Hydrogeological Risk Assessment

Environmental Permit Application
Deposit for Recovery at
The Wave London
Meridian Way, Enfield
London N9 0AR

The Wave London Ltd

2309 R03: Issue 2

July 2025

EPR/VP3821SV

GEMCO

Green Earth Management Co Ltd

Title	Hydrogeological Risk Assessment, Env Permit Application Deposit for Recovery The Wave London, Meridian Way Enfield, London N9 0AR
Prepared for	The Wave London Ltd Main Road Easter Compton Bristol BS35 5RE
EA ref	EPR VP3821SV
File reference	2309
Report number	R03 Issue 2
Date	4th July 2025
Prepared by	Green Earth Management Company Limited Suite 3 Broomfield Park Coggeshall Road Earls Colne Essex CO6 2JX

	Name	Signature	Date
Author:	**P Taylor**		4th July 2025
Author:	**C. Unsworth**	C Unsworth	4th July 2025
Reviewer:	**D. Robson**	Diane Robson	4th July 2025
Authorised by:	**D. Robson**	Diane Robson	25th June 2025

Issue Record						
Project No	2309					
Project Name	The Wave London					
Client	The Wave London Ltd					
Report Title	Hydrogeological Risk Assessment					
Report No.	**Author**	**Reviewer**	**Date of Issue**	**Issue No.**	**Details of Changes**	**Distribution**
R03	PT/CU	DR	10 Mar 2025	-	DRAFT Enhanced pre-app	Environment Agency
			4 July 2025	2	Revised following EA comments	Environment Agency

CONTENTS

REPORT TABLES

FIGURES AND APPENDICES

1. INTRODUCTION

1.1. General

Green Earth Management Company Limited (GEMCO) was commissioned by The Wave London Ltd (the Client) to prepare a site-specific Hydrogeological Risk Assessment (HRA) in support of an application for a bespoke Environmental Permit to permanently deposit waste on land as a recovery activity (DfR) at the Lee Valley Golf Course and Camping & Caravan Park, in Enfield, London. A Site Location Plan is presented at Figure 1 and the application site boundary is presented at Figure 2.

A redevelopment is proposed to replace part of the golf course with an artificial surfing lake and associated facilities and further activity zones (play areas and skate park, etc.); also see Section 1.2.

The site is a former landfill and a cut and fill program are proposed to allow re-engineering of the site to achieve the required levels / development platform specification. The waste recovery operation is required to facilitate this cut and fill program (also see Section 1.3).

The Environment Agency permit / pre-application reference is EPR/VP3821SV/P001-P003.

The HRA is based on the Conceptual Site Model (CSM) presented in the ESSD report 2309 R02.

1.2. Development Proposal

The details of the proposals are currently being developed through pre-application discussions with the London Borough of Enfield (LBE), the Greater London Authority and other key stakeholders. A masterplan of the current proposal is presented at Appendix 1. In summary, the proposal comprises:

- An ‘Endless Wave’ surf lake;
- Operational infrastructure (wave generation, water management/plant buildings) approx. 1,250sqm;
- A clubhouse (approx. 2,500sqm) to include a reception area, surf shop, café/bar, changing facilities, hire facilities and ancillary uses;
- Renewal of existing camping facilities, with provision for additional single storey buildings (accommodation / amenity facilities) of approximately 400 sqm;
- Up to four structures in the landscape, totalling approximately 600sqm, to provide shelter and ‘pop ups’ in the landscape. These may include structures such as a bandstand-style shelter, and lake-side ‘briefing area’, viewing shelters/banks, and covered picnic areas;
- Flood lighting of the surf lake and related external lighting of the site;
- Car Parking;
- Adventure and natural play area;
- Native parkland, nature trails, and an Ecological Corridor along the west boundary;
- Health & Wellness provisions;
- Skate and bike pump track; and
- Cycle Hire.

1.3. Proposed Waste Recovery/ Developmental Operations

1.3.1. Requirement for Cut and Fill Scheme and Waste Recovery Operation

The construction of the surf lake and ancillary buildings requires excavation within the former permit boundary to create the lake and placement of soils to create the landforms associated with the remaining areas of the development. A earthworks cut & fill exercise is required to engineer and reprofile the Application Site to the required levels for construction.

The Site comprises a former infilled land (*Conduit Lane* ref. 8EN017; see Section 2.6.2) and therefore a waste recovery operation/permit is required to allow the re-use of site-won materials. The case for a waste recovery has been outlined in the Waste Recovery Plan (R.4, submitted to the EA and agreed March 2025).

1.3.2. Cut & Fill Scheme and Volumes

The cut and fill scheme is set out in detail in Appendix 1.

