CONSOLIDATED HYDROGEOLOGICAL RISK ASSESSMENT REVIEW 2020

POPLARS MAIN & PFA LANDFILL SITES
LICHFIELD ROAD
CANNOCK
STAFFORDSHIRE
WS11 8NQ

Document Reference: BF5036/05.R0
December 2021

Project Quality Assurance
Information Sheet

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Report Status : Final

Report Reference : BF5036/05.R0

Report Date : December 2021

Prepared for : Biffa Waste Services Limited

Prepared by : Sirius Environmental Limited
The Beacon Centre for Enterprise
Dafen
Llanelli
SA14 8LQ

Written by :

Dylan Thomas BSc (Hons) PGDip MCIWM
Principle Environmental Consultant

Reviewed & Approved by :

Mark Griffiths BSc (Hons) MSc CGeol MCIWM
Environmental Director

Revision	Date	Amendment Details	Author	Reviewer

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1.0 INTRODUCTION

1.1 Scope

1.1.1 Sirius Environmental Limited ('Sirius') have been commissioned by Biffa Waste Services Limited ('Biffa') to prepare an application to consolidate the Environmental Permits held for the operation of the main non-hazardous landfill facility (Ref.: EPR/BW0584IL) and Pulverised Fuel Ash (PFA) landfill facility (EPR/BP3436VS) at the Poplars former colliery site near Cannock. The commission also extends to a 6-year review of Hydrogeological Risk Assessment for the PFA Landfill in accordance with Condition 3.1.4 of Environmental Permit EPR/BP3436VS.

1.1.2 This consolidated review of the HRA for both the PFA and Main Landfill facilities therefore considers the revised development proposals, which includes the development of Phase C2 considered in the original PPC application for the site and the sterilisation of Phase J due to the long-term operation of the AD Facility.

1.1.3 Changes to the local waste market caused importation of PFA at the site to cease ahead of final waste levels being achieved. As part of the construction of the Phase C2 containment area the excavated materials will be used to achieve final levels at the PFA Landfill.

1.2 Background

1.2.1 The original HRA for the Main Landfill Site at Poplars was drafted in November 2003 by Golder Associates to support a PPC application for the continuation of landfilling operations at the Poplars facility. Environmental Permit EPR/BW0584IL was subsequently issued in April 2009 with several Improvement Conditions to update the characterisation of leachate within the existing containment cells and groundwater within the drift and backfill deposits, after which the HRA was to be reviewed and revised accordingly. Subsequently, there have been several HRA reviews and revisions, the most recent of which was prepared in June 2018 *(Doc. Ref: BF4922/HRA (rev1))* to support an application to vary the leachate compliance levels at the site.

1.2.2 The PFA Landfill at Poplars currently operates as a standalone landfill installation with engineered 'external separation' proposed along its boundary with the main landfill facility, in accordance with the requirements of the Landfill Directive. The HRA for the PFA facility was originally agreed in support of the Environmental Permit Application submitted in 2014. Revised models were also submitted in November 2014 in support of a minor variation to the permit to extend the ash materials for deposit at the facility to include those derived from biomass fuelled power generation facilities.

1.3 Site Setting

1.3.1 Poplars Main Landfill Site is centred on National Grid Reference (NGR): SJ 99452 09331. Poplars PFA Landfill Site is centred on National Grid Reference (NGR): SJ 9960 0976, approximately 1.3km east-southeast of Cannock, Staffordshire. The location plan for the sites has been included in **Drawing No. BF5036/09/01**. The PFA site covers an area of c. 2 Ha of open excavated land, consisting largely of un-vegetated bedrock and/or bare superficial deposits. Access to the site is provided by the access road that also services the main Poplars Landfill site.

1.3.2 The main Poplars Landfill Site accepted both hazardous and non-hazardous waste until July 2004. Subsequently, it has accepted only non-hazardous (and inert) waste and is classified as a non-hazardous landfill. The PFA Landfill received deposits of non-biodegradable non-hazardous wastes, strictly limited to fuel ashes from coal and biomass fuelled power generation facilities. The PFA monocell has been developed on an area previously authorised to receive biodegradable non-hazardous wastes under Environmental Permit EPR/BW0584IL, although the area was not formally surrendered in conjunction with the application for Environment Permit EPR/BP3436VS. Currently permit EPR/BP3436VS sits within the boundary of permit EPR/BW0584IL.

1.3.3 The poplars facility was formerly operated as part of the Poplars Opencast coal site. Mining of coal in this area took place from at least the 1880's, up until 1967. Deep coal mining was undertaken in the installation boundary at Leacroft and Cannock Pit, which was recorded as operational in 1903 and closed in 1954.

1.3.4 In 1972, the PFA and the wider Poplars Landfill site was used by Cannock County Council for the disposal of household waste from the Cannock District. Staffordshire County Council later developed the wider Poplars Landfill Site to accept household waste for the south of the county of Staffordshire. This site was subsequently operated by PreMCo and then by Biffa Waste Services who currently operates both the wider and PFA sites after acquiring PreMCo from Staffordshire County Council.

1.3.5 The various phases of the main and PFA landfill facilities are shown on **Drawing No. BF5036/09/01**. The PFA Landfill Site is currently designed with a void of c. 157,600m^3 (or ~236,400 tonnes of PFA).

2.0 HYDROGEOLOGICAL CONCEPTUAL MODEL

2.1 General

2.1.1 A consolidated Hydrogeological Conceptual Model for wider Poplars non-hazardous landfill and PFA Landfill facilities has been developed using the source-pathway-receptor assessment methodology. This method is widely accepted within the Environmental and Waste Industry.

2.2 Source

Site Design and Construction

Poplars Main Landfill Site

2.2.1 The majority of the phases at the main landfill site are located over former opencast workings with basal clay lining of approximately 1 metre, comprising several reworked layers of 300mm. Formal Construction Quality Assured (CQA) lining systems have been implemented since 1996 and comprise either 0.5m of clay at a permeability of less than 1 x 10^{-8} m/s overlain by a Bentomat Geosynthetic Clay Liner (GCL) or 1m of clay at a permeability of less than 1 x 10^{-9} m/s. A summary of the lining systems in-situ at the base of each existing phase is presented in **Table HRA1**, below.

Table HRA1: Liner Types at Poplars Main Landfill Site

Landfill Phase	Lining System
Phases 1, 2, & 11	In-situ rolled clays without CQA.
Phases 3A, 9A, 9B, 9C (1&2), 10A, 10B, G1, G2, G3, H1, H2, I1 & I2	Artificially placed clay with CQA.
Phases 4, 5 & 7	Artificially placed clay without CQA.
Phase 3B	Artificially placed clay and a GCL with CQA.
Phase 6	Natural clay barrier and a GCL with CQA.

Note: Table sourced, adapted and updated from 2003 PPC application ESID report.

2.2.2 Phase 11 is the first cell to have been constructed at the site by Cannock County Council in the 1970's. In light of its size, it is considered very likely that this phase comprises several sub-cells separated by intercellular bunds of unknown dimensions. It is also unclear whether the subsequent pre-1996 cells (i.e. Phase 1, 2, 4, 5 and 7) were constructed to be hydraulically disconnected from Phase 11, although historic information suggests that these subsequent phases were constructed with temporary bunds separating adjacent phases. Once initial fill levels in each adjacent cell were achieved it is understood that these bunds were removed or leachate drainage pipes were installed through them to allow leachate to flow to primary extraction wells located at the perimeter of the site in Phases 1 and/or 6. It is reported that no leachate blankets were constructed within Phases 4, 5 and 11, whilst Phases 1 and 2 comprise 300mm thick drainage blankets constructed of tyres and Phase 6 comprises a piped drainage blanket. The sidewall liner area of Phase 7 is also reported to comprise a piped leachate collection system.

2.2.3 Phases 9A, 9B, 9C (1 & 2), 10A, 10B, G1, G2, G3, H1, H2, and I1 comprise internal separation bunds with leachate collection provided by 300mm (minimum) piped granular or tyre bales blanket with extraction via designated wells in each phase.

2.2.4 Changes to the landfill development are proposed to account for the sterilisation of void in Phase J due to the long-term operation of the AD facility, with Phase C2 being developed in the southern area of the site, in line with the original development proposals considered under the original PPC application for the site.

2.2.5 The base and sidewalls of all future containment cells will be engineered to the same specification installed for all other cells constructed in the eastern development area.

Poplars PFA Landfill Site

2.2.6 At the time of preparing the HRA that supported the 2014 Environmental Permit Application for the PFA landfill the extent and boundaries of the of the Etruria Marl, Middle Coal Measures and backfill deposits beneath the proposed footprint of the monocell was unknown. Due to uncertainties in the physical characteristics of the Coal Measures strata, an Artificially Established Geological Barrier (AEGB) (0.5m thick with maximum permeability of $1x10^{-7}$m/s) was included in the design for basal areas comprising this strata, as well as any fault zones. Under the original application an AEGB was not required to be installed on basal areas of the cell underlain by the Etruria Marl or colliery backfill. However, as result of the subsequent variation to the permit to include additional ash types for deposit at the facility, a 0.75m thick AEGB with a maximum permeability of $1x10^{-7}$m/s was incorporated into the monocell design for areas underlain by colliery backfill.

2.2.7 CQA records indicate that the coal measures only underlie a very narrow section of the northern margin of the western area of the monocell **(Figure HRA1).** To simplify the construction process, the AEGB constructed across the entire base of the western sub-cell was constructed to a thickness of 750mm[1].

Figure HRA1: Extent of the Middle Coal Measures Strata across the base of the PFA Monocell

2.2.8 The side slopes of the landfill are constructed over superficial deposits comprising glacial sand and gravels and boulder clay. Areas of the side-slopes constructed over the glacial sand and gravel deposits were supplemented with a 500mm thick AEGB to a maximum design permeability of $1x10^{-7}$m/s using re-compacted site-won marl/clays. This material is also currently utilised for the

[1] *Stratus, 2015. Construction Quality Assurance Validation Report: Construction of PFA Mono-cell (Western Base and Sidewall – Phase 3). Doc. Ref.: BF4889/08 Rev 1. Date: May 2015.*

construction of the AEGB/ASL within the containment cells of the main Poplars landfill.

2.2.9 Whilst the approved design for the AEGB constructed along the base and sidewalls of the PFA monocell was required to achieve a maximum permeability of $1x10^{-7}$m/s, CQA test data indicates that the recompacted marls used in the western sub-cell typically achieved a permeability range of $7.9x10^{-11}$ m/s and $5x10^{-11}$ m/s during pad trials.

<u>Leachate Levels</u>

Poplars Main Landfill Site

2.2.10 The site's Environmental Permit specifies compliance limits for leachate levels at each monitoring point (Table S3.1); these are summarised in **Table HRA2**, along with a statistical summary of leachate elevations recorded between 2014 and 2020, which mirrors the 6-yearly review period for the PFA landfill. Full recorded and timeseries plots are present in **Appendix HRA1**.

2.2.11 During the early part of the 2014-2020 review period leachate heads in Phases 1-6, 9A-C, 10A-B and 11 were elevated above the current leachate heads that were set following the permit variation submitted in 2018. Since adoption of the revised compliance limits in the permit, notable reductions in leachate heads in the cells have been observed, with heads being managed below current compliance limits in all containment phases at the end of 2020.

2.2.12 For containment cells G-I series leachate heads have been largely maintained below the compliance limit of 2m above the basal level of each cell since their construction dates.

Poplars PFA Landfill Site

2.2.13 The Environmental Permit for the PFA Landfill site does not specify leachate level compliance limits or require monitoring.

