G GEO-ENVIRONMENTAL APPRAISAL

27 Conceptual Site Model

The site has historically been used for the research and development of pharmaceuticals and has been the subject of numerous investigations, which were undertaken both pre and post demolition of the buildings. The reports were summarised in depth in the LEAP Phase1 desk study. The resulting site conceptual model is summarised below:

Identified as potential risks to human health:

- Petroleum hydrocarbons were found by others in former areas of storage and use and these were compared to conservative assessment criteria and in some cases, excavated and removed from site. Resulting excavations were backfilled with either site won or imported clean materials. Residual petroleum hydrocarbons may still be present in these areas or in areas not yet investigated.
- Heavy metals. Elevated concentrations of arsenic and lead were recorded in made grounds soils across the site pre demolition. Post demolition, arsenic, lead, beryllium and copper have been recorded at concentrations above residential land use screening criteria.
- Asbestos was identified in soils pre and post demolition – although generally limited in extent.
- Ground gas generation. There is the potential for backfilled material on site (former clay pit backfilled areas) to generate gas, although the evidence to date suggests the site backfill is not significantly organic or subject to degradation. However off-site sources of backfill have been identified and whilst the risk is considered to be low, there is still the potential for off-site gas to migrate to site.
- Potential asbestos, metals, PAHs, petroleum hydrocarbons, BTEX, VOCs and SVOCs from site use for pharmaceutical production in areas not previously identified.

Identified as potential risks to controlled waters:

- Contaminants that have the potential to compact controlled waters include metals, PAHs, petroleum hydrocarbons, BTEX, VOCs and SVOCs. Previous investigations have included groundwater risk assessment and concluded that the risk to controlled water is very low. However, this assessment may need revising to consider continuity between perched and deeper aquifer if further contamination is identified.

Section C, above notes that the risk to offsite controlled water receptors (groundwater and surface water) from onsite groundwater is low. The only plausible source pathway linkage to

offsite controlled water receptors is via a preferential pathway from site drains that extend through the site and connect to the Horsham Pond 800 m to the southwest.

28 Testing Strategy

28.1 Soil Sampling

Given that previous investigations have targeted potential sources, their findings and the areas not covered previously, it was considered appropriate to spread exploratory hole locations across the site to provide even, non-targeted coverage. The trial hole spacing on a ~30 m grid is consistent with the recommended density of 25 to 50m for an exploratory investigation after BS10175 Section 7.7.

Samples have been tested for the presence of the identified contaminants of concern (heavy metals, PAH compounds, petroleum hydrocarbons, SVOCs, VOCs and asbestos as detailed in section 12.5.

Selected samples have been tested for waste classification purposes.

Whilst not specifically targeting historical sources of contamination, due to the density of the grid system trial holes have been located on or close to many of the previously identified sources of contamination. We note that access to some areas was restricted (particularly in areas north and south of the retained building) due to physical constraints (soft strip activities / vehicle movements) and presence of potential below ground utility services.

28.2 Groundwater monitoring/sampling

Six deep (14m to 20.3m) monitoring wells and 11 shallow (1.0 m to 3.0 m) were installed during this investigation to allow determination of the groundwater regime beneath the site, including groundwater flow direction and groundwater quality.

Six groundwater level monitoring rounds have been completed on all well installations and three groundwater sampling visits have been undertaken on the six deep monitoring wells. A single groundwater sampling round has also been completed at BH101S.

28.3 Land gas / vapour monitoring

The land gas investigation strategy has been designed generally in accordance with BS8576:2013[24] and NHBC[25] guidance.

The investigation strategy makes reference to Section 8 of BS8567:2013 in regard to the location, extent and sensitivity of proposed new buildings; ground conditions at the site (geology and hydrogeology); and the gas generation potential of source(s).

The placement of gas monitoring wells has been considered based on the following potential areas of concern:

- Deep made ground (where identified);
- To provide a general coverage, based on a preliminary non-targeted investigation of ground gas risks at the site to include boundary monitoring of potential off site sources.

At the end of the monitoring period an assessment of the sufficiency of data will be undertaken with reference to Annex F of BS8576:2013. Further monitoring may be required.

29 Assessment Criteria

29.1 Human Health Assessment Criteria

The generic quantitative risk assessment (GQRA) for human health compares the analytical results from the current investigation to Generic Assessment Criteria (GAC). These were selected using the following rationale and assumptions.