Overall, on the basis of the proposed earthworks (top of proposed surf lake at 15.75mAOD) the proposed cut volume is 35,631m^3, with an estimated 4,401m^3 loss of material from removal of unsuitable or hazardous waste (876m^3) for disposal, or segregation of hardcore for recycling as aggregate (3525m^3).

The fill volume required is 31,800m^3, therefore the Mass Balance is a deficit of 570m^3.

It is important to note that no excavation or placement of waste or recovered material is proposed within/below the groundwater as part of the recovery operations.

The estimated total volume of the entire waste deposit is in the order of 1,500,000m^3. The total cut volume (roughly 36,000m^3) represents about 2.4% of the total volume of the deposit, and therefore is considered unlikely to substantially affect the overall Site condition.

Minimal thickness of existing waste deposit is nominally 11m.

Further it is important to note that whilst the scheme will entail relocation of made ground / Historic Waste (HstW) within the Site boundary to other areas where similar ground conditions is already present it will not materially relocate the HstW (contamination source) to areas that are not currently affected or to more sensitive areas (e.g. along the canal boundary). The proposed depths / volumes re-used material will also not significantly affect the general distribution of made ground soils across the Site; i.e. it will not significantly concentrate material or increase or decrease the depths of material at the Site in comparison to the current distribution. Further detail is provided in Section 1.4 and the ESSD report.

1.4. Engineering Proposals and Use of Waste for Recovery

The following drawings are presented at Appendix 1 showing the earthworks engineering proposals and intended areas for deposition of the recovered waste.

Drawing Reference	Content
WAVE-WHE-ZZ-XX-DR-S-0006	Design Levels (P02)
WAVE-WHE-ZZ-XX-DR-S-0007	Proposed Cross Sections (P02)
WAVE-WHE-ZZ-XX-DR-S-0008	Isopachyte (P02)
WAVE-WHE-ZZ-XX-DR-S-0009	Site Zones (P02)

The proposal involves the excavation of a wave pool, creation of a new landform, construction of landscape bunds and associated infrastructure, such as car parks, foot paths, utilities etc.

The difference between the existing ground level and proposed ground level are shown on the isopachyte drawing WAVE WHE ZZ XX DR S 008. The earthworks include the construction of four (4no.) landscaping mounds.

The maximum fill depth is associated with the bunds, which will be a maximum of 3m above the existing ground level. Filling in the area of the club house will be up to 1.5m.

The main areas of cut relate to the main wave pool and attenuation ponds.

1.4.1. The Wave Pool

Generally, the lake is being built in cut material so the overall increase in ground pressures is going to be marginal – Removing typically 1m of soil (at @ 18kN/m3) and replacing it typically with 1.5m of water (at 10kN/m3).

In addition, ground improvement will be undertaken over the whole footprint of the lake, with vibro stone columns or CMC's going through the waste material to the natural ground below. The settlement for these is limited to 25mm max.

1.4.2. The wave generation building

In ~5m of cut and sitting on ground improvement so there will be a relieving of the ground pressures rather than an increase. No waste will be used within the construction of the Wave Generation Building, or within the backfill around foundations.

1.4.3. The club house and surrounding external areas

The levels are being increased up to 1.5m so there will be an increase in pressure on the waste. However, this area is also being ground improved so the top surface of the fill and any structures above it will sit on the ground improvement (which, as above goes, through the waste and loads the natural ground below) rather than load the waste.

Settlement limited for this ground improvement is 25mm. So maybe typically an increase in load on the waste of 1m of fill at 18kN/m3

1.4.4. Road and car parks

No significant change in level so negligible change in load on the existing made ground / Historic Waste.

1.4.5. Bunds

There are four bunds proposed as detailed in Table 1.1 below and shown on the Drawings at Appendix 1.

Table 1.1: Schedule of Proposed Landscape Mounds					
Bund ref	**Site Area**	**Max height (m)**	**Footprint area (m^2)**	**Approx. Volume (m^3)**	**Side slope angle (degrees / gradient)**
Bund 1	Southern site boundary	3.00	7420.76	9000	≤18 / ≤1:3
Bund 2	Central site area, behind wave pool	2.86	3025.25	5100	≤18 / ≤1:3
Bund 3	Western boundary	2.86	2838.95	5000	≤18 / ≤1:3
Bund 4	Northern site area	2.70	1310.12	1550	≤18 / ≤1:3
			Total Volume m^3	20600	

There will be an increase in load under the bunds. Further discussion is provided in Section 6.7.

1.5. Site Layout / Area Terminology

The wider site area (Lee Valley Golf Course and Camping and Caravan Park) can be divided into 2 (no.) areas: north and south (Figure 2). The south comprising the campsite and southern part of the golf course; and the north comprising a large lake and golf course. The areas are also distinguished by their historical site uses / development histories (Section 2.2).