Table HRA2: Leachate Levels and Compliance Limits for Poplars Main Landfill Site (January 2014 - June 2020)

Monitoring Point Reference	Compliance Limit (mAOD)	Minimum Recorded Leachate Elevation (mAOD)	Mean Recorded Leachate Elevation (mAOD)	Maximum Recorded Leachate Elevation (mAOD)	Count	No. of Exceedances
Phase 1 - LRD1a (3201)	130.50	128.74	135.18	145.44	79	47
Phase 1 - LRD2 (3202)	131.77	130.15	137.47	144.28	79	67
Phase 2 - LRD3 (3203)	135.43	134.02	138.79	145.07	79	69
Phase 2 - LRD4 (3204)	135.06	133.36	137.96	144.25	79	55
Phase 3A - LRD5 (3205)	138.46	137.05	140.19	145.31	79	46
Phase 3A - LRD6 (3206)	140.71	138.99	142.07	145.72	79	67
Phase 3B - LW43 (3143)	141.60	139.6	143.02	154.33	79	43
Phase 3B - LW8 (3108)	141.50	139.7	141.48	144.84	61	20
Phase 4 - LRD7 (3207)	139.27	137.88	146.27	152.26	79	73
Phase 4 - LRD8 (3208)	137.95	136.21	140.68	148.07	75	44
Phase 4 - LRD9 (3209)	139.05	137.69	143.75	151.03	78	63
Phase 5 - LRD10 (3210)	142.14	140.42	145.62	151.98	78	57
Phase 5 - LRD11 (3211)	141.99	140.22	146.91	155.00	78	68
Phase 6 - LRD12 (3212)	135.77	134.46	140.44	147.47	77	59
Phase 6 - LRD13 (3213)	138.09	136.35	141.38	147.65	79	58
Phase 9A - LRD20 (3220)	138.24	136.48	141.59	146.40	56	41
Phase 9A - LRD21 (3221)	138.40	136.66	141.81	149.24	46	39
Phase 9B - LRD22 (3222)	138.04	136.25	143.16	150.12	46	32
Phase 9b - LW50 (3050)	136.18	135.38	143.38	150.10	75	70
Phase 9b - LW51 (3051)	136.18	139.08	143.74	148.00	51	51
Phase 9C1 - LRD18 (3218)	137.64	133.49	144.84	153.25	55	43
Phase 9C1 - LRD23 (3223)	137.59	135.86	142.27	152.21	46	32
Phase 9C1 - LRD24 (3224)	136.27	134.47	141.52	152.00	46	32
Phase 9c2 - LW56 (3056)	139.40	139.04	141.71	153.02	58	51
Phase 9c2 - LW57 (3057)	139.40	138.91	140.75	143.02	60	58
Phase 10A - LRD17 (3217)	136.81	135.27	148.48	167.15	37	25
Phase 10A - LRD25 (3225)	135.38	133.62	143.48	157.36	41	30
Phase 10B - LRD19 (3219)	135.19	133.36	143.61	162.71	33	21
Phase 10B - LRD26 (3226)	134.16	135.82	149.18	160.89	40	0
Phase 10B - LRD28 (3228)	134.07	132.77	151.86	156.14	8	7
Phase 11 - LRD14a (3214)	139.96	138.15	148.92	158.29	77	63
Phase 11 - LRD15d (3215)	143.65	141.75	153.67	164.21	75	60
Phase 11 - LRD16a (3126)	145.69	143.24	151.58	159.74	78	52
Phase G1 - LW65 (3065)	139.54	138.52	139.16	140.15	8	1

Monitoring Point Reference	Compliance Limit (mAOD)	Minimum Recorded Leachate Elevation (mAOD)	Mean Recorded Leachate Elevation (mAOD)	Maximum Recorded Leachate Elevation (mAOD)	Count	No. of Exceedances
Phase G1 - LW66 (3066)	139.54	138.08	138.65	140.46	23	1
Phase G2 - LW67 (3067)	136.30	134.91	135.65	136.33	14	1
Phase G2 - LW68 (3068)	136.30	135.07	135.61	136.39	14	1
Phase H1 - LW61 (3061)	142.18	140.38	141.46	142.31	36	1
Phase H1 - LW62 (3062)	142.18	142.00	142.16	142.50	7	1
Phase H2 - LW63 (3063)	140.01	138.95	140.21	143.19	7	2
Phase H2 - LW64 (3064)	140.01	138.04	139.39	141.70	33	4
Phase I1 - LW59 (3059)	141.12	139.01	140.50	141.75	51	7
Phase I1 - LW60 (3060)	141.12	139.45	140.55	144.04	57	9
Phase I1 - LW58 (3058)	141.50	140.88	141.10	141.78	51	2

Leachate Quality

Poplars Main Landfill Site

2.2.14 The risk source comprises the potentially contaminating component of the leachate that will be generated from the deposited waste. A summary of leachate quality recorded within all phases at Poplars Main Landfill site between 2014 and 2020 is presented in **Table HRA3**, along with the previously modelled leachate source terms reported in the 2018 HRA. The contaminants listed have been selected due to their detection in leachate and the variable environmental characteristics. Time-series plots of leachate quality are presented in **Appendix HRA2**. Due to the proposed consolidation of the main landfill and the PFA landfill permits, the parameters listed in **Table HRA3** have been extended to include those considered in the HRA for the PFA landfill site.

Table HRA3: Comparison of modelled leachate source term concentrations and monitored leachate quality between 2014 and 2020

Parameter	Previously Modelled Leachate Source Terms (2018)			Summary of Monitoring Data (2014 - 2020)		
	Min	Median	Max	Min	Median/ Modal	Max
Phases 1, 2 & 4 - 7						
Ammoniacal N (mg/l)	0.3	250	7,790	1,400	2,460	7,790
Arsenic (mg/l)	0.00067	0.005	0.05	0.00098	***0.03***	***0.461***
Cadmium (mg/l)	0.00025	0.0005	0.0051	<0.0006	<0.0006	<0.006
Chloride (mg/l	3	2,450	9,610	52.3	***3,760***	***10,300***
Chromium (mg/l)	-	-	-	0.002	0.126	0.64
Mecoprop (µg/l)	0.04	3.86	133	0.04	39.45	101
Naphthalene (µg/l)	1	7.50	20.4	<1	<40	<800
Nickel (mg/l)	0.003	0.075	2.19	0.024	**0.159**	0.454
Phenol (µg/l)	1	10	37,400	<1	<50	33,600
Sulphate (mg/l)	-	-	-	1	25	1,620
Phase 3A						
Ammoniacal N (mg/l)	315	850	1,410	330	771	1,340
Arsenic (mg/l)	0.000673	0.005	0.05	0.0039	0.00745	0.012
Cadmium (mg/l)	0.001	0.001	0.002	**<0.0006**	<0.0006	0.0015
Chloride (mg/l	532	1360	1,730	***496***	1,025	***1,840***
Chromium (mg/l)	-	-	-	0.019	0.061	0.22
Mecoprop (µg/l)	17.50	21.30	33.40	22.6	**27**	**34.1**
Naphthalene (µg/l)	0.005	0.46	42	<8	<20	<20
Nickel (mg/l)	0.083	0.105	0.23	***0.061***	***0.141***	0.175
Phenol (µg/l)	139	1,524.5	2,910	<4	<10	<20
Sulphate (mg/l)	-	-	-	5	48	447
Phase 3B						
Ammoniacal N (mg/l)	324	1,240	2,420	1,420	***1,890***	***3,240***
Arsenic (mg/l)	0.000673	0.005	0.05	0.014	***0.026***	***0.064***
Cadmium (mg/l)	0.0005	0.001	0.004	<0.0006	<0.0006	0.0006
Chloride (mg/l	996	4,300	7,240	2,850	***7,170***	***9,770***
Chromium (mg/l)	-	-	-	0.145	0.249	0.306
Mecoprop (µg/l)	8.21	22.2	127	21.2	27.6	38.1
Naphthalene (µg/l)	5.50	7.85	10.20	<10	<40	<100
Nickel (mg/l)	0.049	0.115	0.26	0.133	**0.197**	0.22

Parameter	Previously Modelled Leachate Source Terms (2018)			Summary of Monitoring Data (2014 - 2020)		
	Min	Median	Max	Min	Median/ Modal	Max
Phenol (µg/l)	64.80	742	2,140	<20	<20	<100
Sulphate (mg/l)	-	-	-	10.53	36.14	141
Phase 11						
Ammoniacal N (mg/l)	0.30	250	7,790	1,250	**2,120**	3,690
Arsenic (mg/l)	0.000673	0.005	0.05	0.063	***0.081***	***0.161***
Cadmium (mg/l)	0.00025	0.0005	0.0051	<0.0006	<0.0006	<0.006
Chloride (mg/l	3	2,450	9,610	4,830	**5,980**	8,380
Chromium (mg/l)	-	-	-	0.154	0.1905	0.301
Mecoprop (µg/l)	0.04	3.86	133	35.8	40.3	43.6
Naphthalene (µg/l)	1	7.50	20.40	<10	<40	<400
Nickel (mg/l)	0.003	0.075	2.19	0.212	**0.237**	0.307
Phenol (µg/l)	1	10	37,400	<20	<200	1,890
Sulphate (mg/l)	-	-	-	5	16.22	226
Future Phases (Phases 9A-C2, 10A&B, H, I & G)						
Ammoniacal N (mg/l)	367	1,900	3,220	***88***	***2,260***	***5,870***
Arsenic (mg/l)	0.000673	0.005	0.048	0.001	0.005	***0.334***
Cadmium (mg/l)	0.0008	0.00145	0.0051	***<0.00007***	0.0011	***0.0411***
Chloride (mg/l	2,560	5,500	12,400	***15.2***	***5,525***	***59,200***
Chromium (mg/l)	-	-	-	0.002	0.672	2.57
Mecoprop (µg/l)	38.6	162.5	313	***0.08***	53.9	202
Naphthalene (µg/l)	0.05	0.46	42	<1	<80	<400
Nickel (mg/l)	0.04	0.23	0.349	***0.009***	***0.308***	***0.968***
Phenol (µg/l)	139	1,524.5	2,910	***<1***	200	***9,300***
Sulphate (mg/l)	-	-	-	1	27	1,200

*Note: Figures in **bold italic** have been input to the revised model.*

2.2.15 Within the older landfill phases (1-7) leachate concentrations recorded between 2014 and 2020 have remained largely within the parameter ranges previously modelled for these phases. However, it is noted that ammoniacal nitrogen, arsenic, chloride and nickel have been detected at higher concentrations in some cells than previously detected.

2.2.16 For the younger containment Phases 9A-C, 10A&B, and G-I the concentrations of a number of substances recorded between 2014 and 2020 have been detected higher than the previous modelled range. For chloride the maximum concentrations recorded are approximately five times the previously modelled concentrations, however the median concentration has remained similar. The timeseries plots presented in **Appendix HRA2** indicate that the concentrations are notably higher in Phase H1, with a few elevated concentrations also recorded in Phase 9A, 10B and H2. Otherwise, chloride concentrations were largely recorded below the previously modelled maximum concentration. Arsenic, cadmium and phenol each recorded concentrations above the previously modelled maximum concentration in a number of cells, although as with chloride, the median or modal concentrations remain similar to that previously modelled. Ammoniacal nitrogen and nickel have seen some increases in the median/modal concentrations and approximate two-fold increases in the recorded maximum values.

2.2.17 A review of other hazardous substances and non-hazardous pollutants detected in leachate since 2014 has been carried out (**Appendix HRA2**) and is summarised in **Table HRA4,** below.

Table HRA4: Hazardous Substances and Non-Hazardous Pollutants Detected in Leachate between 2014 and 2020

Parameter	Maximum Concentration Recorded (2014 – 2020)	No. of samples over detection limit	Total number of samples
Hazardous Substances			
1,2,4 Trichlorobenzene (µg/l)	183	16	69
1,2,3, Trimethylbenzene (µg/l)	92.6	19	69
1,2-Dichlorobenzene (µg/l)	1.61	1	69
1,4 Dichlorobenzene (µg/l)	3.28	6	69
2,4,5 T (µg/l)	29.9	1	69
4-Chlorophenol (µg/l)	2.29	1	2
4-Chlorotoluene (µg/l)	1.07	1	69
Benazolin (µg/l)	22.3	1	69
Benzene (µg/l)	8.2	13	69
Chlorobenzene (µg/l)	4.56	4	69
Clopyralid (µg/l)	5.38	7	69
Dicamba (µg/l)	14.7	1	69
Dichlobenil (ng/l)	293	12	69
Dichloroprop (µg/l)	82.1	28	69
Dieldrin (ng/l)	338	3	69
Ethyl Benzene (µg/l)	87.8	21	69
Hexachlorobutadiene (ng/l)	31	1	69
Ioxynil (µg/l)	13.6	1	69
Lead (mg/l)	0.626	89	156
M,p- Xylene (µg/l)	185	30	69
Mercury (mg/l)	0.0004	2	69
O-xylene (µg/l)	85.8	19	69
Styrene (µg/l)	21.5	4	69
Toluene (µg/l)	106	30	69
Tributyltin (µg/l)	0.61	2	69
Triclopyr (µg/l)	25.3	1	69
Non-Hazardous Pollutants			
1,2,3 Trichlorobenzene (ng/l)	127	4	69
1,2 Dichloroethane (µg/l)	4.51	9	69
1,3,5 Trimethylbenzene (µg/l)	25.2	10	69
2,4 Dimethylphenol (µg/l)	60	11	69
2,6 Dinitrotoluene (µg/l)	11.5	2	67
2 Methylphenol (mg/l)	0.137	27	69
3+4 Methylphenol (mg/l)	16.7	37	53
4 Methylphenol (mg/l)	6.53	8	16
Antimony (mg/l)	0.165	34	37
Barium (mg/l)	3.42	35	35
Bentazone (µg/l)	5.7	1	69
Bis(2-Ethylhexyl)phthalate (µg/l)	220	4	67
Boron (mg/l)	62.9	36	37
Calcium (mg/l)	8780	245	246
Chloromethane (µg/l)	24	1	69
Cobalt (mg/l)	0.125	34	35
Copper (mg/l)	0.839	122	156
Cyanide (mg/l)	1.3	57	67
Dichloromethane (µg/l)	197	2	69
Diethyl Phthalate (µg/l)	69.2	1	67
Dimethyl Phthalate (µg/l)	91.6	1	69
Di-N-Butyl Phthalate (µg/l)	26.2	1	51
Fluoride (mg/l)	35	35	35
HCH-Gamma (ng/l)	321	1	69
Iron (mg/l)	189	148	156