Defra and the EA have published a limited number of Soil Guideline Values (SGVs)[26] that represent minimal chronic risk to human health. CL:AIRE has published a limited number of Category Four Screening Levels (C4SLs)[27] which represent a low but still strongly precautionary

[24] BS8576:2013 Guidance on investigations for ground gas. Permanent gases and Volatile Organic Compounds ()

[25] Guidance on evaluation of development proposals on sites where methane and carbon dioxide are present, incorporating "traffic lights", Report 10627-R01-(02) for NHBC 2006 Boyle, R and Witherington, P

[26] Environment Agency Science Report SC050021 series.

[27] CL:AIRE Final Project Report. SP1010 – Development of Category 4 Screening Levels for assessment of land affected by contamination. CL:AIRE, December 2013

level of chronic risk to human health. Both the SGVs and C4SLs have both been derived for a Soil Organic Matter (SOM) content of 6%, which is not always representative of the low SOM that are encountered within Made Ground on brownfield sites.

LQM responded to the demand for a more comprehensive set of screening values for a wider range of SOM and produced Suitable for Use Levels (S4ULs)[28] which are a hybrid of SGVs and C4SLs. The S4ULs have been endorsed by the Chartered Institute of Environmental Health (CIEH).

LEAP uses C4SLs where they are available as generic assessment criteria to quantitatively assess the potential chronic risks to human health. Where C4SLs are not available, the S4ULs are used. It is noted that S4ULs are not equivalent to C4SLs in all their exposure assumptions but are generally more conservative in their assumptions. For benzene and benzo(a)pyrene), LEAP has calculated equivalent C4SLs for 1% and 2.5% SOM. This does not affect the inorganic contaminants.

In accordance with current Public Health England (PHE) guidance[29], the assessment of PAHs has been carried out using a surrogate marker approach, whereby the assessment of risk from benzo(a)pyrene also captures potential risks from other carcinogenic PAHs that may be present. The alternative S4ULs for PAHs using the Toxic Equivalent Factor (TEF) approach have not been used because this approach is likely to under predict the true carcinogenicity of PAHs and is not advocated by PHE. The threshold PAHs have been assessed similarly, by using naphthalene as a marker compound due to its high volatility relative to other PAHs.

Sets of GACs have been generated for SOMs of 1%, 2.5% and 6%. In this case the TOC in the Made Ground samples that were analysed averaged 1.6%. Using the conversion of SOM = TOC x 1.72, this equates to a SOM of around 2.7% therefore 2.5% SOM was considered to be appropriate to maintain conservatism.

Whilst the details of the development proposals are not yet finalised, it is clear from the outline proposals that part of the site, mostly likely the western side, will include low rise residential development with private gardens and apartment blocks and the eastern side will be a commercial land use. Soil data will be initially screened against residential with homegrown produce generic assessment criteria (GAC) to maintain conservatism for the outline development. Where potential contaminants are identified at concentrations above

[28] The LQM/CIEH S4ULs for Human Health Risk Assessment, Nathaniel P et al, 2015. Copyright Land Quality Management Ltd, reproduced with permission: Publication Number S4UL3509

[29] HPA Contaminated Land Information Sheet. Risk Assessment Approaches for Polycyclic Aromatic Hydrocarbons (PAHs). Public Health England, 2017.

this GAC in samples collected from the proposed commercial areas the results will also be compared to commercial land use GACs as an informative.

29.2 Groundwater and Surface Water Assessment Criteria

The generic controlled waters risk assessment was conducted in accordance with the principles of EA '*Remedial Targets Methodology: Hydrogeological Risk Assessment for Land Contamination'* 2006 (EA 2006) and the 'prevent and limit' approach of the Water Framework Directive (2000/60.EC). Generic controlled waters risk assessments compare directly measured concentrations with standard assessment criteria.

Appropriate Water Quality Standards (WQS) are selected based on both a hierarchy of relevance to England and Wales and the receptor. In this case, the controlled water receptor identified in the CSM was the Upper Tunbridge Well Sand Secondary A Aquifer and the Horsham Pond and so the following hierarchy of WQS were considered to be appropriate:

Groundwater

- UK Drinking Water Quality Standards (DWS) from *The Water Supply (Water Quality) Regulations* 2016 (England).
- Environment Agency 2017 *Hazardous substances to groundwater: minimum reporting values*
- World Health Organisation *Guidelines for Drinking Water Quality*, Fourth Edition, Volume 1, (2011).

Surface Water

- Environmental Quality Standards (EQS) from The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015.

In the case of petroleum hydrocarbons the CL:AIRE guidance on assessing petroleum hydrocarbons using existing hydrogeological risk assessment methodologies[30], itself based on WHO guidelines, will be used where applicable for considering petroleum hydrocarbon fractions and derivatives in more detail.