In the previous site investigation reports relied upon for this assessment (Section 1.6), the southern and northern areas were referred to as Phase 1 and Phase 2 respectively; for the purpose of this report this terminology will carry through.

The proposed development relates to the 'Phase 1' area only, with no development proposed in the northern Phase 2 area. Therefore, for the purpose of this report the Phase 1 area is referred to as the 'Application Site'. The Application Site boundary is shown at Figure 2. The Masterplan is included at Appendix 1.

1.6. Ground Water-Body Terminology

The site investigation data (set out in Sections 3 and 4) indicate that the site is underlain by made ground (the waste body) across the entirety of the site, up to around 11.0m thick and thinning toward the eastern site boundary. The waste body overlays in part remnant Kempton Park Gravel (KPG) sand and gravel deposits and then / or directly the London Clay which is generally around 12 – 14m thick. The remnant KPG deposits are discontinuous across the site and relatively thin where present.

Groundwater monitoring data indicates a shallow water body in the made ground (waste body) and the KPG, with good hydraulic connectivity between the made ground and the KPG.

The water body in the waste would be classified as a 'leachate' and that in the KPG as 'groundwater'. Within the context of the site however, given the degree of hydraulic connectivity, the discontinuity of the KPG and its limited thickness and the underlying hydraulic boundary presented by the London Clay, there is no material / significant difference between the water in the waste body and that in the KPG (the site investigation chemical data bears this out).

Given the age of the materials in the waste body (>50yrs old) and their nature (largely inert construction and demolition wastes and soils) any 'new leachate generation' (i.e. additional contaminant load leachable from the waste soils) is likely to be very limited – both hypothetically and as borne out by the site data.

The water bodies in the waste and the remnant KPG are effectively the same water body (or are at least indistinguishable water bodies) comprising 'groundwater' inflowing from the north (the regional groundwater flow in the Lee Valley is north to south) and any infiltrated water from the site area. The groundwater quality at the site will be a compound of the water input from the north (through a highly developed area with a long and extensive industrial history) which is likely to carry a significant contamination signature plus any 'leachate' generated from the waste body.

The report refers to a shallow water body – which is the combination of the leachate and the 'groundwater' in the KPG; literally water in the ground including the 'leachate' and the 'groundwater'

The London Clay overlays the Lambeth Group, Thanet Sand Formation and Chalk within which there are deeper groundwater bodies.

1.7. Historic Waste and Terminology

The Application Site (the Site) is an historic landfill, which was permitted prior to the implementation of the European Union's Landfill Directive (1999/31/EC). The Site was therefore operated 'pre-directive' and did not have to adhere to the same stringent standard post-directive e.g. without engineered attenuation layers, waste acceptance, pre-treatment etc.

For the purpose of description in this report, the historic waste is also described as Made Ground.

1.8. Source Term

The source-term for the Deposit for Recovery is the historic waste, abbreviated to HstW, that will undergo a treatment process to remove geotechnically deleterious materials such as wood, metal, textiles, and ACM as far as practically possible. Recyclable inert materials such as concrete, brick, masonry and ceramics will be processed on-site to create aggregates for use in the construction works.

Section 3 presents the baseline ground conditions encountered and describes the physical characteristics of the made ground / HstW and the baseline groundwater observations.

Section 4 below provides a detailed characterization of the Source Term, which can generally be described as soils (clay, sand and gravel) derived from construction wastes. The characteristics of the Source Term are essentially represented by the characterization of the made ground / HstW described in previous sections, however, the treatment process will include the removal of grossly contaminated soils, degradable materials such as wood, textiles, paper etc.

1.9. Information Sources

The following site investigation reports were made available and reviewed by GEMCO for this assessment/ report:

- Norwest Holst Soil Engineering, Ground Investigation Report (Ref: F13229), May 2004 (R.1)
- Hydrock Consultants Ltd Desk Study Report (Ref: WAV-HYD-DS-RP-GE-1000-S0-P01), September 2018 (R.2); and
- Hydrock Consultants Ltd Site Investigation Report (Ref: WAV-HYD-XX-XX-RP-GE-1000-S2-P01, August 2019, and second issue (WAV-HYD-XX-XX-RP-GE-1000-S2-P02), December 2019 (R.3).
- Additional groundwater and surface water monitoring data and sampling / analysis results undertaken by Hydrock subsequent to the above reports provided by Hydrock.

Additional information has been provided by the Client (Topographic surveys, developmental information) or procured from free-to-access information resources (BGS, MagicMap etc).