Parameter	Maximum Concentration Recorded (2014 – 2020)	No. of samples over detection limit	Total number of samples
Isophorone (µg/l)	50	1	67
Iso-Propylbenzene (µg/l)	1.12	1	24
Magnesium (mg/l)	965	244	246
Manganese (mg/l)	25.8	153	156
MCPA (µg/l)	17.8	1	69
MCPB (µg/l)	14.2	1	69
Molybdenum (mg/l)	1.91	27	37
Monuron (µg/l)	1.6	1	67
MTBE (µg/l)	31.5	10	24
Naphthalene (µg/l)	100	15	69
Nitrate (mg/l)	339	45	127
Nitrite (mg/l)	23.5	31	125
Nitrogen (Oxidised) (mg/l)	363	50	127
N-Propylbenzene (µg/l)	1.01	1	69
Phenol (mg/l)	33.6	35	69
Phosphorus (Total, inorganic) (mg/l)	50	32	35
P-Isopropyltoluene (µg/l)	113	23	69
Potassium (mg/l)	8,710	245	246
Selenium (mg/l)	0.103	13	35
Silver (mg/l)	0.0042	24	35
Sodium (mg/l)	74,700	245	246
Tin (mg/l)	0.873	29	35
Titanium (mg/l)	0.862	31	35
Uranium (µg/l)	7.46	17	35
Vanadium (mg/l)	0.317	32	35
Zinc (mg/l)	12	141	156

Poplars PFA Landfill Site

2.2.18 The current Environmental Permit for the PFA Landfill site does not state a requirement for leachate quality monitoring. The modelled source term for the ash deposits derived in the original model was based on published data ranged for coal derived pulverised fuel ash (UKQAA, 2004), together with source specified test data for biomass derived fly and bottom ashes. The source term used in the original models assumed that the amount of coal and biomass derived ash deposited in the landfill would have been roughly equal, with bottom and fly ash from biomass fuelled facilities deposited at a ratio of 1:9.

2.2.19 Ash deposits to the monocell ceased in 2016. Waste acceptance records show that only ~76,260 tonnes have been deposited at the site, which equates to ~32% of the current permitted capacity ~241,500 tonnes. Of the current deposits, ~80% were derived from coal fired facilities, whilst fly and bottom ash derived from biomass fired facilities were deposited at a ratio of ~1:4.5.

2.2.20 Taking account of the revised ratios of the ash types deposited at the facility, the source term concentration parameters have been adjusted accordingly. The concentrations continue to be derived using the UKQAA (2004) for coal derived ashes and biomass ash test results used to determine the original source terms parameters. A comparative summary of the previous and updated source term concentration ranges is presented in **Table HRA5.** New source term concentrations are also presented for parameters which weren't previously modelled but are included to account for the proposed consolidation of the PFA and main landfill permits.

2.2.21 The remaining void of the PFA Landfill will be filled using site-won materials (colliery spoil, superficial deposits and marl) excavated as part of the construction of containment cells in the Phase C2 development area.

Table HRA5: Comparison of original and revised leachate source terms calculated for the PFA Landfill

Parameter	Statistic	Previous Source Term Concentration Values (mg/l)	Revised Source Term Concentration Values (mg/l)
Arsenic	Min	0.0031	0.0049
	Most Likely	0.0057	0.0091
	Max	0.0082	0.0133
Chloride	Min	Not modelled	17.1
	Most Likely		24.4
	Max		33.6
Chromium (total)	Min	0.083	0.0087
	Most Likely	0.158	0.0161
	Max	0.21	0.0221
Hexavalent Chromium	Min	0.0026	0.0007
	Most Likely	0.0096	0.0014
	Max	0.021	0.0025
Nickel	Min	Not modelled	0.0009
	Most Likely		0.0057
	Max		0.0121
Sulphate	Min	205.8	20.7
	Most Likely	313.5	87.4
	Max	434.5	156.1

2.3 Pathways

2.3.1 The pathways defined by the site's conceptual model are dependent upon the underlying and surrounding geology and hydrogeology, and in the case of the main landfill site, the design of the engineered containment systems within each phase. The geology and hydrogeology within the vicinity of the site was previously determined through a review of available desk study information and the results of an intrusive investigation within the eastern development area (locally referred to as the 'Graveyard Area') of the former colliery and landfill complex. These previous interpretations have been updated further based on the more recent CQA records for the PFA and main landfill facilities and monitoring data collected from subsequent groundwater monitoring boreholes installed at the site targeting the bedrock lithologies beneath and surrounding the site.

<u>Geology</u>

Poplars Main Landfill Site

2.3.2 Landfill containment Phases 1-7, 9A, 10A, 10B and 11 of the Main Poplars landfill site are located over areas formerly operated as the Poplars 'East' and the southern leg of the Poplars 'Northeast' opencast coal mine. The Poplars East opencast is recorded to have been excavated within the productive Middle Coal Measures to depths of ~64mAOD, whilst the Poplars Northeast opencast extended to shallower depths of ~90mAOD, with the eastern most section worked to ~136mAOD. Both opencast areas are understood to have been backfilled with low permeability colliery spoil with all existing landfill containment phases constructed within the backfill to basal depths of as low as ~127.5mAOD.

2.3.3 The Leacroft Fault is interpreted to trend north-south through the eastern development area, which was observed to transect through the approximate centre of the PFA landfill. This fault is also interpreted to have a displacement of ~60m and the resulting presence of the Etruria Marl across much of the future eastern containment areas of the site. The depth of the Marl is interpreted from sections on abandonment plans for the Cannock & Leacroft Colliery located on site to be at c. 80mAOD.

2.3.4 The northern leg of the former Poplars Northeast opencast mine is also suggested to have been further displaced by ~30m because of an oblique slip fault trending west-east, from which it is estimated to have displaced the Leacroft fault line eastwards by ~70m. This subsequent displacement resulted in the extraction of coal within the north-western area of the Landfill site to ~90mAOD. The interface between the Etruria Marl and Middle Coal Measures was exposed at the edge of Phase 11 during construction of Phase G2 **(see Figure HRA2).**

Figure HRA2: Exposed fault line on the western edge of Phase G2

2.3.5 Of the eastern development area Phases 9 (B & C only), G, H and I are/will be constructed wholly or mainly over the Etruria Marl, although the proposed development footprint for Phase G5 could be underlain partially by coal measures (and/or backfill).

2.3.6 Geological maps show the superficial deposits across the area to comprise Devensian Till. Borehole logs around the periphery of the site demonstrate that these deposits are locally dominated by brown, orange and yellow sands and gravels interbedded with silty and clayey layers. The base of the superficial deposits is locally dominated by boulder clay (Babtie, 2007).

2.3.7 In summation, it is considered that Phases 1-7, 9A, 10A and 10B are constructed wholly on superficial or backfill deposits; Phases 9B, 9C, G1, G3, G4, H1, H2, I and C2 are/will be wholly constructed over areas comprising Etruria Marl; Phase 11 is constructed over areas comprising Etruria Marl, Coal Measures and backfill deposits; and Phases G2 and G5 is or will be constructed over Etruria Marl, with some areas constructed or likely to be constructed over either Coal Measures or backfill deposits.

Poplars PFA Landfill Site

2.3.8 The PFA Landfill is located along the northern edge of the eastern section of the main Poplars Landfill facility. The superficial geology of this area of the site comprises glacial sand and gravels and Devensian Till (boulder clay), much of which has been excavated in support of the operational requirements of the main Poplars Landfill.

2.3.9 The PFA monocell has been constructed with a basal footprint of ~1.23 Ha, with approximate dimensions of ~250m (approx. W-E at its longest point) by ~55m (approx. N-S).

2.3.10 CQA details for the monocell development determined that the presence of the Middle Coal Measure strata beneath the base of the monocell is not as extensive as originally assumed in the 2014 HRAs. As shown in **Figure HRA1**, only a very limited section of the PFA cell basal footprint has been identified to be underlain by the Middle Coal Measure strata, with the eastern section of the cell underlain by Etruria Marl and the western section underlain principally by colliery backfill associated with former Poplars Northeast opencast workings.

Hydrology

2.3.11 The surface water features closest to the site are drains that run adjacent to the southern and western site boundary lines, as well as several surface water lagoons within the vicinity. There are no rivers or streams located within 250m of the site boundary. The nearest river is Ridings Brook, which lies c.420m east of the site boundary.

2.3.12 Poplars Main Landfill Site is located within a Flood Zone 1, meaning there is less than a 1 in 1,000 annual probability of river flooding (<0.1%).

Hydrogeology

2.3.13 The current aquifer classification system allocates the Devensian till as 'Secondary Undifferentiated' which indicates that it has likely previously been designated as both minor and non-aquifer in various locations due to the variable characteristics of the rock type. Groundwater is known to be present locally, with laboratory and in-situ testing confirming that the permeability of the deposits varies from 10^{-5} m/s in the sand and gravel to as low as 10^{-10} m/s in the clay/silt horizons (Enviroarm, 2002).

2.3.14 Hydraulic testing of spoil backfill concludes that these deposits typically consist of very low permeabilities, typically between 10^{-7} to 10^{-11} m/s (Enviroarm, 2002) and can be classified as unproductive, although they are known to be saturated. Consolidated backfill deposits at the site have typically proven to achieve permeabilities of between approximately 5×10^{-11} and 5×10^{-10} m/s. The Middle Coal Measures and Etruria Marl are classified as Secondary A aquifers.

2.3.15 The base of the sand and gravel deposits immediately west of the extent of the colliery backfill has been proven to be at ~139mAOD (Babtie, 1997), which typically overlies low permeability boulder clay[2] of varying thicknesses at the base of the superficial deposits. The base of the sand and gravel aquifer deposits is therefore situated above the landfill cell basal elevations and many of the leachate compliance levels of the existing and future containment cells within the Main Poplars Landfill facility.

[2] *As described in drillers logs included within Babtie (1997).*

Groundwater Levels & Flow

2.3.16 There are 15 groundwater monitoring boreholes located around the periphery of both the main landfill and the PFA monocell. **Table HRA6** summarises the groundwater levels at Poplars Main and PFA Landfill Sites during the review period. Timeseries plots of the groundwater levels are included in **Appendix HRA3**.

Table HRA6: Summary of Groundwater Levels (mAOD) at Poplars Main and PFA Landfill Sites

Monitoring Point Ref	Count	Min	Mean	Max	Range
Superficial/Backfill Deposits (2014 – 2020)					
Up Gradient Boreholes					
1330	78	145.74	146.55	146.97	1.23
1340	78	145.66	147.53	152.14	6.48
1351	6	152.02	153.00	153.41	1.39
1352	6	146.62	149.15	152.22	5.6
1360	61	139.75	140.08	140.53	0.78
Cross Gradient Boreholes					
1010	63	143.69	145.56	146.79	3.1
1320	77	133.81	138.60	143.30	9.49
Down Gradient Boreholes					
1090	61	133.74	134.24	135.61	1.87
1140	60	135.32	135.82	136.41	1.09
1190	63	133.48	134.17	134.85	1.37
1260	61	132.42	133.28	134.88	2.46
Etruria Marl/Middle Coal Measures (2019 – 2020)[1]					
Up Gradient Boreholes					
1470	19	145.09	145.90	146.36	1.27
1480	19	144.51	145.60	146.70	2.19
1490	19	146.36	146.76	147.14	0.78
Down Gradient Borehole					
1460	19	134.31	134.69	135.22	0.91

[1] - monitoring commenced in boreholes 1351, 1352 and 1460-1490 from Jan-2019.