29.3 Land Gas Assessment Criteria

An initial assessment has been made using the method outlined in BS8485:2015. Gas concentrations and borehole flow rates are combined to provide gas screening values (GSV) for both carbon dioxide and methane. In this assessment the highest concentrations per

[30] Petroleum Hydrocarbons in Groundwater - Guidance on assessing petroleum hydrocarbons using existing hydrogeological risk assessment methodologies – CL:AIRE, March 2017

monitoring well have been combined with the highest flow rates to provide a conservative Tier 1 assessment.

A gas screening value is assigned to the site / zone in conjunction with the conceptual site model and typical gassing levels associated with the identified source to characterise the gassing regime. Appropriate design protection measures are recommended in line with BS8485:2015.

30 Analytical Test Results – Soils

30.1 Metals and Non Metals

A screening table including all of the laboratory testing is included within Appendix H and a summary of results is provided below. At the initial screening stage the sample results have not been sub-divided into separate populations based on depth profile / stratum.

Table 21: Summary of soil contamination test results

Determinant	Minimum (mg/kg)	Maximum (mg/kg)	Number of samples tested	Tier 1 Generic Assessment Criteria (mg/kg)		Samples which exceed residential GAC
				Residential with homegrown produce	Commercial	
Arsenic	5.3	**63.2**	63	37	640	**TP112 0.35m 63.2mg/kg** *TP146 0.20m 44.3mg/kg*
Cadmium	0.5	3.5	63	22	410	None
Chromium	13.3	87.5	63	910	8600	None
Hexavalent Chromium	<0.8	<0.8	63	21	49	None
Copper	7.8	1550	63	2,400	68000	None
Lead	20	**1050**	63	200	2300	**TP112 0.35 m 1050mg/kg** *TP127 0.20m 222mg/kg* *TP128 0.10m 547mg/kg*

						TP140 0.1m 352mg/kg *TP141 0.1m 613mg/kg* **WS105 0.25m 214mg/kg** *WS113 0.7m 320mg/kg*
Mercury[1]	0.6	0.8	63	40[1]	1100	None
Nickel	9.8	153	63	130	980	**TP112 0.35m - 153mg/kg**
Selenium	<1.0	<1.0	63	250	12000	None
Zinc	66.1	2850	63	3,700	730000	None

Notes to table

1. *Assessment criterion based on inorganic mercury*
2. *Values in italics relate to samples located in the proposed commercial use area.*
3. *Values in bold relate to samples located in the proposed residential use area*

Of the 63 samples tested for heavy metals, arsenic, lead and nickel were recorded at concentrations above residential land use GACs. Of samples collected from the proposed residential land use area (Western Area) only soil samples collected from TP112 and WS105 reported metal contaminants at concentrations above screening criteria.

The sample from TP112 at 0.35m recorded arsenic, lead and nickel at concentrations above residential GAC, the trial pit log records black stained sand and gravel fill beneath a reinforced concrete slab. WS105 at 0.25 m recorded lead at concentrations marginally above the GAC. Made ground was recorded to 0.40 m in this location and included brick and 'blacktop'/clinker fragments.

Five soil samples collected from the Eastern Area reported lead at concentrations above the residential GAC, but at concentrations less than the commercial land use GAC.

Samples collected from 'natural' soils did not record metal contaminants at concentrations above the soil screening criteria.

30.2 Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs are widespread within made ground and the urban environment generally. They are one of the most common contaminants in made ground and the one that most commonly drives remediation. Benzo(a)pyrene is a particular problem, being very commonly found in

association with tarmac, clinker and any burnt products and also being highly toxic to human health.

The mean Soil Organic Matter of the population has been used to determine an appropriate Tier 1 GAC and results are summarised as follows:

Table 22: Summary of BaP and Naphthalene

Determinant	Minimum (mg/kg)	Maximum (mg/kg)	Number of samples tested	Tier1 Generic Assessment Criteria[1] (mg/kg)		Samples that exceed GAC
				Residential with home grown produce 2.5% SOM	Commercial	
Benzo(a)pyrene[1]	0.2	87.3	63	5.0	77	*BH104 at 0.5m-6.3mg/kg* **WS105 at 0.25m-87.3mg/kg** *TP141 at 0.10m-14mg/kg*
Naphthalene[2]	0.2	1.2	63	5.6	190	None

Notes to table

1. *As a surrogate marker for genotoxic PAH*
2. *As a marker compound for threshold PAH*
3. *Values in italics relate to samples located in the proposed commercial use area.*
4. *Values in bold relate to samples located in the proposed residential use area.*

Three samples recorded benzo(a)pyrene above the 5mg/kg GAC for a residential setting with plant uptake. It is noted that the highest concentration, 87.3mg/kg recorded at WS105 at 0.20m was sampled from the former car park area to the northwest of the retained building.