It is noted that the Hydrock reports and Groundsure included in the Desk Study (R.2) refer to a site boundary which includes both the Phase 1 and 2 areas (Section 1.4). However, the Phase 2 area is not under consideration at this stage, and therefore the 'Site boundary' for the purpose of this report is considered to be the Phase 1 Application Site area only.

1.10. Findings of HRA

It is concluded in the HRA that the Site in its present condition does not pose a risk to controlled waters and further that the proposed deposition of recovered wastes does not pose a significant risk to controlled waters. The re-use of recovered wastes will be subject to Waste Acceptance Procedures which are described in the ESSD/ EMS and Appendix 6.

2. SITE DETAILS

2.1. Site Location and Context

The Site is located to the east of Meridian Way (A1055) and to the west of the William Girling Reservoir in Enfield, London N9 0AR, centred on British National Grid Reference TQ 36185, 94216 (Figure 1).

The Site comprises part of the Lee Valley Golf Course and Camping and Caravan Park. The golf course covers the majority of the Site with the camping ground in the north. The Application Site occupies an area of approximately 22.8 hectares.

The Site topography has three (3no.) plateaus; at and to the south of the campsite (17-18mAOD), in the south of the Site (14-15mAOD), and along the eastern extent (11-12mAOD). The general topographical trend is sloping down to the south/southeast, however to the north of the campsite the landform significantly drops into a bowl (with a lake in the centre) at around 10mAOD. There are artificial undulations and bunds throughout the golf course, and the highest point of the Site is a large bund to the south of the campsite at 22mAOD. A topographic survey is included in Appendix 3.

The Application Site is bounded to the south by Picketts Lock Lane with residential properties and a large sewage works beyond to the southwest and south, respectively. To the southeast are builders' merchants/yards, and to the east is the River Lee Navigation canal and the William Girling Reservoir.

To the west is the Lee Valley Athletics Centre, commercial spaces (including cinema) and parking, with the A1055 / Meridian Way beyond.

To the north of the Application Site is a continuation of the Lee Valley Golf Course with a large lake.

In the wider area, the Site sits within the Lee Valley in North London, with significantly built-up areas (largely residential) to the east (beyond the reservoirs) and west. There is significant commercial / industrial development in the Lee Valley corridor to the north and south of the Site. See Figure 3.

2.2. Summary of Site History

The site and surrounding area were open low land until the early 1900s – 1910s, adjacent to the River Lee Navigation (canal) to the east and around 300m form a railway line (Great Eastern Railway) to the west.

Gravel pits first appear in the centre of the Site in 1910, expanding in the 1930s over the majority of the Site and extending off-site to the west. The pits seem to have been infilled in the 1950/60s (contradicting landfill records, see Section 2.6.2) and restored to a golf course by the 1970s. The campsite was added in the 1990s.

A creosote works is shown just off-site to the west in 1910, disappearing by the mid-1930s following the westward expansion of the on-site gravel pits.

The area to the north of the Site (northern section of the current golf course) had a small pumping station and filter tanks (sewage works) around 350 – 450m north-west of the subject site close to the railway by the 1890s. This expanded in the 1900s and again between the 1930s and 1960s to occupy the whole area to the north of the Site.

The sewage works was cleared for gravel extraction works during the late 1970/80s with a lake consistent with the current layout. The northern area was recorded as a golf course by the 1990s.

Further north (beyond the current golf course area), by the 1890s there was a linoleum works and a White Lead Works around 500m and 750n north of the Site respectively. This area evolved to include chemical works, stone works, timber yard and cabinet works through the 1920s – 1960s and then to closer to its current layout in the 1970s – 80s. There was a small gas works 950m to the north by the 1860s, which expanded in the 1930s - 1960s to include large gas holders within 750 - 800m of the site.

By the 1890s there was a small sewage works around 600m to the south which expanded over time to encompass the whole of area between the railway and canal around 80m south of the Site.

Construction of the William Girling Reservoir to the east of the Site started in 1936 and completed by 1951.

More recent developments in the surrounding area include the Picketts Lock Centre just west of the Site (late 1990s) and the cinema/event centre complex (2000s). The athletic centre was added by around 2010.

2.3. Geological Setting

The local and regional geological setting based on BGS records are summarised in the table below:

Table 2.1. Published Geological Setting.	
Lithology	**Information**
Artificial Ground	
Infilled/worked Ground	Backfilled/deposited material - Present across the whole of the Application Site area except for the eastern margin (see below).
Made Ground (undivided/unspecified)	Present to the north (wider golf course and lake area), to the west between the Site and Meridian Way, and along the east margin of the Site.
Superficial Geology	
Alluvium (clay, silt, sand, gravel)	Present across the Lee Valley basin, indicated on the eastern margin of the Site.
Kempton Park Gravel (KPG, Sand and gravel)	Underlies the Alluvium in the Lee Valley basin. Indicated across the entire site except for on the eastern margin of the Site.
Bedrock Geology	
London Clay Formation (clay silt and sand)	Underlies superficial deposits in the entire surrounding area, outcropping at the surface to the east of the Lee Valley. Typically, brown/blue silty clay.
Lambeth Group	Mottled clay with sand and pebble beds.
Thanet Sand	Fine grained glauconitic sand.
White Chalk Subgroup	Chalk.