2.3.17 Groundwater levels within the superficial deposits and colliery backfill have remained largely stable between 2014 and 2020, with levels within the colliery backfill (boreholes 1010-1260) lower than the water levels within the superficial deposits present around the eastern section of the site.

2.3.18 Variability has been observed in boreholes 1320 and 1340 with ranges of ~9.5m and ~6.5m respectively. In borehole 1340 water levels within the sands and gravels horizons with the till deposits are largely around 146-147mAOD with seasonal winter peaks observed in 2014/15, 2015/16 and 2016/17, but no subsequent winter increases observed thereafter, although some increases of a similar magnitude were observed in May and June 2020.

2.3.19 In borehole 1320, groundwater levels have reduced from ~142mAOD to as low as ~134mAOD in 2014, returning to the ~142mAOD again from early 2015, where it remained relatively stable until the end of 2017 where levels reduced again and have remained between ~133 and ~136mAOD ever since.

2.3.20 The changes in seasonal variations in borehole 1340 correlates with the construction timescales of Phase H1. Similarly, the level changes observed in 1320 would suggest a correlation with the construction of the PFA cells, however there were no levels changes observed in borehole 1330 which is located immediately adjacent to the PFA monocell. However, as reported in the June 2018 HRA for the main landfill, the range of groundwater levels recorded between 2014 and 2020 is no different to the range recorded at this installation since 2001.

2.3.21 Historic BGS borehole logs include several drift probes in the vicinity of borehole 1320. These logs suggest a high variability in the drift thickness in the vicinity of this borehole, with a thickness of 31ft (~9.5m) recorded to the east (BGS BH Ref.: SJ90NE11) (possibly extending to 45ft (~13.7m)) and 53 or 61ft (~16 or ~20m)) to the west (BGS BH Ref.: SJ90NE10). These historic logs and that for borehole 1320 also highlight the presence of silt and clay bands which are likely to act as an aquiclude to the downward percolation of waters from the upper sand and gravel aquifer unit to the lower unit present in the vicinity of borehole 1320. The presence of groundwater in the upper sand and gravel unit is therefore likely to respond to recharge events at the surface, and could also be responding to water level changes in the wetland habitat located adjacent to the site offices.

2.3.22 Groundwater levels within the Middle Coal Measures and Etruria Marl have historically been assumed to be suppressed in the area by the regional mine water management. Based on the interpolation of groundwater level contours from regional boreholes located outside of the zone influence of the mine water management operations, groundwater levels within the Middle Coal Measures (and assuming hydraulic connection with the Etruria Marl) were calculated to rebound to ~114mAOD in the long-term, with a rebounded groundwater flow in the MCM (and EM) interpreted to be to northwest.

2.3.23 As summarised in **Table HRA7** below and discussed in the June 2018 HRA, the site investigation carried out in May 2013 (SEL, 2013a) encountered several water strikes within the Etruria Marl across the future containment phase area. Three of the four strikes were encountered within shallow sandstone bands between the elevations of 139.7 and 143.7mAOD. The source of these shallow water strikes was considered to relate to the surface water management lagoons located across the eastern development ('Graveyard') area. Consequently, it was deemed that as the landfill development advanced across the site the source(s) of each groundwater strike will be removed.

Table HRA7: Summary of Groundwater Strikes in Etruria Marl (May 2013)

BH Ref	Groundwater Depth (mbgl)	Groundwater Elevation (mAOD)	Post-strike Behaviours
SELBH02	No groundwater encountered.		
SELBH03	0.3	143.71	Wet
SELBH04	10.7	133.39	Seepage
SELBH05	3.5	141.71	Rose to 2.4mbgl (142.81 mAOD) after standing period
SELBH06	11.5	139.71	Rose to 10.9mbgl (140.31 mAOD) after standing period and to 5.7 mbgl (145.51 mAOD) overnight.

2.3.24 The 'seepage' at SELBH04 occurred within fractured mudstone as opposed to a discrete sandstone band. The likely source of this was deemed to be more likely to be attributed to the proximity of faulting, which may either have resulted in hydraulic connection with a permeable horizon in the adjacent Middle Coal Measures or downward percolation of water from the surface.

2.3.25 CQA records for the development of various cells in the eastern development area also only elude to the presence of discrete seepages along excavated sidewalls within the sand and gravels and marl, with backwall drainage mattresses/grips installed to address potential stability concerns during infilling of the cells, as with the groundwater management requirements for the superficial deposits. A similar seepage was also noted in Coal Measures exposed in the north-western corner of Phase G2, with a groundwater grip subsequently installed behind the lining system.

2.3.26 In 2018, new monitoring boreholes were installed around the periphery of the eastern development area of the site to monitor groundwater levels within the Middle Coal Measures [MCM] (1460) and Etruria Marl [EM] (1470-1490) - borehole logs are presented in **Appendix HRA4**. These boreholes were installed to a depth ~10m below the maximum permitted excavation depth of the landfill (132mAOD), with only the lower 6m of the installed length screened. The groundwater levels recorded in these boreholes indicate the presence of a potentiometric head that mimics the groundwater levels observed in the nearest borehole installed in the overlying superficial deposits that surround the landfill. These recorded water levels are unaffected by the ongoing groundwater management practices at the site with regards to seepages from sandstone horizons with the EM.

2.3.27 The groundwater levels recorded within the MCM at borehole 1460 are ~10m lower than those recorded in the EM, whist the levels recorded in the EM are similar to the levels and trends recorded in the nearest boreholes that screen the superficial deposits and colliery backfill. The levels recorded in borehole 1460 are similar to groundwater levels recorded in the superficial borehole 1320, although this borehole is ~100m west of borehole 1460 and would suggest that water levels in the coal measures are lower than the superficial deposits and backfill.

2.3.28 The groundwater levels recorded in the EM along the eastern edge of the site also replicate the standing water levels recorded in exploratory hole SELBH06 observed during the 2013 investigation (see **Table HRA7**). This would indicate that even though no sandstone units were encountered below the formation level, there is a degree of saturation within the EM that is generating a potentiometric head above the top of the formation.

2.3.29 The locations of boreholes 1470-1490 that are installed in the EM do not enable suitable triangulation of water levels for contouring purposes in order to provide an indication of the direction groundwater flow within the EM itself. Therefore, assuming that groundwater flow between the EM and MCM is in continuity, the direction of groundwater flow in the solid geology is towards the west. However, due to the lateral extent of the Poplars opencast excavations, which envelopes the whole of the eastern edge of the eastern development and a proportion of the northern edges, groundwater flow through the EM will be intercepted by the colliery backfill, the base of which extends to an elevation of ~60mAOD.

2.3.30 Groundwater seepages encountered on the sidewall (elevation of between at 138-144mAOD) of Phase G2 also suggests that groundwater levels within the MCM (and EM), where it is enveloped by the backfilled Poplars Northeast Opencast, may be higher than that being recorded within borehole 1460, which is located to the north of the opencast footprint and possibly in continuity with water levels recorded in the backfill. Should these higher water levels be identified along the western edge of the eastern development area, hydraulic containment conditions may prevail around and beneath this area.

2.3.31 Whilst the potentiometric head recorded in borehole 1470 suggests that part of the east section of the PFA landfill in which the wastes have been deposited directly over the EM is below the water table, previous investigations of the EM footprint (Stratus, 2013) have identified at least 3m of mudstone/clay at the upper boundary that prevents the direct discharge of pollutants to groundwater that is principally struck within the more permeable Espley sandstone bands present in this lithology.

2.3.32 Due to the sterilisation of void in the former Phase J footprint, owing to the proposed retention of the AD facility, it would be prudent to install a monitoring borehole in the MCM at a point to the north of where this unit was exposed in the corner of Phase G2 to determine the water levels along the eastern edge of the eastern development area. This borehole would be to provide a better insight into water levels, and as it would not be at the perimeter of the site it would not be for compliance purposes or quality monitoring. Further boreholes would also be appropriate along the edges of the eastern and/or southern edges of Phase C2, the southern edges of Phase 9B and the northern edge of the PFA landfill.

Summary of Pathways

2.3.33 For the western development area (i.e. Phase 1-7, 9A, 10 and 11) of the site and western section of the PFA landfill, in which the containment cells are constructed over colliery backfill, the pathways ways continue to be vertically down through the saturated backfill into the underlying MCM strata, where the direction of groundwater flow is now likely to be to the west.

2.3.34 For the eastern development area (Phases 9B, 9C, C2 & G-I and the eastern section of the PFA landfill) any leachate that leaks from the containment cells will percolate into the underlying EM and MCM where it flows west and is intercepted by the colliery backfill.

2.4 Receptors

2.4.1 The groundwaters encountered in the colliery backfill deposits are considered to present a limited resource potential. Any groundwaters within and passing through these deposits are therefore not considered to be a receptor. The potential receptors of hazardous substances and non-hazardous pollutants are assumed to be the groundwaters within the superficial deposits perched on top of the underlying bedrock as well as the natural bedrock (Etruria Marl and Middle Coal Measures) on the western edge of the west of the backfilled Poplars complex.

Groundwater Monitoring

2.4.2 There are currently 15 groundwater monitoring boreholes located around the periphery of both the main site and the PFA site. These have been installed to target the superficial backfill deposits, and the MCM and EM bedrock aquifers.

2.4.3 The permit for the Main Landfill site (EPR/BW0584IL) specifies the compliance limits for groundwater quality, which are outlined in **Table HRA8**, as well as other groundwater monitoring requirements in **Table HRA9**, below.

Table HRA8: Current Groundwater Compliance Limits for the Poplars Main Landfill Site

Borehole ID	Parameter	Compliance Limit (mg/l)	Monitoring Frequency
1010, 1090, 1140, 1190, 1260 & 1320.	Ammoniacal Nitrogen	30	Quarterly
	Chloride	1,000	
1010	Cadmium	0.004	

Borehole ID	Parameter	Compliance Limit (mg/l)	Monitoring Frequency
1090		0.001	
1140		0.0025	
1190		0.0025	
1260		0.01	
1320		0.003	

Table HRA9: Current Groundwater Monitoring Requirements for the Poplars Main Landfill Site

Borehole ID	Parameter	Monitoring Frequency
Up, down and cross gradient boreholes (1330, 1340, 1360, 1090, 1140, 1190, 1260, 1010 & 1320).	Water level, Ammoniacal Nitrogen, Chloride, Electrical Conductivity & pH.	Quarterly
	Calcium, Chromium, Copper, Iron, Lead, Magnesium, Manganese, Nickel, Potassium, Sodium, Total Alkalinity, Total Sulphates & Zinc.	Annually
	Hazardous substances detected in leachate.	Annually for the first six years of operation, then every two years.
	Base of monitoring point (mAOD).	Annually

2.4.4 Groundwater quality at the PFA Landfill site is monitored in compliance with the Environmental Permit (EPR/BP3436VS). The current groundwater compliance limits are specified in **Table HRA10,** with all other existing monitoring requirements are outlined in **Table HRA11**.

Table HRA10: Current Groundwater Compliance Limits for the PFA Landfill

Borehole ID	Parameter	Compliance Limit (mg/l)	Monitoring Frequency
1320	Arsenic	0.007	Monthly
	Chromium	0.05	
	Hexavalent Chromium	0.001	
	Sulphate	250	

Table HRA11: Current Groundwater Monitoring Requirements for the PFA Landfill

Borehole ID	Parameter	Monitoring Frequency
Superficial Deposits		
1320, 1330 & 1340	Water Level	Monthly
1320 & 1330	Arsenic, Chromium, Dissolved Oxygen, Electrical Conductivity, Hexavalent Chromium, pH, Sulphate & Temperature.	Monthly
	Barium, Boron, Cadmium, Calcium, Chloride, Magnesium, Phosphorus, Potassium, Selenium & Vanadium.	Quarterly
Etruria Marl/Middle Coal Measures		
1460, 1470, 1480 & 1490	Arsenic, Chromium, Dissolved Oxygen, Electrical Conductivity, Hexavalent Chromium, pH, Sulphate, Temperature & Water Level.	Monthly
	Barium, Boron, Cadmium, Calcium, Chloride, Fluoride, Magnesium, Phosphorus, Potassium, Selenium & Vanadium.	Quarterly

2.4.5 Groundwater quality within the colliery backfill and superficial deposits are currently monitored in a total of 11 boreholes located around the periphery of the main landfill and PFA landfill facilities. Boreholes 1330, 1340, 1360, 1351 and 1352 are considered upgradient, boreholes 1090, 1140, 1190 and 1260 are downgradient of the main landfill, borehole 1320 is downgradient of the PFA monocell and cross gradient of the main landfill, and borehole 1010 is cross gradient of the main landfill. A summary of the groundwater quality recorded within the colliery backfill and superficial deposits are presented in **Table HRA12**. Time-series charts for monitored groundwater quality in the superficial and backfill deposits are presented in **Appendix HRA5**.