Two soil samples collected from the Eastern Area (TP141 at 0.10 m and BH104 at 0.50 m) exceeded the residential GAC concentration for benzo(a)pyrene, but were less than the commercial GAC.

Naphthalene in the samples tested was not detected at concentrations above GAC for either residential or commercial land use.

No elevated PAH concentrations were recorded within the eight natural soils tested.

30.3 Petroleum Hydrocarbons (PHC)

Speciated PHC testing spilt by aromatic and aliphatic fractions and by carbon chain length, was carried out on 15 samples taken from made ground, reworked soils and natural deposits. The rationale for the analysis was based on olfactory or visual signs of hydrocarbons, noting that non-aqueous phase liquids, tars, heavy oil or strong hydrocarbon odours were not observed in any of the trial holes excavated during this phase of investigation.

A summary of total petroleum hydrocarbon concentrations detected is summarised below:

Table 23: Summary of Petroleum Hydrocarbon Results

Matrix	Exploratory location and depth	Total >C5-C40 Aliphatic/Aromatic concentration (mg/kg)
Made ground	TP112 – 0.1m	1050
	TP112 – 0.35m	14.3
	TP124 – 0.9m	*1.5*
	TP131 – 0.3m	*210*
	TP150 – 0.3m	*24*
	TP151 – 0.7m	*47.1*
	WS102 – 0.2m	*1170*
	WS105 – 0.25m	2140
Reworked Clay	*TP117 – 0.6m*	*387*
Silt	*TP126A – 1.0m*	*1.1*
	TP111 – 0.4m	5.1

Notes to table

1. *Values in italics relate to samples located in the proposed commercial use area.*

In all samples tested none of the PHC fractions exceeded the residential or commercial GAC.

Sample TP112 at 0.1m comprised blacktop hardstanding and samples TP112 0.35m, TP131 0.3m, WS102 0.2m and WS105 0.25m contained blacktop fragments or were closely overlain by blacktop hardstanding. No BTEX compounds were recorded at concentrations above the analytical limits of detection in any of the samples tested.

It should also be noted that the current works comprised non targeted testing across the site to provide information on post demolition ground conditions and did not specifically target areas where hydrocarbons had previously been encountered or where remediation of grossly

impacted soils was known to occurred. However, where trial holes coincided with these areas evidence of PHC was not recorded.

30.4 Volatile and Semi Volatile Organic Compounds (VOCs and SVOCs)

Two samples were tested for the presence of VOCs and SVOCs. No VOCs above the 10 µg/kg detection limit were recorded in either sample. Several SVOCs were detected above analytical limits of detection, most of related to PAH compounds and were not at concentrations above relative assessment criteria for their marker compounds for a residential end use. Low concentrations, at or slightly above, the detection limit of the following SVOC were recorded in TP115 at 1.4m: 3 and 4 methylphenol, 2-methylnaphthalene, 1-methylnaphthalene and carbazole. Given that carbazole (recorded at 0.04mg/kg) is a PAH, the risk posed from this compound is considered against benzo(a)pyrene (residential GAC 5mg/kg). It is therefore not considered to be significantly elevated. The methyl naphthalene compounds (0.01mg/kg) are also not considered a risk compared with the naphthalene GAC of 5.6m/kg.

It is noted that previous post demolition investigations also recorded low levels of carbazole and limited other SVOCs and their risk was assessed using benzo(a)pyrene as a marker compound. The concentrations were recorded at below the benzo(a)pyrene GAC and determined not a significant risk.

30.5 Asbestos

Sixty-six samples from the current investigations were screened for the presence of asbestos containing materials and/or loose asbestos fibres.

Asbestos was detected in one sample, namely chrysotile bitumen in TP133 at 0.1m. In a previous investigation by LEAP (August 2020), no asbestos was found and investigations carried out previously by others post-commencement of demolition recorded 11 positive asbestos identifications.

No visual signs of ACM were noted at surface during this phase of the investigation. On the basis of the visual inspections and laboratory testing the risk of ACM contamination of surface ground by the security breaches and removal of valuable metals from the retained building noted by WSCC in Section 8 is not considered to be significant.

30.6 Poly Chlorinated Biphenyls (PCBs)

Eight samples were tested for total PCB content as for waste classification purposes. One sample of made ground from TP108 at 2.0m recorded a total PCB concentration of 0.03mg/kg, which is at the analytical detection limit.