Only one (1no.) borehole is identified within the Application Site in the BGS borehole database, at the very north end (BGS ID: 12709960) at British National Grid 536150,194530. The log indicates made ground to 6.5m, logged as an (illegible) thickness of clay overlying "ash, clinkers, tin etc." No water was struck.

A number of boreholes are recorded north of the Application Site in the wider golf course area, and beyond to the west and to the south (Appendix 4). In summary, the boreholes to the north of the Site encountered:

- Made ground to 3.35mbgl;
- Alluvial deposits were only identified on the eastern side of the golf course;

- Generally, around 4-5mbgl to the base of the Kempton Park Gravel, overlying London Clay; and
- The base of the London Clay (where proven / encountered) was at around 12 – 14mbgl.

Boreholes to the west and south of the Site encountered:

- 'Ballast' / made ground (sand clay/sandy gravel with brick, clinker and ash etc) to 3-5mbgl;
- Sandy clay (recorded as alluvium, but potentially KPG) to 4.5 – 5.5mbgl;
- Sand and gravel/sandy gravel deposits to 5 – 6.5mbgl; and
- London Clay to >12mbgl.

All records indicate resting ground water levels at around 1.2 – 1.8mbgl.

The Groundsure report indicates extensive historic ground workings throughout the Site and the wider golf course area to the north. The surrounding area includes gravel extraction pits and unspecified ground workings/pit and cuttings which have been backfilled.

Prior to any gravel extraction and backfilling the Site geology would likely have comprised sandy clay overlying around 6m of Kempton Park sand and gravel, in turn overlying London Clay, Lambeth Group, Thanet Sand, and Chalk. The Kempton Park sand and gravel was the target of the gravel extraction activities.

2.4. Hydrogeological Setting

The hydrogeological setting is summarised in in the table below:

Table 2.2. Published Hydrogeological Setting.		
Superficial Geology	Alluvium	Secondary 'A' Aquifer
	Kempton Park Gravel Member	Secondary 'A' Aquifer
Bedrock Geology	London Clay	Unproductive Strata
	Lambeth Group and Thanet Formation	Secondary 'A' Aquifer
	Chalk	Principal Aquifer

The southeastern-most corner of the Site is marginally within a groundwater Source Protection Zone (SPZ) Zone II (Outer) – associated with a Zone 1 (Inner Zone) 301m to the southeast. See Appendix 4.

The Zone II noted above also extends to the south-west of the Site around 250m from the Site at closest (associated with a number of SPZ I's to the south) and there are further SPZ II's around 350m north-east and 700m north of the Site.

There are no groundwater abstraction licenses located within 500m of the Site.

Between 500-1000m, there are six (6no.) active licensed groundwater abstraction licenses (closest 783m to southeast). All are Potable Water abstractions for Thames Water (North London Artificial Recharge Scheme, NLARS) which extract from the Thanet Sand and Chalk aquifers.

These abstraction licenses do not appear to correlate with the location of the SPZ centres.

2.4.1. *Groundwater Flow Direction and Hydraulic Gradient*

Groundwater flow in the shallow aquifer is expected to be generally north to south with a potential minor east to west component however the flow has likely been significantly disrupted by to the removal of the Kempton Park deposit and replacement with clay or clayey (i.e. lower permeability) infill material, as well as the reservoir to the east (puddle clay core etc) and the geology to the west.

The site data (presented and discussed in Section 3.4) indicates good hydraulic conductivity within and between the waste deposit and the residual Kempton Park Gravels. In terms of flow direction, the site data (with some local inconsistency likely due to the heterogeneity of the made ground) indicates a general gradient in the shallow aquifer / waste body from north to south (1:900) and very minorly west to east (1:4000). Little information is available to confidently determine the hydraulic gradient in the wider area.

With regard to potential hydraulic connectivity between the shallow and deep aquifers, no significant hydraulic connection between them would be expected given the significant thickness of the London Clay aquiclude between the made ground and the Thanet/Chalk (10-14m at minimum on the basis of the site investigation data presented in Section 3.2). This is borne out by the site data (Section 3.4).

Groundwater flow in the deep aquifers (Thanet/Chalk) is poorly defined and likely to be relatively complex however based on what might be expected considering hydrogeological principals and SPZ maps, it is likely to be toward the southeast on a regional level. No inferences can be made from the site investigation data.