2.4.6 Groundwater quality in most boreholes remained relatively stable between 2014 and 2020, with no significant increasing trends observed. Only borehole 1010 resulted in breaches of the ammoniacal nitrogen and chloride compliance limits. Exceedances of the ammoniacal nitrogen compliance limit of 30mg/l was exceeded on two occasions in 2015 and on a further two occasions in 2017. On both occasions the concentration quickly reduced to below the compliance limit. For chloride the compliance limit was exceeded on four occasions in the mid-part of 2017 and have since returned towards pre-2017 concentrations. Mecoprop concentrations at borehole 1010 has also increased year on year since 2016. In contrast, nickel concentrations decreased in borehole 1010 between 2014 and 2020.

2.4.7 The concentration changes in borehole 1010 do not correlate with any increasing leachate heads or source term concentrations within the perimeter cells closest to this borehole, with reducing heads and concentrations recorded between 2014 and 2020. It is understood that a leachate cut off trench has been installed along this area in order to manage seepages of leachate from the landfill. The elevated pollutant concentrations in borehole 1010 are therefore likely to be attributed to these historical leachate seepages.

Groundwater Quality - Superficial/Backfill Deposits

Table HRA12: Statistical Summary of Groundwater Quality in the Superficial/Backfill Deposits at Poplars Main and PFA Landfill Sites 2014 - 2020

Borehole ID	Statistic	Ammoniacal Nitrogen (mg/l)	Arsenic (mg/l)	Cadmium (mg/l)	Chloride (mg/l)	Chromium (mg/l)	Hexavalent Chromium (µg/l)	Sulphate (mg/l)
Upgradient Monitoring Boreholes								
1330	*Min*	<0.06	<0.00024	<0.00007	47.4	<0.00051	<0.4	45.6
	Mean	0.252	-	<0.0006	88.35	0.002	-	76.02
	Max	0.72 (3.89)	<0.001 (0.0011)	0.0006	116 (428)	0.003 (0.005)	<0.4 (16.2)	181
	St Dev	0.171	-	0.000073	16.899	0.00022	-	25.98
	Count	78	65	53	77	68	62	69
1340	*Min*	0.07	-	<0.0006	4.7	<0.002	-	62
	Mean	0.501	-	-	19.16	0.002	-	107.81
	Max	1.94	-	<0.0006	78.5	<0.002	-	181
	St Dev	0.323	-	-	13.081	*NA*	-	36.57
	Count	50	-	12	50	15	-	15
1360	*Min*	<0.06	-	<0.0006	21.2	<0.002	-	403
	Mean	-	-	-	106.02	0.002	-	475.57
	Max	0.06 (0.86)	-	<0.0006	129	<0.002	-	541 (802)
	St Dev	-	-	-	18.23	*NA*	-	42.24
	Count	48	-	10	48	15	-	14
1351	*Min*	<0.06	-	<0.00007	8.9	<0.002	-	33.9
	Mean	0.09429	-	-	13.35	0.002	-	44.85
	Max	0.19	-	<0.0006	17.5 (101)	<0.002	-	55.8
	St Dev	0.05028	-	-	3.593	*NA*	-	15.49
	Count	7	-	6	6	2	-	2
1352	*Min*	0.1	-	<0.00007	8.3	<0.002	-	22.6
	Mean	0.20286	-	-	14.44	0.002	-	43.4
	Max	0.39	-	<0.0006	21	<0.002	-	64.2
	St Dev	0.10452	-	-	3.83	*NA*	-	29.42
	Count	7	-	7	7	2	-	2
Downgradient Monitoring Boreholes								
1090	*Min*	<0.06	-	<0.00007	28.3	<0.002	-	107
	Mean	0.268	-	0.00059	57.1281	0.002	-	293.87
	Max	0.66 (4.84)	-	<0.0006	82.8 (452)	<0.002 (0.003)	-	461
	St Dev	0.138	-	0.000084	13.3906	*NA*	-	135.09
	Count	64	-	40	64	14	-	15

Borehole ID	Statistic	Ammoniacal Nitrogen (mg/l)	Arsenic (mg/l)	Cadmium (mg/l)	Chloride (mg/l)	Chromium (mg/l)	Hexavalent Chromium (µg/l)	Sulphate (mg/l)
1140	*Min*	11.9	-	<0.00007	679	<0.002	-	<1.3
	Mean	13.74	-	0.00059	817.677	0.002	-	12.72
	Max	16.8	-	<0.0006	882	<0.002	-	72.6
	St Dev	0.905	-	0.000083	47.6829	*NA*	-	17.82
	Count	65	-	41	65	15	-	15
1190	*Min*	0.4	-	<0.00007	101	<0.002	-	31.1
	Mean	0.624	-	0.00059	111.25	0.002	-	201.75
	Max	0.85 (1.18)	-	<0.0006	120	<0.002	-	538
	St Dev	0.087	-	0.000084	3.82971	*NA*	-	143.03
	Count	64	-	40	64	15	-	15
1260	*Min*	0.28	-	0.00024	143	<0.002	-	155
	Mean	0.715	-	0.00059	169.462	0.002	-	232.6
	Max	1.29	-	<0.0006	210	<0.002	-	497
	St Dev	0.288	-	0.000056	13.0517	*NA*	-	93.87
	Count	65	-	41	65	15	-	15
Cross Gradient Monitoring Boreholes								
1010	*Min*	<0.06	-	0.00014	60.1	0.002	-	232
	Mean	8.809	-	0.0006	522.35	0.0026	-	581.9
	Max	72.5	-	0.0006	2490	0.006 (0.013)	-	915
	St Dev	12.631	-	0.00007	369.69	0.0012	-	210.0
	Count	69	-	42	69	14	-	15
1320	*Min*	<0.06	<0.00024	0.0001	37.2	<0.00051	<0.4	64.3
	Mean	0.08	-	0.00059	47.99	0.002	<0.4	95.4
	Max	0.34 (20)	<0.001 (0.0015)	0.0006	75.1 (830)	0.003 (0.006)	1.03 (14.2)	147
	St Dev	0.046	-	0.000073	7.49839	0.00031	0.21	22.7
	Count	76	65	47	77	66	64	69

Note: Highest statistical outlier presented in brackets.

2.4.8 Groundwater monitoring boreholes have been installed into the Etruria Marl/Middle Coal Measures aquifer at the site. These comprise four boreholes; 1460, 1470, 1480 and 1490, the locations of which can be seen in **Drawing No. BF5036/09/05**.

2.4.9 Groundwater quality within all boreholes installed in the MCM and EM are largely comparable, with sulphate showing the most notable variations between the strata. Mean concentrations in the EM boreholes range from ~19mg/l to ~130mg/l, with the mean concentration in 1460, which screens the MCM, returning a mean concentration of ~330mg/l. Concentration trends since 2019 are however steady, which suggests they are representative of natural baseline concentrations.

Groundwater Quality - Etruria Marl/Middle Coal Measures

Table HRA13: Statistical Summary of Groundwater Quality in the Etruria Marl/Middle Coal Measures at Poplars Main and PFA Landfill Sites 2019 - 2020

Borehole ID	Statistic	Ammoniacal Nitrogen (mg/l)	Arsenic (mg/l)	Cadmium (mg/l)	Chloride (mg/l)	Chromium (mg/l)	Hexavalent Chromium (µg/l)	Sulphate (mg/l)
Downgradient Monitoring Borehole								
1460	*Min*	<0.06	<0.00024	<0.0006	18.2	<0.00051	<0.4	269
	Mean	0.102	-	-	24.94	0.00414	-	332.78
	Max	0.32 (13.4)	0.00032 (<0.001)	0.0011 (<0.006)	43 (868)	0.024	<0.4 (30.3)	377
	St Dev	0.069	-	0.00126	6.31	0.00654	-	29.01
	Count	18	(18)	18	18	18	15	18
Upgradient Monitoring Boreholes								
1470	*Min*	<0.06	<0.00024	<0.00007	49	<0.00051	<0.4	8.6
	Mean	0.512	-	-	52.35	0.00214	-	23.55
	Max	0.77	0.00067 (<0.001)	<0.0006	60.9 (113)	0.004	<0.4 (40.8)	67.35
	St Dev	0.217	-	-	3.213	0.00076	-	16.69
	Count	19	(17)	19	18	18	15	18
1480	*Min*	<0.06	<0.00024	<0.00007	11.5	<0.00051	<0.4	81
	Mean	0.161	-	-	14.76	-	-	129.78
	Max	0.45	0.00032 (<0.001)	<0.0006	18.5 (163)	<0.002	<0.4 (64.9)	244
	St Dev	0.135	-	-	2.158	-	-	51.09
	Count	19	(18)	19	18	18	16	18
1490	*Min*	<0.06	<0.00024	<0.00007	12.6	<0.00051	<0.4	14.1
	Mean	0.334	-	-	15.15	-	-	18.96
	Max	0.77	<0.001	<0.0006	17.3 (49.8)	<0.002 (0.007)	<0.4 (52.7)	23.7 (69.9)
	St Dev	0.285	-	-	1.191	-	-	2.76
	Count	19	(19)	19	17	18	18	18

Note: Highest statistical outlier presented in brackets.

Other Substances Detected in Groundwater

2.4.10 The other parameters detected on more than one occasion in groundwater between 2014 and 2020 have been summarised in **Table HRA14**. Many of these substances consist of major ions and trace elements commonly found in groundwater with no significant impact evident from any contamination sources.

Table HRA14: Other Hazardous Substances and Non-Hazardous Pollutants detected in leachate and also detected in groundwater

Determinand	Max Concentration Detected	Number of samples over detection limit	Total number of samples
Hazardous Substances			
Superficial Deposits (BH 1010, 1090, 1140, 1190, 1260, 1320, 1330, 1340, 1351, 1352 & 1360) (2014 – 2020)			
Mercury (µg/l)	0.00053	13	25
Non-Hazardous Pollutants			
Superficial Deposits (BH 1010, 1090, 1140, 1190, 1260, 1320, 1330, 1340, 1351, 1352 & 1360) (2014 – 2020)			
Barium (mg/l)	0.197	46	46
Calcium (mg/l)	403	176	176
Copper (mg/l)	0.089	30	154
Fluoride (mg/l)	0.3	32	46
Iron (mg/l)	22.3	71	154
Magnesium (mg/l)	137	176	176
Manganese (mg/l)	9.04	153	154
Mecoprop (µg/l)	0.34	6	25
Nitrate (mg/l)	159	43	110
Nitrite (mg/l)	4.98	5	110
Potassium (mg/l)	106	176	176
Selenium (µg/l)	0.0079	5	42
Sodium (mg/l)	490	156	156
Vanadium (µg/l)	0.004	3	46
Zinc (mg/l)	0.147	42	154
Etruria Marl/Middle Coal Measures (BH1460, 1470, 1480 & 1490) (Nov 2017 and 2019 – 2020)			
Barium (mg/l)	0.52	24	24
Boron (mg/l)	0.73	15	24
Calcium (mg/l)	150	24	24
Copper (mg/l)	0.018	5	8
Fluoride (mg/l)	0.7	24	24
Iron (mg/l)	1.4	1	8
Magnesium (mg/l)	49.6	24	24
Manganese (mg/l)	2.75	8	8
Phosphorus (mg/l)	0.043	4	4
Potassium (mg/l)	21.9	24	24
Selenium (mg/l)	0.0024	2	16
Sodium (mg/l)	48.4	8	8
Vanadium (mg/l)	0.00054	4	24
Zinc (mg/l)	0.04	3	8

2.5 Environmental Assessment Levels

2.5.1 Baseline groundwater quality in the superficial deposits, colliery backfill, Etruria Marl, and Middle Coal Measures is either naturally or anthropogenically inferior to water quality standards in respect of several containments. EALs have been determined using the principle that the landfill development does not impede future improvement in groundwater quality. The EALs for hazardous substances have therefore been set to Minimum Reporting Values (MRVs), Limit of Quantification (LoQ), or upgradient baseline quality where it is higher. The EALs for non-hazardous pollutants have been set to Drinking Water Standards (DWS) or the upgradient baseline quality. In light of the groundwater flow in the Etruria Marl and Coal Measures being towards the west and intercepted by the colliery backfill the baseline quality of the backfill is likely to have long-term influence on groundwater quality in the MCM along the western edge of the site. EALs have therefore been derived based on a consolidated review of upgradient concentration within the backfill, superficial deposits and bedrock aquifers units. Selected EALs are listed in **Table HRA15**.

