F: 01173 179535
www.slrconsulting.com

Site: COCKHIDE FARM

Project: HYDROGEOLOGICAL RISK ASSESSMENT

Drawing Title: **GROUNDWATER MONITORING PLAN AND GROUNDWATER CONTOURS**

Scale: 1:4,000 @ A3

Date: AUGUST 2019

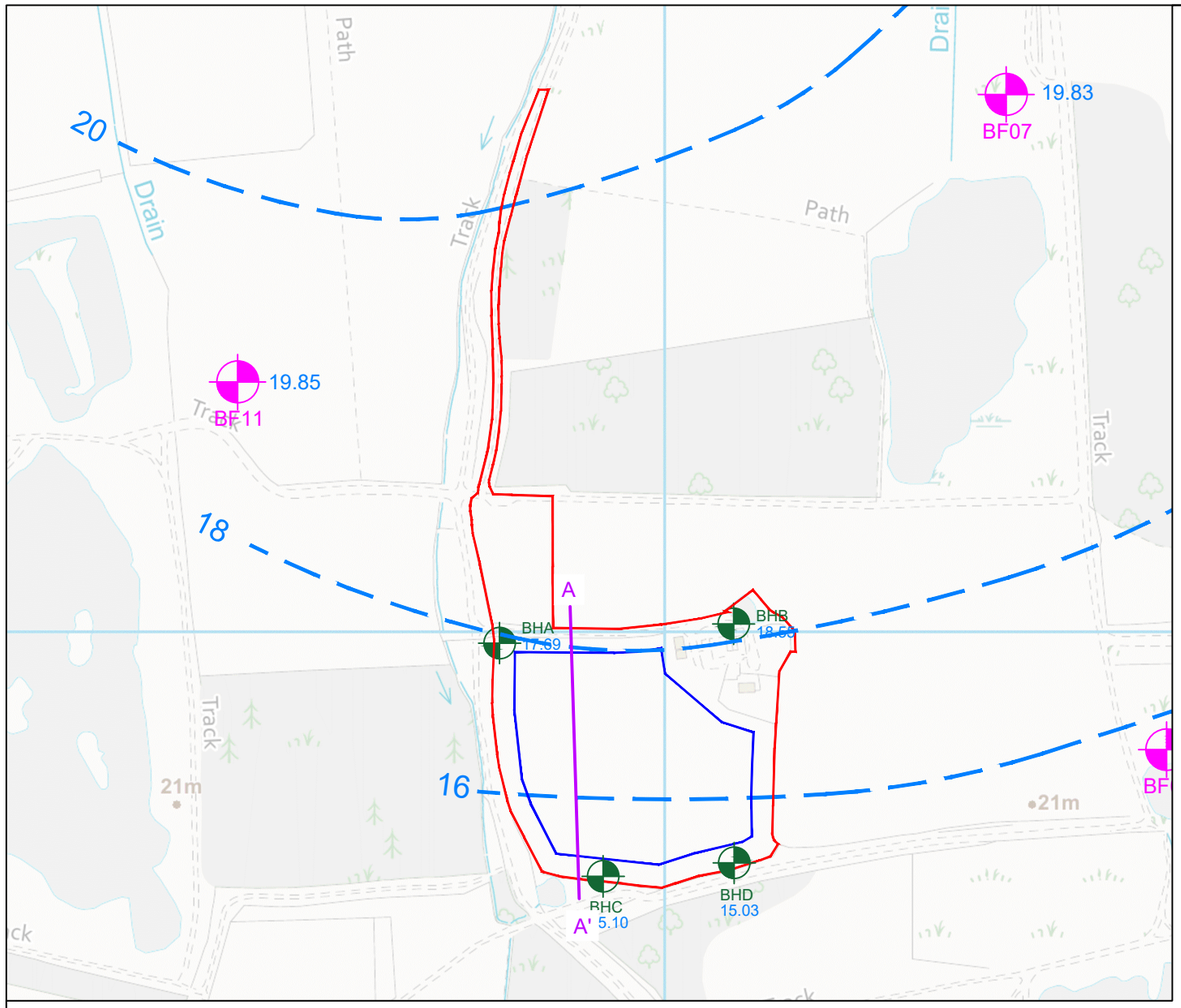
Drawing Number: **DRAWING HRA1**

Revision: 1

416.01526.00045_001_Hydrogeological_Plan.dwg

DRAWING HRA2

Hydrogeological Cross-Section



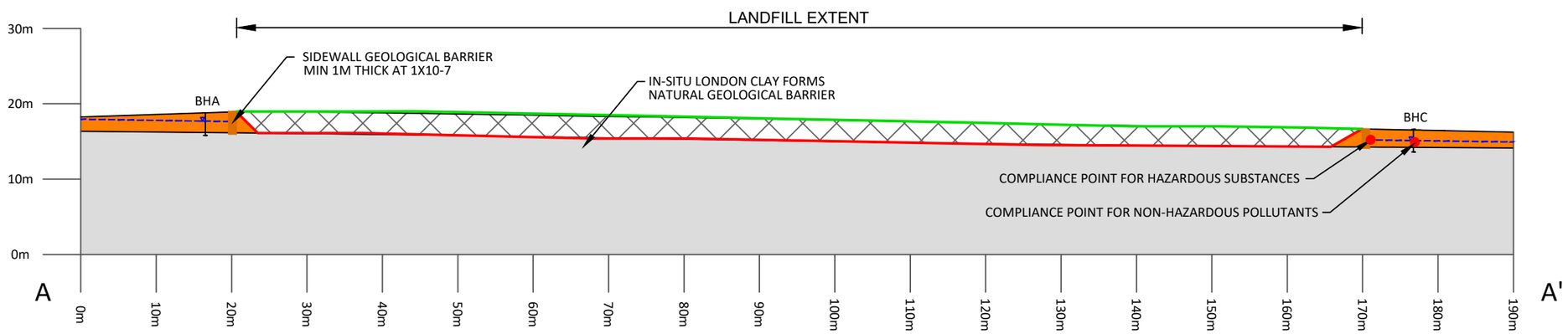
N

LEGEND

- SITE BOUNDARY
- LANDFILL BOUNDARY
- BALDWINS FARM GROUNDWATER MONITORING BOREHOLES
- COCKHIDE FARM GROUNDWATER MONITORING BOREHOLES
- 15.42 — GROUNDWATER LEVEL (MARCH 2019)
- INDICATIVE GROUNDWATER CONTOURS (MARCH 2019) (mAOD)

SECTIONS

- EXTRACTION / RESTORATION AREA
- IN-SITU SAND & GRAVEL
- LONDON CLAY
- EXTRACTION PROFILE
- RESTORATION PROFILE / EXISTING GROUND PROFILE



Revision	By	Chk'd By	Date	Comments
V1	SM	PS	21.08.19	

SLR global environmental solutions
LANGFORD LODGE
109 PEMBROKE ROAD
CLIFTON, BRISTOL
BS8 3EU
T: 01179 064280
F: 01173 179535
www.slrconsulting.com

Site
COCKHIDE FARM

Project
HYDROGEOLOGCIAL RISK ASSESSMENT