2.5. Hydrological Setting

A ditch (identified variously as Pymmes Brook or Enfield Ditch) runs north-south in the east of the Site around 40m from the boundary. The brook/ditch joins other drainage channels to the south of the Site. The Groundsure (R.2) indicates it as water-bearing year-round in normal conditions, however the ditch has been observed to be dry during site inspections.

To the east of the Site, parallel to the east boundary, is the River Lee Navigation, which has a main canal and an overflow channel to the east with a tow path in between. The water level in the canal is around 11.0mAOD.

There is a lake (Ponders End Lake) around 100m to the north (formed by extraction activities in 1980s) within the current golf course area which measures roughly 315m x 220m with a water level of 10.8mAOD.

The William Girling Reservoir (WGR) is east of the canal (90m from the Site) beyond a large embankment (top at around 21mAOD). The WGR has a volume of approximately 16M m^3, with the water level in the reservoir at around 18mAOD and a mean depth of 12.2m. It therefore follows that the base of the reservoir is around 6mAOD. The depth to the reservoir base is consistent with the top of the London Clay as recorded by on-site SI data (5-7mAOD, Section 3.2.3).

The WGR was constructed between 1936 and 1951 and includes a puddle clay core in the embankments which is 3.7m wide at the base and extends into the underlying London Clay. The northwest corner was reinforced with sheet piles in 2020.

2.5.1. Surface Water Abstractions

There is one (1no.) active potable water abstraction within 500m of the Site, 198m north at Keids Weir.

The next nearest is 784m southeast (Chingford Supply Channel/ River Lee Diversion), however it is noted that this is on the eastern side of the reservoir, well Upgradient of where any surface water flowing past the Site would meet that watercourse.

2.5.2. Discharge Consents

There is one (1no.) licensed discharge consent on-site for 'miscellaneous discharges – surface water' to the Enfield Ditch, for the Picketts Lock Leisure Centre which was revoked in 1994 – the location is consistent with the ditch on-Site to the east of the campsite area. This should also not have had a significant impact on the Site if the discharge operated properly, and in any case was revoked in 1994.

The closest off-site discharge consents are 68m south (sewage discharges to the Enfield Ditch), and 102m south (process effluent) to a tributary of Enfield Ditch at Deephams Sewage Treatment Works.

Further trade and sewage discharges are located 150m-480m from the Site.

2.5.3. Surface Water Quality

Information on surface water quality, procured from Defra's Catchment Data Explorer (R.5) and Water Quality Archive (R.6) is summarised in the table below:

Table 2.3. Surface Water Quality.

Surface Water Body Reference	ID	Easting/ Northing	Ecological Rating	Biological Quality	Physicochemical Quality	Specific Pollutants	Chemical rating
Lee Navigation Enfield Lock to Tottenham Locks	GB 10603-8027 950	537482/ 194974	Poor	Poor	Moderate (ammonia High)	High	Fail[1]
Enfield Ditch (Pymmes brook) & Salmon Brook (Deephams STW to Tottenham Locks)	GB 10603-8027 910	534707/ 189464; 535649/ 192146	Moderate	Poor	Moderate (ammonia High)	High	Fail[1]

[1]Failed due to Poly-brominated Dipheny Ethers (PBDE), which failed by default as they are not tested for. Priority Hazardous Substances, Priority Substances, and 'Other Pollutants' were otherwise 'Good'.

The Lee Navigation Lock to Tottenham Locks sample was obtained from a channel to the east of the WGR. The Pymmes & Salmon Brooks sample(s) were obtained from Salmons Brook to the south of the Site near the A406, and where Salmon Brook meets the Lee Navigation further south beneath the A503.

2.5.4. Flooding

The EA Flood Map for Planning service (R.7) indicates that the majority of the Site is Zone 1 (low risk).

Areas of Flood Zones 2 and 3 are shown along the south-eastern margin of the Site (low-lying areas).

2.6. Environmental Setting

2.6.1. Environmental Permits, Land Use Records, and Registry Entries

The Site is currently a golf course and campsite. On-site records relate to electrical pylons (2no.), and a tank (generic) within the campsite area. Nearby off-site records are generally for tanks (generic), further pylons, electricity substations and container storage.

It is considered that none are likely to be significant in the context of this assessment.

The Groundsure report identified the following historical potentially contaminative land uses/features:

- **On-site:** Gravel pits, ground workings, heaps and cuttings; railway sidings, wharfs, and tanks.
- **On or in close proximity to the Site:** Creosote works and varnish works; sewage farm, filter tanks, pumping station and unspecified tanks; unspecified commercial industrial (1970s); and
- **Within the wider area:** Linoleum works, chemical and pharmaceutical works, lead works, gas works, stone works and cabinet works; other industrial/commercial sites; railway.