Table HRA15: Environmental Assessment Levels Review

Determinand	MRV / LoQ	Environmental Quality Standard (EQS)	Maximum Concentration in Upgradient Groundwater in Backfill & Superficial Deposits (2014 – 2020)	Maximum Concentration in Upgradient Groundwater in EM & MCM (2014 – 2020)	Previous EAL (2014 HRA) [Backfill & Superficial Deposits/Bedrock]	Proposed EAL
Ammoniacal Nitrogen (mg/l)	-	0.39	1.94	0.77	2.1/0.39	2.1[1]
Arsenic (mg/l)	0.005	-	<0.001	0.001	0.001/0.0014	0.005[2]
Cadmium (mg/l)	-	0.005	0.0006	0.0008	0.002/0.0006	0.002[1]
Chloride (mg/l)	-	250	129	60.9	250/250	250[4]
Chromium (mg/l)	-	0.05	0.003	0.004	0.05/0.05	0.005[3]
Hexavalent Chromium (mg/l)	0.001	-	<0.0004	<0.0004	0.001/0.001	0.001[2]
Mecoprop (µg/l)	-	0.1	0.04[5]	<0.04	0.1/0.1	0.1[4]
Naphthalene (µg/l)	-	2	<2	<2	2/2	2[1]
Nickel (mg/l)	-	0.02	0.029	<0.003	0.022/0.02	0.029[1]
Phenol (µg/l)	-	7.7	<1	<1	2/2	2
Sulphate (mg/l)	-	400	541	244	250/250	541[1]

[1] - based on maximum recorded upgradient groundwater quality
[2] - Based on Minimum Reporting Values (MRVs) or Limit of Quantification (LoQ)
[3] - ~20% above maximum recorded baseline groundwater quality
[4] - Based on Drinking Water Standard

2.6 Conceptual Site Model Review Summary

2.6.1 Based on a review of monitoring data collected between 2014 and2020 (inclusive) the following conclusions have been determined in relation to the Conceptual Site Models for the main landfill and PFA monocell landfill operated at Poplars:-

- The leachate heads in each containment cell in which leachate management is required are currently being managed in accordance with the compliance limits specified in the Environmental Permit;
- the proportion of each ash type deposited at the facility differs to those originally assumed for deriving the PFA monocell source term concentrations. Re-evaluation of the significance of these changes is therefore considered appropriate as part of this review;
- leachate quality monitored between 2014 and 2020 in the main landfill have identified that the modal/median and maximum source term concentrations are higher for a number of pollutants. Re-evaluation of the significance of these changes is therefore considered appropriate as part of this review;
- CQA information has provided further insight into the extent to which the various strata beneath the footprint of the current developed PFA monocell landfill (with colliery backfill dominating the western area) and the eastern development area of the main landfill;
- groundwater levels within the colliery backfill and superficial deposits have remained within the range of levels previously recorded at the site.
- groundwater levels recorded in the newly installed boreholes that screen the Middle Coal Measures and Etruria Marl beneath the eastern development area suggest a potentiometric head that sits at or above the base of the overlying superficial deposits, with no or a very limited unsaturated zone present beneath the formation levels of the containment cells. To date the CSM has considered that groundwater levels were suppressed by mine water management operations in the region and that they would rebound to ~114mAOD beneath the site when these management operations ceased, which is ~30m beneath the lowest elevation recorded in the new monitoring boreholes. Further investigations are therefore proposed subsequent to the consolidation application to further refine the CSM and determine a more accurate understanding of groundwater levels across the eastern development area (refer to **Section 4.2**);
- groundwater levels recorded in the newly installed boreholes that screen the Middle Coal Measures and Etruria Marl beneath the eastern development area also suggest that the direction of groundwater flow is towards the west, where these waters are intercepted by the deep colliery backfill deposits. The site CSM previously assumed a rebounded groundwater flow direction in the EM and MCM to the northwest;
- groundwater quality within colliery spoil and superficial deposits has largely remained consistent with previous reviews. Exceedances of existing compliance limits were largely restricted to ammoniacal nitrogen and chloride for relatively short and un-sustained periods, with concentrations having returned to previous background concentration ranges in recent years. The source of these exceedances continues to be the presence of a leachate cut off trench that is understood to have be constructed in this area;

- baseline groundwater quality with the MCM and EM has been established and the EALs updated accordingly.

2.6.2 In light of the changes to the leachate source term concentrations identified within the main landfill and PFA monocell landfill, the proposed revisions to the development footprints of these facilities, and the revised understanding of groundwater levels and flow it is considered appropriate to update the Hydrogeological Risk Assessment.

3.0 HYDROGEOLOGICAL RISK ASSESSMENT

3.1 Proposed Assessment Scenarios

3.1.1 The original hydrogeological risk assessments for Poplars Main Landfill Site and PFA monocell landfill were designed to assess the risk to groundwater throughout the lifetime of the landfill. This assessment continues to consider the risks through the lifetime of the landfill, in line with requirements of the site's current permit. This assessment seeks to consider the updates outlined as part of the conceptual site model review, including revised leachate source term concentrations, basal development footprints of each regulated landfill facility, definition of the unsaturated zone, vertical pathways and aquifer flow domains.

3.1.2 This Hydrogeological Risk Assessment considers the hydraulically contained and non-hydraulically contained cells at Poplars landfill complex. For the hydraulically contained cells, this assessment continues to consider the potential for diffusion of contaminants through the lining system of the Phases (9A). For other cells which aren't hydraulically contained, including the PFA monocell, their potential risk to the groundwater has been assess using the Environment Agency's Landfill v2.5 modelling software.

3.2 Numerical Modelling

Justification for Modelling Software

Hydraulic Containment

3.2.1 For cells at Poplars Main Landfill Site which are considered to be hydraulically contained the risk assessment has been performed using the Environment Agency spreadsheet tool "Contaminant Fluxes from Hydraulic Containment Landfills Worksheet Version 1.0". This worksheet allows the (screening) assessment of the impact on groundwater of landfills operated under hydraulic containment by the computation of diffusive fluxes.

3.2.2 The spreadsheet tool was devised by the Environment Agency to support groundwater risk assessment performed for existing and proposed landfill sites operated in settings where there is hydraulic containment and to help indicate whether a landfill can be engineered to comply with current regulatory regimes.

3.2.3 The spreadsheet has been used to calculate the diffusive flux of a conservative solute (Chloride) from each hydraulic containment cell. The conservatism offered by Chloride results from its higher free water diffusion coefficient value relative to other priority contaminants and its presence in leachate at significantly higher concentrations.

3.2.4 This HRA utilises "Scenario 1" of the Environment Agency spreadsheet in which the artificial clay liners of each phase and low permeability backfill deposits are considered as one entity due to the similarity of their permeabilities. Whilst the Middle Coal Measures aquifer beneath the site is not confined by the overlaying backfill deposits, the rebounded groundwater level beneath the site (c.114mAOD) is likely to rise above the base of the backfill deposits, which are below 114mAOD beneath all hydraulically contained cells.

Advection Models

3.2.5 Phases 9B, 9C1, 9C2, the majority of the eastern development area (including parts of the PFA monocell) and part of Phase 11 are located over the Etruria Marl/Middle Coal Measures. Phases 1, 2, 3A, 3B, 4, 5, 6, 7, 10A, 10B, the majority of Phase 11 and a small area of the eastern development area (including the PFA monocell) are constructed over backfill deposits, in which the proposed leachate compliance levels are above the groundwater levels surrounding the site. Leachate generated in each of these cells have the potential to leak through the base and sidewalls of the cells via advection.

3.2.6 The Environment Agency's LandSim v2.5 software was used to provide an estimate of the potential risks associated with these proposed cells. The model was developed to assess the potential impact of leakage through the mineral element of the liner and underlying saturated and unsaturated pathways. Due to the complex geological setting at the site, the previous risk assessment carried out for the site developed separate models for phases constructed in/over bedrock and those constructed in colliery backfill. However, in lieu of the results of the CSM review, these models have been combined due to the flow pathways beneath the eastern development area and its interception by the backfill deposits.

3.2.7 Whilst it is recognised that the bases of all containment phases of the main landfill facility are now below groundwater levels within the backfill, EM and MCM the use of Landsim is considered appropriate as the primary receptor has previously been agreed with the EA to be groundwater within the bedrock aquifer, with the backfill assumed to represent a vertical pathway. As the review of the CSM presented in **Section 2.0** has indicated a groundwater flow direction within the EM and MCM to the west, which is subsequently intercepted by the same backfill deposits modelled as a saturated vertical pathway beneath the containment cells beneath the western development area, the consolidation of both previous models is therefore considered appropriate, and the vertical pathway assigned to all development areas of the site.

3.2.8 Due to the direction of groundwater flow (i.e. towards the west) currently interpreted for the site, the PFA Landfill remains to be modelled separately as its flow path does not overlap with that of other the containment cells associated with the main landfill.

3.3 Model Parameterisation

<u>PFA Landfill Review</u>

3.3.1 The revised input parameter tables for the PFA models are presented in **Appendix HRA6**. As CQA records have confirmed that the MCM only extends beneath a very small section of the basal area at northernmost edge of the monocell with the AEGB thickness increased to 750mm instead of the originally designed 500mm the MCM models have not been re-run. Additionally, the colliery backfill models have been revised to account for the whole of the western footprint of the monocell. Similarly, the presence of the colliery spoil will have removed any potentially brecciated material that may have been present along any fault zones. This review is therefore supported by updates to the original Etruria Marl and Colliery Backfill basal models only.

<u>Hydraulically Contained Phases</u>

3.3.2 Providing hydraulic containment is maintained, the only pathway for leachate migration from Phases 9A is by diffusion through the liner. Details of the model parameters used in the spreadsheets for each individually assessed landfill phase are presented within the worksheets included in **Appendix HRA7**. Hydraulic containment model 'Scenario 1' has been selected with the backfill treated as a vertical pathway to the estimated groundwater rebound level in the Middle Coal Measures.

Consolidated Advection Models

3.3.3 The input parameters for consolidated Landsim model for all current and future containment cells overlying the Etruria Marl, Middle Coal Measures and backfill deposits are presented in **Appendix HRA6**. A copy of the model file is presented in **Appendix HRA7**.

3.4 Emissions to Groundwater

PFA Landfill Review

3.4.1 The results of the updated Landsim models for the PFA landfill based on its current developed footprint is presented in **Table HRA17.** The results are quoted at the monitoring well for each model phase.

Table HRA16: PFA Monocell Landfill Landsim model predicted groundwater concentration at the monitoring well

Substance	95%ile resultant Peak Concentration (mg/l)	Approx. Time to peak impact (years)	Long term EAL (mg/l)
Western Area (Over Colliery Backfill)			
Arsenic	0.0021	16,000	0.005
Cadmium	0.00004	>20,000	0.002
Chromium	<0.00001	>20,000	0.005
Hexavalent Chromium	<0.00001	>20,000	0.001
Sulphate	11	60	541
Eastern Area (Over Etruria Marl)			
Arsenic	0.003	5,000	0.005
Cadmium	0.00007	>20,000	0.002
Chromium	<0.00001	>20,000	0.005
Hexavalent Chromium	0.00034	>20,000	0.001
Sulphate	5.6	105	541

3.4.2 The results of the models continue to demonstrate the PFA landfill will not result in the discernible discharge of hazardous substances to groundwater and limit the input of non-hazardous pollutants to prevent pollution.

Hydraulically Contained Phases

3.4.3 The results of the updated diffusive flux calculations for Phase 9A are presented in **Table HRA18**.

Table HRA17: Summary of results of contaminant fluxes (Chloride) from Phase 9A

Landfill Phase	EAL	Peak Concentration at Compliance Point in Aquifer (mg/l)	Time until Peak Concentration (years)
9A	250	0.003	>20,000

3.4.4 The results of the spreadsheet calculations demonstrate that the contaminant flux from the hydraulically contained landfill cell (Phase 9A) when the leachate head is managed at or below the current leachate compliance limit will continue to present a low risk to groundwater.