TP108 is located in the Western Area north of the footprint of Building 18. Historical and anecdotal records and previous reports have not identified potential PCB sources at this location.

31 Analytical Test Results – Water

Three rounds of groundwater monitoring of the deep groundwater wells installed within BH101-BH106 were undertaken between 8th February and 9th March 2021. A single shallow groundwater sample was collected from BH101S on 6th April 2021, to ascertain if the phenol and xylene recorded in BH101D was from a shallow source. A summary of the recorded contaminant concentrations and the Tier 1 assessment criteria are summarised below.

Table 24: Summary of Groundwater Test Results Above Tier 1 Assessment Criteria

Determinant (Total, unless otherwise specified)	Measured Range (µg/l)	Tier 1 Assessment Criteria (µg/l)		Samples that exceed Tier 1 Criteria
		UK Drinking Water Standard[2] or other relevant standard as indicated	Annual Average Environmental Quality Standard	
METALS				
Copper	<5-13	2,000	1(bio)	*BH101D 1st round only* *BH101S* *BH105 All rounds*
Mercury	<0.1-0.3	1	0.07	*BH101D 1st round* *BH101S*
Nickel	<5-46	20	4 (bio)	*BH101D All rounds* *BH102 2nd and 3rd round* **BH104 1st and 2nd round** *BH104 3rd round* *BH105 2nd and 3rd round* *BH106 1st and 2nd round* **BH106 3rd round** **BH101S**
Zinc	<5-21	5000	10.9	*BH102 3rd round* *BH104 All rounds*

				BH106 3rd monitoring round
Cyanide	<5-18	50	1	*BH105 3rd monitoring round* *BH101S*
PHC				
Total Petroleum Hydrocarbons (TPH)	<5 – 357	10 [4]		**BH101D 2nd and 3rd Monitoring round** **BH101S**
Phenols	<1 – 392	-	7.7	*BH101 All rounds* *BH105 3rd monitoring round*
PAHs				
Benzo(a)pyrene	<0.1 – 0.01	0.01	0.00017	**BH101D 2nd monitoring round** **BH101S**
BTEX				
Xylenes[6]	<1 – 72.4	3	30	**BH101D 2nd and 3rd rounds** **BH101S**
Others				
pH	6.3-12.4	6.5-9.5	6-9	**BH101D All rounds** **BH101S** **BH104 2nd and 3rd round** **BH105 1st and 2nd monitoring round**

Notes to Table

1. *Range in Assessment criterion representing variation in dissolved $CaCO_3$ within waters*
2. *UK Drinking Water Standards, unless otherwise stated*
3. *WHO drinking water objective 2017 (2008 for petroleum hydrocarbons)*
4. *Assessment Criterion based on former target concentration for dissolved or emulsified hydrocarbons – now withdrawn.*
5. *Values in italics exceed UK EQS, values in **bold** exceed UKDWS*
6. *EA 2017 Hazardous substances to groundwater: minimum reporting values*

Nickel was marginally above UK DWS in BH104 in the first two monitoring rounds and in BH101 (shallow) and BH106 on one occasion.

Total TPH was recorded above a withdrawn screening criterion of 10 µg/l in BH101 (deep) during the second and third monitoring rounds (values ranging from 76.3 µg/l to 357 µg/l) and in BH101 (shallow) in the single sampling round (126 µg/l), but below published WHO TPH guidance values for speciated petroleum hydrocarbons in all samples tested.

Xylene was reported above an indicative minimum reporting value of 3 µg/l in BH101 (deep) in the second and third monitoring rounds (72.4 to 75.3 µg/l) and BH101 (shallow) (28 µg/l) only.

Benzo(a)pyrene was reported at analytical detection limit (0.01 µg/l) in BH101 (deep) on the second monitoring round and BH101 (shallow) during the additional monitoring round.

Potential contaminants that exceeded the published UK Environmental Quality Standards are copper (BH101D/BH101S), mercury (BH101D/BH101S), nickel (BH101D/ BH101S, BH102, BH104, BH105, BH106), and zinc (BH102, BH104, BH106). Cyanide was recorded above the EQS value in BH105 in the final monitoring round, but below the UK DWS.

Phenol was detected above UK EQS in BH101D during all monitoring rounds, but not in the single shallow ground water sample collected from BH101S. Phenol was also marginally above the UK EQS in BH105 during the last monitoring round.

pH values fall outside of the published UKDWS or UKEQS ranges for groundwater sampled in BH101D/S, BH104 and BH105.