All appear consistent with the Site history, and do not offer any new source(s) of potential contamination. The Site has most recently been a golf course and campsite, which is considered unlikely to present a significant contributory source of contamination.

There is one (1no.) recorded pollution incident 4m south of the Site for 'inert materials and wastes / construction and demolition materials' in 2003. There are also a number of incidents in the surrounding area (59m-345m to the west, northwest and southwest), generally involving household waste or storm sewage between 2002 and 2003. Around 750-800m north of the Site there are also records of one (1no.) incident involving organic chemicals, and two (2no.) potentially harmful discharges to the public sewer, attributed to Aesica Pharmaceuticals Ltd.

A number of the sites had pollution control records, or registry entries for the control of potentially dangerous substances; Aesica Pharmaceuticals Ltd (organic chemicals), Merck Sharp and Dohme Ltd (chromium, copper, lead, nickel and zinc), Deephams Sewage Treatment Works, Shell Gas Ltd (LPG), and bulk cement, metal processing and coating purposes (all historical).

None of the activities identified are likely to have had a direct impact on the Application Site condition, but may potentially have had impacts on the general background environmental quality of the wider area.

2.6.2. Extraction, Landfill and Waste Sites

There is an historic landfill recorded on-site, covering the whole of the Application Site area plus the wider golf course to the north, and extending westward. The record is referred to as *Conduit Lane* (Ref. 8EN017), operated by Sir Alfred McAlpine and Son (Northern) Limited, which accepted inert waste, household waste, and liquid sludge between December 1979 and December 1985.

The landfill record is consistent with the outline of the gravel pits shown on historic maps (1930s); however, the dates of input (1979-1985) are not consistent as historic information shows the Application Site to have been restored to a golf course by the 1970s. Conduit Lane is identifiable roughly 1.5km south of the Site.

No landfilling records match the timeline of deposition demonstrated by the historical maps. The dates are however potentially consistent with the historic infilling of the northern area (formerly a sewage works, then subject to gravel extraction and restored to a golf course and lake by the 1990s).

There are also four (4no.) records 'ground workings and refuse heaps' on-site from the 1930s, and records of potentially infilled land (gravel pits, ponds, wharfs, heaps and unspecified ground workings) between the 1920s and 1960s.

The following waste records/sites are identified in the surrounding area:

- A (1no.) waste transfer facility (WEEE) planning application 6m southeast of the Site;
- A (1no.) historic landfill site 371m southwest (inert, industrial and liquid sludge 1958-1965);
- Four (4no.) other historic landfill sites 500m-1000m from the Site with waste types including household, but generally not recorded, operating principally in the 1960s and 1970s;
- Three (3no.) historic landfill sites within 1500m (last recorded input in 1960s);
- Two (2no.) refuse tips (or two records of the same tip) 368m and 377m south;
- Three (3no.) EA licensed waste storage sites between 366m and 479m of the Site;
- The Deephams Sewage Treatment Works within 100m to the south; and
- Numerous further sites within 1500m – including household, commercial and industrial' waste transfer stations, compositing sites, physical treatment facilities, and metal recycling.

Only the landfill recorded on-site is likely to have a significant direct impact on the Site, but the other sites may have had an impact on the general 'background' environmental quality of the area and the controlled waters quality in the wider area in particular.

Refer to plans at Appendix 4 (obtained from the Groundsure within the Hydrock Phase I report).

2.6.3. Environmentally Sensitive Areas

The Site (and surrounding area) is within a Nitrate Vulnerable Zone (NVZ) and the London Area Greenbelt. The reservoir 44m to the east of the Site is part of the Chingford Reservoirs SSSI (see Appendix 4).

No other environmentally sensitive areas were identified within 500m of the Site.

2.7. Climate

The Site is in north London, which has a temperate oceanic climate.

London in general is vulnerable to climate change from sea level rise and drought, the latter resulting in water shortages (R.8, R.9). The UK average annual rainfall has not changed since records began (18th century), however there has been a trend shift to increased winter rainfall, and summer droughts (R.10).

Met office data indicates an average annual precipitation (1991 – 2020) of 660mm for the 12 x 12km grid square which includes the Site (Grid ID: BK-88, R.11).

Nearly half of all rainfall is lost to evapotranspiration, with the remaining running into surface waters and percolating into the ground, known as Effective Rainfall (R.10).

Considering potential climate change effects, there is potential for increased rainfall in the future but also this is likely to occur in more concentrated events (more extreme weather) which is likely to result in increased run-off rather than increased infiltration.