Advection Models

3.4.5 Revised modelling has been carried out to determine the impact of the revised leachate source term concentrations and development layout will have on the original risk assessment results. Model files are presented in **Appendix HRA7**. The modelled concentration of Hazardous Substances at the edge of each cell are presented in **Table HRA19**, whilst the modelled concentrations of Non-Hazardous Pollutants at the site boundary or edge of the backfill deposits are presented in **Table HRA20**. The results are only presented for the maximum leachate levels at which regulatory compliance can be achieved.

Table HRA18: Consolidated Landsim model predicted Hazardous Substance concentrations at the monitoring wells (60yr post-closure management period)

Determinand	95%ile peak concentration (mg/l)	Approx. time to peak impact (years)	Long term EAL (mg/l)
Phase 3A			
Arsenic	0.00004	>20,000	0.005
Phase 3B			
Arsenic	0.00001	>20,000	0.005
Phases 1, 2, 4, 5, 6 & 7			
Arsenic	0.0021	>20,000	0.005
Phases 10A & 10B			
Arsenic	0.00023	9,000	0.005
Phase 11			
Arsenic	0.0009	>20,000	0.005
Eastern Development Area (Phase 9B – I)			
Arsenic (GCL Cap)	0.0017	>20,000	0.005
Arsenic (PE Cap)	0.0016	10,000	

Table HRA19: Landsim model results for Non-Hazardous Pollutants concentration at the western site boundary (60yr post-closure management period)

Determinand	95^{tho}%ile peak concentration (mg/l)	50^{tho}%ile peak concentration (mg/l)	Approx. time to peak impact (years)	Long term EAL (mg/l)
GCL Cap Only Option				
Ammoniacal Nitrogen	<0.00001	<0.00001	-	2.1
Cadmium	<0.00001	<0.00001	>20,000	0.002
Chloride	**948**	81	700	250
Chromium	<0.00001	<0.00001	-	0.005
Mecoprop	<0.00001	<0.00001	-	0.0001
Naphthalene	<0.00001	<0.00001	-	0.002
Nickel	0.011	0.0004	8,000	0.029
Phenol	<0.000001	<0.000001	-	0.002
Sulphate	37	3.5	750	541
GCL & PE Cap Options				
Ammoniacal Nitrogen	<0.00001	<0.00001	-	2.1
Cadmium	<0.00001	<0.00001	>20,000	0.002
Chloride	**1,280**	84	1,000	250
Chromium	<0.00001	<0.00001	-	0.005
Mecoprop	<0.00001	<0.00001	-	0.0001

Determinand	95th%ile peak concentration (mg/l)	50th%ile peak concentration (mg/l)	Approx. time to peak impact (years)	Long term EAL (mg/l)
Naphthalene	<0.00001	<0.00001	-	0.002
Nickel	0.0099	0.0003	7,000	0.029
Phenol	<0.000001	<0.000001	-	0.002
Sulphate	52	3.5	1,000	541

*Note: Values in **bold** are in exceedance of the EAL*

3.4.6 Whilst the 95th percentile chloride concentration along the western site boundary is predicted to exceed the EAL the 50th percentile value is significantly below the EAL of 250mg/l, at less than 85mg/l under both permanent capping options. These differences highlight the influence where the leakage volume is not used to calculate the diluted concentration at the modelled compliance point, whereby the modelled leakage exceeded 10% of the aquifer flow in approximately 25-30% of the model iterations.

3.4.7 A review of the diluted concentrations of chloride predicted at the monitoring wells modelled at the downgradient edges of each modelled phase (**Table HRA20**), where leakage volumes are used in the predicted concentrations, indicates that the eastern development area is the only modelled phase in which the modelled concentration exceeds the EAL of 250mg/l at its downgradient edge. As discussed in **Section 2.0**, the source term concentrations of chloride recorded within the eastern development area cells in recent years are nearly 5 times greater than previously modelled. The duration of post-closure management will be dependent on how quickly these source-term concentration decline. However, as also shown in **Table HRA20** that by running the model with a post-closure management period of 20,000 years the predicted chloride concentration at the down gradient edge of the eastern development area is reduced to less than the EAL for both GCL and geomembrane capping options. This result indicates that leachate management will be effective in protecting groundwater in the short and long-term.

Table HRA20: Predicted 95th percentile groundwater concentration of chloride at the downgradient edge (monitoring well) of each model phase

Model Phase	Peak Concentration (mg/l)	
	60 Years Post Closure Management	*20,000 Years Post-Closure Management*
Phase 3A	6	4
Phase 3B	9	<1
Phases 1, 2, 4, 5, 6 & 7	215	163
Phases 10A & 10B	125	78
Phase 11	222	**263**
EDA *(GCL Capping Option)*	**493**	151
EDA (*PE Capping Option)*	**670**	226

*Note: Values in **bold** are in exceedance of the EAL*

3.4.8 Note, the increased concentrations for the Phase 11 model configuration during the 20,000 year post-closure management model is determined to be due to the reduction in leachate head when management ceases owing to the permeability values selected for the backfill. This suggests that the modelled maximum permeability value of $1x10^{-9}$ m/s is unlikely to result in the generation of leachate heads as high as the compliance limits currently set for the site and is not representative of the bulk hydraulic conductivity of the underlying strata.

3.4.9 The results of the Landsim models demonstrate that the main landfill can continue to be managed to prevent the discernible input of hazardous substances to groundwater and limit the input of non-hazardous pollutants to prevent pollution.

3.5 Review of Technical Precautions

3.5.1 This Hydrogeological Risk Assessment Review has demonstrated that the landfill can continue to be managed to comply with the requirements of Schedule 22 to the Environmental Permitting (England and Wales) Regulations 2016.

Basal and Sidewall Liners

3.5.2 The presence and type of basal and side wall lining systems within the existing phases at Poplars Main Landfill site vary between each one because of the age and the associated changes in regulatory regimes. Details of the lining systems present in each phase are presented in **Table HRA1**. Where no engineered or CQA supervised, or tested basal or side wall liner is present the natural low permeability characteristics of the colliery spoil is considered to demonstrate a bulk permeability that is typically less than $1x10^{-9}$ m/s.

3.5.3 At the PFA Landfill site, the Etruria Marl forms a natural geological barrier beneath the western footprint of the cell, with the basal areas overlying the Middle Coal Measures and colliery backfill deposits supplemented by the construction of a 750mm thickness Artificially Established Geological Barrier. A 500m thick artificial geological barrier has also been constructed on areas of the side-slopes overlying glacial sands and gravel. The AEGBs comprise site-won marl and clays.

Capping

3.5.4 To date, permanent capping has been applied to Phases 1 to 7, 9A, 9B, 9C1, 10A, 10B (partial), 11 (partial), G1 (partial), H1(partial) and H2 (partial), with temporary capping constructed over 10B (partial), 11 (partial), G2 (partial) and I1. All subsequent cells will continue to be finished off with a low permeability engineered cap as soon as reasonably practicable following completion of landfilling in that cell to limit potential surface infiltration. The remaining areas of Phases G2, H1 and H2 will be provided with temporary cap by end of January 2022. Recent capping designs have incorporated GCL systems installed under a regulator approved CQA regime, although it is proposed that future areas may also be capped with a geomembrane capping system. A covering of 1m of restoration soils will be included for either capping design.

3.5.5 The capping systems employed at Poplars is compliant with the requirement of the Landfill Directive.

3.5.6 With regards to the PFA, as leachate management is still not considered to be necessary for the PFA Landfill no engineering cap is therefore required to minimise infiltration and leachate generation, which itself will be regulated by the low permeability of the waste deposits themselves, together with a significant thickness of site-won materials, the surface of which will be reseeded in the accordance with the agreed scheme of restoration for the site.

Leachate Control

3.5.7 Leachate head control within the existing and future containment phases at Poplars Main Landfill will continue to be undertaken to ensure that risks to groundwater are minimised, as far as reasonably practicable in lieu of uncertainties in formation levels of historical containment cells.

3.5.8 The leachate compliance levels for existing and future containment cells are presented in **Table HRA21.** Due to the uncertainties of formation levels compliance levels have been set at 2 m above the base of each re-drilled well or 2m above the lowest well of that phase (if they were part of the original basal engineering). Advancement of alternative installations within these cells is likely to present a significant risk of penetrating the basal sealing liners of these cells.

3.5.9 By managing the leachate within each phase to these levels there appears to be limited risk to the groundwater, in that there will be limited discernible discharges of Hazardous Substances to groundwater, whilst limiting the introduction of Non-Hazardous Pollutants into groundwater to avoid pollution throughout the life of the landfill.

3.5.10 Consideration of the risks to groundwater will also continue to be supported by monitoring of groundwater within the colliery backfill, superficial deposits and bedrock at locations immediately downgradient of the containment cells. To date, monitoring records indicate that leakage from the containment cells has not impacted upon groundwater within the backfill or superficial deposits, even whilst leachate levels were above existing and proposed compliance levels.

3.5.11 Due to concerns relating to the proximity of future cells to receptors, where possible Biffa propose that extraction and monitoring of leachate will be carried out by upslope risers in the peripheral cells.

3.5.12 Should further leachate wells be lost, replacement infrastructure should be installed as soon as possible to ensure that leachate levels can continue to be maintained at or below the compliance levels.

3.5.13 It is also noted that the proposed development of the Phase C2 area will result in the over-tipping of containment cells H1, H2 and I1 and the area in which the headworks of their current side slope risers are located. Prior to over-tipping of these areas vertical wells will be retro-drilled to the target pads on which the side-slope risers are located.

3.5.14 As aforementioned, the PFA Landfill does not require leachate control and there is no collection system proposed.

Groundwater Management

3.5.15 Groundwater hydrographs for the site (presented in **Appendix HRA3**) have long-term, fluctuating groundwater levels within the superficial/backfill deposits within monitoring boreholes 1320 and 1340, located at the north-western and north-eastern site boundaries respectively. The exact cause(s) of these increases have not been identified. However, these fluctuations are not considered to have any significant impact on the future management of the site, and therefore do not require any additional management.

3.5.16 No further significant changes in groundwater levels in the colliery backfill and superficial deposits are anticipated in the future, and levels within Boreholes 1320 and 1340 have largely remained constant since 2018. This is the case primarily because the regime of this superficial aquifer unit is a low flow system which is perched on the Etruria Marl/Middle Coal Measures and regulated to the west by the Ridings Brook and other surface water features located around the edge of the site. The superficial/backfill deposits will remain in place around the perimeter of the site.

3.5.17 The current practice of constructing back drainage and additional AEGB where seepages are encountered at the interface of drift/backfill and underlying solid geology will also be adopted for all future containment phases to maintain the efficacy of the engineered barriers within these cells.

3.5.18 Within the Etruria Marl/Middle Coal Measures, groundwater levels have remained fairly constant between 2019 and 2020 following the installation of the boreholes. However, due to the limited lateral coverage of the current monitoring network for the bedrock aquifer unit, further monitoring installation are proposed, as presented on **Drawing No. BF5036/09/05.**

Surface Water Management

3.5.19 The existing surface water settlement ponds at Poplars Main Landfill Site within the future containment area will be removed during the progressive construction of the engineered phases. As the later phases are constructed into the northern section of the eastern development area, further consideration has been given to the surface water management scheme for the final parts of the containment areas.

3.5.20 Surface waters from the PFA Landfill will be managed within a designated settlement lagoon to be located to the northwest of the containment cell area. The surface water is used for dust suppression requirements at the site. Management of surface waters generated on-site includes an assessment of its quality prior to discharge from the site.

4.0 REQUISITE SURVEILLANCE

4.1 Leachate Monitoring

4.1.1 There are no proposed changes to the leachate monitoring schedule currently in place for the Poplars Main Landfill site. The previous 2018 HRA proposed revisions to the schedule to account for the replacement extraction and monitoring wells installed from 2012 on.

4.1.2 As is currently the case, there is no in-waste leachate monitoring required or proposed for the PFA Landfill.

4.1.3 In the event that a compliance level for leachate head is breached, procedures will be followed in accordance with the main landfill site's permit and Leachate Management Plan.

4.1.4 The Leachate compliance levels put forward in the 2018 HRA will continue to be utilised for the site. These are summarised in **Table HRA21**, below. Phases 1-6, 10A and 10B are based on a level that is 2m above the highest well basal level in each cell. For Phase 11 the compliance levels are derived at 2m above the basal level of each well in order to minimise the head across this cell as a whole and ensure that the maximum head remains below the surface levels along the eastern boundary (i.e. c.145mAOD). Levels within eastern development area cell will remain at the current compliance level of 2m above the base of the cell, or base of well where retro-drilled installations are not in connection with the base of the cell. Phase 9A is hydraulically contained, in which the compliance level accounts for surrounding groundwater levels within the colliery spoil.