32 Land Gas Monitoring Results

As described above six gas monitoring rounds have been completed at the site and the results are provided in Appendix I and summarised in Table 25, below:

Table 25: Summary of land gas monitoring results

Monitoring Visit Date / Location Ref.	Maximum Recorded Concentration*							
	CO_2 (%)	CH_4 (%)	CO (%)	O_2 (%)	VOC peak (ppm)	Peak Flow rate (l/hr)	Atmospheric Pressure (mB)	Was response zone flooded?
WS102								
08/02/21	0.9	0.1	0	16.0	1.2	-1.7	996	Yes
22/02/21	0.1	0.1	0	20.5	0.7	0	1013	Yes
08/03/21	1.1	0.1	2	19.7	0.4	0	1025	Partially
15/03/21	0.2	0.2	0	20.8	n.m.	0.03	1017	Partially
22/03/21	0.7	0.2	0	20.2	n.m.	0	1024	Partially
06/04/21	2.0	0	0	20.2	0.1	0	1017	No
WS103								
08/02/21	0.1	0	21	20.3	0	0.1	1008	Yes
22/02/21	0.1	0.1	9	20.8	1.1	-2.3	1013	Yes
08/03/21	0	0	1	21.0	0.8	-3.0	1022	Yes
15/03/21	0	0.1	1	20.9	n.m.	0.1	1017	Yes
22/03/21	0.1	0.1	7	20.0	n.m.	13.7	1024	Yes
06/04/21	0	0.1	15	19.8	5.3	0.0	1017	Partially
16/04/21	0.8	0.0	-10	20.1	n.m.	0.60	1025	No
WS105								
08/02/21	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.
22/02/21	8.6	0.1	4	18.3	3.9	-2.7	1013	Yes
08/03/21	0.6	0.1	0	21.1	1.0	0	1020	Yes
15/03/21	0.1	0.1	0	21.2	n.m.	0	1017	Yes
22/03/21	0.1	0.2	0	21.2	n.m.	0	1022	Yes
06/04/21	4.8	0.2	0	19.0	1.1	0	1017	Yes
WS106								
08/02/21	0.9	0.1	0	16.0	0	0	1009	Yes
22/02/21	0.6	0.5	0	16.2	1.2	-5.7	1013	Yes
08/03/21	1.7	0.4	0	15.3	0	0.1	1022	Partially
15/03/21	0.7	0.4	0	15.3	n.m.	3.8	1017	Partially

Monitoring Visit Date / Location Ref.	Maximum Recorded Concentration*							
	CO_2 (%)	CH_4 (%)	CO (%)	O_2 (%)	VOC peak (ppm)	Peak Flow rate (l/hr)	Atmospheric Pressure (mB)	Was response zone flooded?
22/03/21	0.8	0.3	0	14.5	n.m.	0	1017	Partially
06/04/21	0.7	0.1	0	13.6	0.8	0	1017	Partially
16/04/21	0.7	0.0	0	16.5	n.m.	0	1025	Partially
WS108								
08/02/21	0.9	0.1	11	20.0	1.8	-5.1 (0.0)	997	Yes
22/02/21	1.5	0.1	1	19.7	1.5	0	1014	Yes
08/03/21	2.4	0.1	0	20.5	1.2	-0.2	1021	Yes
15/03/21	0.2	0.2	0	20.9	n.m.	0	1017	Yes
22/03/21	3.0	0.1	0	20.8	n.m.	4.1 (0.0)	1022	Yes
06/04/21	1.6	0.1	0	19.5	0.8	2.0 (0.0)	1017	Partially
WS109								
08/02/21	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.
22/02/21	0.2	0.3	0	20.4	4.5	0	1013	Yes
08/03/21	0.5	0.1	0	21.1	0.1	0	1021	Yes
15/03/21	0.5	0.2	0	20.5	n.m.	0	1017	Yes
22/03/21	0.1	0.2	0	20.6	n.m.	0	1022	Partially
06/04/21	0.3	0.1	0	21.0	0.3	0	1017	Yes
WS111								
08/02/21	0	0	0	14.8	0.8	0.4	1001	Yes
22/02/21	0.1	0.1	0	20.3	0.6	-0.1	1013	Partially
08/03/21	0.1	0.1	0	20.7	0.3	0	1021	No
15/03/21	0	0.1	1	20.8	n.m.	0	1016	No
22/03/21	0	0.2	0	20.8	n.m.	0	1022	No
06/04/21	0	0.1	0	21.1	0.6	0	1017	No
WS113								
08/02/21	0.1	0.1	3	20.5	3.1	0.8	1000	Yes
22/02/21	0.1	0.2	0	20.8	4.8	0	1013	Yes
08/03/21	0	0.1	0	20.7	2.5	0	1021	Partially