Drawing Title
HYDROGEOLOGICAL CROSS-SECTION

Scale	Date
1:1,500 @ A3	AUGUST 2019

Drawing Number	Revision
DRAWING HRA1	1

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416.01526.00045_001_Hydrogeological_Plan.dwg

EUROPEAN OFFICES

United Kingdom

AYLESBURY
T: +44 (0)1844 337380

BELFAST
T: +44 (0)28 9073 2493

BRADFORD-ON-AVON
T: +44 (0)1225 309400

BRISTOL
T: +44 (0)117 906 4280

CAMBRIDGE
T: + 44 (0)1223 813805

CARDIFF
T: +44 (0)29 2049 1010

CHELMSFORD
T: +44 (0)1245 392170

EDINBURGH
T: +44 (0)131 335 6830

EXETER
T: + 44 (0)1392 490152

GLASGOW
T: +44 (0)141 353 5037

GUILDFORD
T: +44 (0)1483 889800

LEEDS
T: +44 (0)113 258 0650

LONDON
T: +44 (0)203 805 6418

MAIDSTONE
T: +44 (0)1622 609242

MANCHESTER
T: +44 (0)161 872 7564

NEWCASTLE UPON TYNE
T: +44 (0)191 261 1966

NOTTINGHAM
T: +44 (0)115 964 7280

SHEFFIELD
T: +44 (0)114 245 5153

SHREWSBURY
T: +44 (0)1743 23 9250

STAFFORD
T: +44 (0)1785 241755

STIRLING
T: +44 (0)1786 239900

WORCESTER
T: +44 (0)1905 751310

Ireland

DUBLIN
T: + 353 (0)1 296 4667

France

GRENOBLE
T: +33 (0)4 76 70 93 41