Table HRA21: Leachate Compliance Levels and Points

Phase	Compliance Point	Retrodrilled?	Well Base (mAOD)	Leachate Compliance Limit (mAOD)	Leachate Head (m)
Phase 1	3201	Y	128.5	130.5	2
Phase 1	3202	Y	129.77	131.77	2
Phase 2	3203	Y	133.43	135.43	2
Phase 2	3204	Y	133.06	135.06	2
Phase 3A	3205	Y	136.46	138.46	2
Phase 3A	3206	Y	138.71	140.71	2
Phase 3B	3108	Y	139.5	141.5	2
Phase 3B	3143	Y	139.6	141.6	2
Phase 4	3207	Y	137.27	139.27	2
Phase 4	3208	Y	135.95	137.95	2
Phase 4	3209	Y	137.05	139.05	2
Phase 5	3210	Y	140.14	142.14	2
Phase 5	3211	Y	139.99	141.99	2
Phase 6	3212	Y	133.77	135.77	2
Phase 6	3213	Y	136.09	138.09	2
Phase 9A	3220	Y	136.24	138.24	2
Phase 9A	3221	Y	136.4	138.4	2
Phase 9B	3050	N	135.28	136.18	0.9
Phase 9B	3051	N	134.18	136.18	2
Phase 9B	3222	Y	136.04	138.04	2
Phase 9C1	3218	Y	135.64	137.64	2

Phase	Compliance Point	Retrodrilled?	Well Base (mAOD)	Leachate Compliance Limit (mAOD)	Leachate Head (m)
Phase 9C1	3223	Y	135.59	137.59	2
Phase 9C1	3224	Y	134.27	136.27	2
Phase 9C2	3056	N	138.1	139.4	1.3
Phase 9C2	3057[1]	N	137.4	139.4	2
Phase 10A	3217	Y	134.81	136.81	2
Phase 10A	3225	Y	133.38	135.38	2
Phase 10B	3219	Y	133.19	135.19	2
Phase 10B	3228	Y	132.07	134.07	2
Phase 11	3214	Y	137.96	139.96	2
Phase 11	3215	Y	141.65	143.65	2
Phase 11	3126	Y	143.69	145.69	2
Phase I1	3058	N	141	141.5	0.5
Phase I1	3059	N	139.99	141.12	1.13
Phase I1	3060	N	139.12	141.12	2
Phase H1	3061	N	140.18	142.18	2
Phase H1	3062	N	141.42	142.18	0.76
Phase H2	3063	N	138.44	140.01	1.57
Phase H2	3064	N	138.01	140.01	2
Phase G1	3065	N	138.52	139.54	2
Phase G1	3066	N	137.54	139.54	2
Phase G2	3067	N	134.30	136.3	2
Phase G2	3068	N	134.30	136.3	2
Future Phases	All associated monitoring points.	-	-	TBC	TBC

[1] - well 3057 lost – replacement well to be installed once final pre settlement levels reached

4.2 Groundwater Monitoring

4.2.1 To ensure that the hydraulic containment of relevant cells is maintained, it is important to ensure that groundwater levels within the superficial/backfill deposits continue to be monitored regularly. The existing monitoring locations and frequencies specified in the main landfill permit and Groundwater Monitoring Plan are considered adequate to monitor groundwater in the superficial/backfill deposits, including for the PFA landfill. All groundwater boreholes were surveyed in 2017 with camera equipment and found to be fit for purpose.

4.2.2 Based on the limited risk to receptors associated with the Etruria Marl aquifer, it was proposed in a previous HRA that four groundwater monitoring boreholes be installed around the future containment phase area - this was completed in June 2018. These monitoring installations were designed to target potential groundwater within the discrete sandstone bands within the Etruria Marl and Middle Coal Measures, although previous investigations of the eastern development areas indicated that below the proposed basal elevations, these bands become thinner and more discrete. Since their installation, recorded groundwater levels indicate a potentiometric head above that of the upper boundary of the formation. It is therefore proposed that the monitoring network for the EM and MCM is extended. The proposed positions of these additional monitoring installations are presented in **Drawing No. BF5036/09/05.** These additional installations will principally be used to further establish the groundwater levels within the various strata underlying and surrounding the site and the hydraulic continuity between them, with those around the periphery of the site potentially being used for establishing water quality and compliance going forward also. These proposals also include for a borehole between the eastern development area and Phase 11, although it is not intended for this borehole to be used for baseline or compliance monitoring going forward.

4.2.3 The quality of the groundwater within the superficial/backfill deposits is currently monitored in 11 borehole installations around the perimeter of the site, although as previously mentioned boreholes 1351 and 1352 are not currently listed in the permit.

4.2.4 To support the consolidation of the PFA and main landfill permits a consolidated groundwater monitoring schedule is presented in **Table HRA22**. Note, all monthly monitoring frequencies specified have been reduced to quarterly frequency.

Table HRA22: Consolidated groundwater monitoring schedule

<table>
<tr><th>Locations</th><th>Frequency</th><th>Measurement and Analytical Suite</th></tr>
<tr><td colspan="3">Superficial Deposits</td></tr>
<tr><td>1010, 1090, 1140, 1190, 1260, 1330, 1340, 1351, 1352 & 1360.</td><td rowspan="2">Quarterly</td><td>Groundwater Level, Ammoniacal Nitrogen, Arsenic, Cadmium, Chloride, Electrical Conductivity & pH.</td></tr>
<tr><td>1320</td><td>Groundwater Level, Ammoniacal Nitrogen, Arsenic, Cadmium, Chloride, Chromium, Dissolved Oxygen, Electrical Conductivity, Hexavalent Chromium, pH, Sulphate & Temperature</td></tr>
<tr><td>1010, 1090, 1140, 1190, 1260, 1330, 1340, 1351, 1352 & 1360.</td><td rowspan="2">Annual</td><td>Borehole Base, COD, TOC, Total Sulphates, Alkalinity, Nitrate (for TON), Nitrite (for TON), Sodium, Potassium, Calcium, Magnesium, Iron, Manganese, Copper, Chromium, Lead, Nickel & Zinc.</td></tr>
<tr><td>1320</td><td>Borehole Base, Barium, Boron, COD, TOC, Alkalinity, Nitrate (for TON), Nitrite (for TON), Sodium, Potassium, Calcium, Fluoride, Magnesium, Iron, Manganese, Copper, Lead, Nickel, Phosphorous, Selenium, Vanadium & Zinc.</td></tr>
<tr><td>1090, 1140, 1190 & 1260.</td><td>Every two years for down-gradient wells.</td><td>Hazardous substances identified in leachate.</td></tr>
<tr><td colspan="3">Etruria Marl/Middle Coal Measures</td></tr>
<tr><td rowspan="2">1460, 1470, 1480, 1490 and replacement monitoring installations</td><td>Quarterly.</td><td>Groundwater Level, Ammoniacal Nitrogen, Arsenic, Cadmium, Chloride, Chromium, Dissolved Oxygen, Electrical Conductivity, Hexavalent Chromium, pH, Sulphate & Temperature</td></tr>
<tr><td>Annually.</td><td>Borehole Base, Barium, Boron, COD, TOC, Alkalinity, Nitrate (for TON), Nitrite (for TON), Sodium, Potassium, Calcium, Fluoride, Magnesium, Iron, Manganese, Copper, Lead, Nickel, Phosphorous, Selenium, Vanadium & Zinc.</td></tr>
</table>

Locations	Frequency	Measurement and Analytical Suite
Future new monitoring installations	Monthly for the first year, then quarterly.	Groundwater Level, Ammoniacal Nitrogen, Arsenic, Cadmium, Chloride, Chromium, Dissolved Oxygen, Electrical Conductivity, Hexavalent Chromium, pH, Sulphate & Temperature
	Six-monthly for first two years, then annually.	Borehole Base, Barium, Boron, COD, TOC, Alkalinity, Nitrate (for TON), Nitrite (for TON), Sodium, Potassium, Calcium, Fluoride, Magnesium, Iron, Manganese, Copper, Lead, Nickel, Phosphorous, Selenium, Vanadium & Zinc.
	Annually for the first six years of operation, then every two years (for down and cross gradient boreholes only)	Hazardous substances identified in leachate.
	Annual	Borehole Base.

4.2.5 The Landfill Directive requires that groundwater trigger levels are set for potentially polluting substances. Trigger levels are currently set within the main landfill permit (Ref.: EPR/BW0584IL) for ammoniacal nitrogen, chloride and cadmium at six of the perimeter boreholes installed in the superficial/backfill deposits. There are no changes proposed to these existing limits as part of this HRAR. Similarly, there are no changes proposed to the compliance limits specified in PFA landfill permit (EPR/BP3436VS). This review also does not propose to derive compliance limits for the priority substances selected for the PFA landfill to the compliance points for the main landfill facility.

4.2.6 A consolidated schedule of groundwater compliance limits, including new limits for borehole 1460 is presented in **Table HRA23.** Ahead of the development of the Phase C2 containment area, the derivation of groundwater compliance limits should be considered at borehole 1360.

Table HRA23: Consolidated schedule of existing and proposed groundwater compliance limits

Compliance Point ID	Parameter	Compliance Limit
1010	Ammoniacal Nitrogen	30 mg/l
	Chloride	1,000 mg/l
	Cadmium	0.004 mg/l
1090	Ammoniacal Nitrogen	30 mg/l
	Chloride	1,000 mg/l
	Cadmium	0.001 mg/l
1140	Ammoniacal Nitrogen	30 mg/l
	Chloride	1,000 mg/l
	Cadmium	0.0025 mg/l
1190	Ammoniacal Nitrogen	30 mg/l
	Chloride	1,000 mg/l
	Cadmium	0.0025 mg/l
1260	Ammoniacal Nitrogen	30 mg/l
	Chloride	1,000 mg/l
	Cadmium	0.01 mg/l
1320	Ammoniacal Nitrogen	30 mg/l
	Arsenic	0.007 mg/l
	Chloride	1,000 mg/l
	Cadmium	0.003 mg/l
	Chromium (total dissolved)	0.05 mg/l
	Hexavalent Chromium	0.001 mg/l
	Sulphate	250 mg/l

Compliance Point ID	Parameter	Compliance Limit
1460	Ammoniacal Nitrogen	0.96 mg/l [1]
	Arsenic	0.005 mg/l [2]
	Chloride	250 mg/l [3]
	Cadmium	0.0015 mg/l [1]
	Chromium (total dissolved)	0.03 mg/l [1]
	Hexavalent Chromium	0.001 mg/l [2]
	Sulphate	391 mg/l [4]

[1] - Maximum recorded concentration + 25%
[2] - MRV or LoQ
[3] - DWS
[4] – 2 x standard deviations above the mean recorded concentration in borehole (refer to Table HRA13)

5.0 CONCLUSIONS

5.1.1 This Hydrogeological Risk Assessment has been prepared to include a 6-year review of the current agreed PFA Landfill Monocell development and a revised, consolidated assessment to support consolidation of the PFA landfill and main landfill permits. Compliance with the Landfill Directive and Schedule 22 to the Environmental Permitting Regulations 2016 (as amended) is summarised below.

Compliance with the Landfill Directive 1999

5.1.2 The results of this risk assessment have established the following:-

- The PFA Landfill site does not pose a potential hazard to soil or water; owing to the nature of the waste at the PFA landfill, the collection of leachate will not be necessary;
- All phases of the main landfill site could pose a potential hazard to ground and surface water quality. Consequently, arrangements must continue to be made to collect the contaminated water (leachate) that is generated by the main landfill site.
- Control and trigger levels have been reviewed to ensure the adequate protection of ground and surface water resources.
- The site in its entirety complies with the relevant requirements of the Landfill Directive.

Compliance with Schedule 22 of the Environmental Permitting Regulations 2016.

5.1.3 The results of the risk assessment have established the following:-

- The PFA landfill and all phases of the main landfill site could pose a potential hazard to ground and surface water quality. Consequently, it continues to fall within the scope of the Schedule 22 to the Environmental Permitting Regulations 2016.
- This risk assessment forms a review of the “prior investigation” that must be carried out for this type of development.
- The technical precautions in place for the PFA landfill and main landfill site are still considered appropriate and reasonable to avoid the entry of hazardous substances into groundwater.
- The technical precautions in place for both the PFA landfill and the main landfill will continue to limit the introduction of Non-hazardous Pollutants into groundwater to avoid pollution throughout their respective lifecycles.

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