Monitoring Visit Date / Location Ref.	Maximum Recorded Concentration*							
	CO_2 (%)	CH_4 (%)	CO (%)	O_2 (%)	VOC peak (ppm)	Peak Flow rate (l/hr)	Atmospheric Pressure (mB)	Was response zone flooded?
15/03/21	0	0.2	0	20.4	n.m.	0	1016	Partially
22/03/21	0	0.2	0	20.4	n.m.	0	1022	Partially
06/04/21	0.1	0.1	0	20.5	2.4	0	1022	No
WS115								
08/02/21	0	0	0	16.2	0.8	17.7 (0.0)	1001	Yes
22/02/21	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.	1013	Yes
08/03/21	0.1	0	0	21.3	0.2	-0.1	1020	Partially
15/03/21	0	0.2	0	21.3	n.m.	-0.1	1016	Yes
22/03/21	0	0.2	0	16.5	n.m.	10.1 (0.0)	1022	Yes
06/04/21	0	0.1	3	17.9	1.2	0	1017	Yes
WS116								
08/02/21	0.7	0	0	16.1	0.1	-1.1	995	Yes
22/02/21	0	0.2	0	21.1	0.6	-0.1	1013	Yes
08/03/21	0.1	0	0	21.1	1.1	-0.1	1021	Yes
15/03/21	0	0.1	0	21.1	n.m.	0	1016	Yes
22/03/21	0	0.2	1	20.8	n.m.	0	1023	Yes
06/04/21	0	0.1	1	21.2	3.2	0	1016	Yes
WS118								
08/02/21	0.1	0	0	2.6	0.8	66.6 (1.5)	996	Yes
22/02/21	1.7	0.1	0	20.8	1.2	0	1012	Yes
08/03/21	1.6	0	0	19.3	0.2	0	1022	Yes
15/03/21	0.4	0.2	1	21.0	n.m.	0.5 (0.0)	1016	Yes
22/03/21	1.4	0	0	19.3	n.m.	0	1024	Yes
06/04/21	3.6	0.1	0	13.2	0.4	0	1016	Yes
BH101S								
08/02/21	0	0	0	16.2	3.1	0.3 (0.1)	1000	Yes
22/02/21	0.1	0.2	0	21.0	0.4	0	1013	Partially
08/03/21	0.1	0.1	0	21.2	1.4	0	1021	Partially

Monitoring Visit Date / Location Ref.	Maximum Recorded Concentration*							
	CO_2 (%)	CH_4 (%)	CO (%)	O_2 (%)	VOC peak (ppm)	Peak Flow rate (l/hr)	Atmospheric Pressure (mB)	Was response zone flooded?
15/03/21	0	0.2	1	20.8	n.m.	0	1016	Partially
22/03/21	0	0.2	0	20.8	n.m.	0	1022	Partially
06/04/21	0	0.1	0	19.7	5.4	0	1022	Partially
BH103S								
08/02/21	0.1	0.1	0	16.0	1.2	-0.1	996	Yes
22/02/21	0.1	0.1	0	21.1	1.7	-0.1	1013	Yes
08/03/21	1.2	0.1	0	15.6	0.6	0	1020	No
15/03/21	0.2	0.2	0	20.3	n.m.	0	1016	Partially
22/03/21	1.0	0.2	0	14.9	n.m.	0	1023	Partially
06/04/21	0.9	0.2	0	17.6	3.2	0	1016	Partially
BH106								
19/01/21	13.6	0.0	0	1.0	n.r.	104	984	n.r.
08/02/21	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.
22/02/21	0.1	0.1	0	21.2	0.3	5.7	1014	Partially
08/03/21	7.9	0	9	10.4	0.4	3.8	1022	Partially
15/03/21	0	0.1	0	21.2	n.m.	3.4	1022	Partially
22/03/21	0	0.1	0	20.8	n.m.	3.6	1024	Partially
06/04/21	8.1	0.1	32	10.1	0.5	2.8	1016	Partially
16/04/21	0.0	0.0	-10	20.5	n.m	52 (7.2)	1025	Partially

Notes to table

** With the exception of Oxygen which is recorded as minimum*

n.m. – not measured

Values in bracket steady state readings

Seven land gas monitoring rounds have been carried out at the site during this investigation. Carbon dioxide concentrations ranged from 0.1% to 13.6% and methane concentrations ranged from 0.1% to 0.5%. A maximum flow rate of 104 l/hr was reported in BH106, noting that this was outside of the programmed monitoring visits. The first monitoring round was undertaken during low <1000 mB atmospheric pressure conditions.

Detected carbon monoxide concentrations ranged from 1 up to 32 ppm measured in BH106.

We note that the response zones in all wells were flooded or partially flooded during one or more of the monitoring rounds, as such the gas concentrations and flow rates in monitoring wells affected by fully flooded wells are not representative of land gases for the stratum that they are screened within.

Outside of the planned gas monitoring rounds, and as described in Section 13.5 on 19th January 2021 land gases were observed venting from ground around the headworks to BH106. A flow rate of 104 l/hr was recorded from the gas valve, with 13.6% carbon dioxide, 0% methane, 1.0% oxygen recorded. The high flows were noted for several days following the initial event. The response zone from BH106 was screened across the Tunbridge Wells Sand Formation from 11-20 m. Significantly high flow rates were not recorded in BH106 in subsequent monitoring rounds, with the exception of an additional visit on 16/04/21 where a peak flow of 52 l/hr was recorded reducing to a steady state reading of 7.2 l/hr.

33 Risk Assessment

33.1 Human Health

This investigation found that the made ground and reworked soils beneath the site are locally impacted with arsenic, lead, nickel, and benzo(a)pyrene for a residential land use. Figure 13 highlights sample locations with contaminants above a residential GAC. Asbestos was identified in one location. Previous investigations by KDC Contractors Ltd in 2015/16 also identified elevated concentrations of arsenic, beryllium, lead, copper and benzo(a)pyrene for a residential land use and asbestos in onsite soils.

These determinands pose a risk to residential land users in uncapped areas i.e. gardens or soft landscaping. Contamination may impact human health through the direct ingestion, inhalation, skin contact and/or plant uptake pathways that would be present in a residential setting.

For a commercial land use, potential contaminants of concern were not recorded at concentrations above generic assessment criteria and as such the existing soils are not considered to pose an unacceptable risk for this land use. The exception is asbestos in soils, which could also pose a potential risk to commercial land users in soft landscaped areas, as well as for the construction workers on site present during the construction works phase.

PAHs and PHC contamination may pose a risk to incoming water via permeation into the supply lines. LEAP has not been made aware of the proposed locations of services. The use of protective water supply infrastructure may be required by the water supplier if water services are to be placed within the made ground soils on site.

Some remediation to eliminate human health risk from potential asbestos fibres, heavy metals and benzo(a)pyrene would be required within all soft landscaped areas (private gardens, public open space and commercial landscaped areas) – See Section 36. A remediation strategy addressing these areas will also be required.

There remains the possibility that as yet unidentified contamination may be present, particularly north and south of the retained building where below ground services limited investigations in these areas, including possible below ground interceptors and historically decommissioned fuel storage tanks.

33.2 Controlled Waters

33.2.1 Groundwater

Previous investigations recorded some potential contaminants of concern at elevated concentrations above screening criteria in the shallow perched aquifer. Although discounted as a risk to groundwater the previous investigations did not investigate the groundwater quality of the deeper aquifer. This investigation has found that there is a shallow perched groundwater towards the base of the made ground layer, but also groundwater seepages in the upper layers of the Upper Tunbridge Wells Sand Formation (generally between 1-2m bgl). However, there are differences between recorded groundwater elevations in the deep and shallow monitoring wells, which imply that there is limited connectivity between the shallow and deeper groundwater bodies and the weathered clays and silts at the top of the bedrock may limit vertical migration of potential contaminants of concern.

With respect to risks to the deep aquifer BH105 and BH106 located in the western half of the site within the Secondary A Aquifer of the Tunbridge Wells Sand - sandstone and mudstone. BH101-BH104 are in the eastern half of the site within the unproductive aquifer of the Tunbridge Wells Sand – mudstone.

The groundwater laboratory tests recorded nickel at concentrations above UK Drinking Water Standards in three location namely BH104, BH106 and BH101S. Nickel was reported at concentrations between 21 and 28 µg/l in BH104 and BH106 and 46 µg/l in BH101S compared with the screening value of 20 µg/l. Nickel was not detected above UK DWS in BH101D. Soil testing of shallow made ground or reworked soils at these locations did not report nickel concentrations in soils above normal background concentrations (42 mg/kg) suggesting that a significant soil source is not present at these locations.

BH104, BH106 and BH101S are located in an area where the bedrock is mapped as unproductive strata. On the basis of marginal exceedances, low sensitivity of the aquifer (mapped as an unproductive aquifer) and absence of potable water abstractions proximal to the site, identified nickel is not considered to pose a significant risk to groundwater receptors.