3. BASELINE GROUND CONDITIONS

3.1. General and Site Investigation Scope

This section presents a review of the current ground conditions based on the data available from site investigations (SI, or Ground Investigation – GI) undertaken and reports compiled by Norwest Holst and (primarily) Hydrock (Section 1.4) to inform the Site's baseline ground model.

The Hydrock SI in the Application Site area, undertaken in 2018/2019 can be summarised as:

- Initial intrusive site works (December 2018 and January 2019), comprising:
  - Eighteen (18no.) cable percussive boreholes (BH101 – BH115, 15no. locations but 3no. repeat boreholes at BH103A, BH104A and BH111A) to depths of 12.0 – 30.0mbgl;
  - Gas/groundwater well installations at eight (8no.) boreholes (details in Table 3.2);
  - Six (6no.) trial pit excavations (TP103, TP104, TP106-TP109) to a maximum 4.7mbgl;
  - Collection of forty-eight (48no.) soil samples for analysis; and
  - Return visits for ground gas monitoring and the sampling of ground- and surface- water;
- Supplementary Investigation (August and September 2019), comprising:
  - One hundred and forty-four (144no.) trial pit excavations to 0.3m to 3.3mbgl to further investigate the made ground/contaminant distribution with emphasis on asbestos;
  - Collection of two hundred and twenty-three (223no.) soil samples for analysis;
  - Collection of eighty-nine (89no.) potential asbestos materials for laboratory analysis; and
  - One (1no.) further round of gas monitoring and ground/surface water sampling.

A drawing (by Hydrock) showing the locations of the boring/excavations is included at Appendix 4.

A schedule of relevant boreholes is provided at Appendix 4.

3.2. Summary of Ground Conditions Encountered

A summary of the ground conditions encountered is presented below in Table 3.1.

In summary, made ground was encountered at all locations overlying superficial deposits consistent with remnant the Kempton Park Gravel (KPG) deposits, or directly overlying the London Clay (LC).

The Lambeth Group (LMB) was encountered at two (2no.) locations (BH101 and BH106), beneath the LC, with the Thanet Formation (Thanet Sand / ThSD) also identified at BH101. These are not represented in the summary table.

Note that none of the trial pits (up to a maximum depth of 4.7mbgl) penetrated the base of the made ground and are not included in the summary table.

The geological cross sections inferred on the basis of the published records and site investigation data discussed in the next sections, are presented in Appendix 2, GEMCO Drawings.

Table 3.1. Summary of Ground Conditions.										
Ref.	**GL**[1]	**MG**			**KPG**			**LC**		
		mbgl	**Thk (m)**	**mAOD**	**mbgl**	**Thk (m)**	**mAOD**	**mbgl**	**Thk (m)**	**mAOD**[2]
BH101	16.53	0.0-10.0	10.0	16.5-6.5	-	-	-	10.0-20.4	10.4+	6.5-(-3.9)[3]
BH102	16.05	0.0-8.5	8.5	16.1-7.6	8.5-10.0	1.5	7.6-6.1	***10.0-20.0***	***10.0+***	***6.1- (-4.0)+***
BH103	13.09	**0.0-2.5**	**2.5+**	***13.1-10.6***	-	-	-	-	-	-
BH103a	17.40	0.0-9.0	9.0	17.4-8.4	9.0-10.5	1.5	8.4-6.9	***10.5-15.0***	***4.5+***	***6.9-2.4+***
BH104	15.13	**0.0-2.4**	**2.4+**	***15.1-12.7***	-	-	-	-	-	-
BH104a	15.70	0.0-8.4	8.4	15.7-6.9	8.4-10.4	2.0	6.9-4.9	***10.4-15.0***	***4.6+***	***4.9-0.3+***
BH105	17.68	0.0-10.0	10.0	17.7-7.7	10.0-10.8	0.8	7.7-6.9	***10.8-20.0***	***9.2+***	***6.9-(-2.3)+***
BH106	13.79	0.0-4.4	4.4	13.8-9.4	4.4-8.4	4.0	9.4-5.4	8.4-27.5	19.1	5.4-(-13.7)[3]
BH107	17.85	0.0-11.0	11.0	17.9-6.9	***11.0-12.9***	***1.9+***	***6.9-5.0***	-	-	-
BH108	18.24	0.0-11.0	11.0	18.2-7.2	***11.0-13.0***	***2.0+***	***7.2-5.2***	-	-	-
BH109	14.69	0.0-7.4	7.4	14.7-7.3	-	-	-	***7.4-13.5***	***6.1+***	***7.3-1.2+***
BH110	14.37	0.0-8.0	8.0	14.4-6.4	-	-	-	***8.0-27.5***	***19.5+***	***6.4-(-13.1)+***[3]
BH111	13.78	0.0-8.0	8.0	13.8-5.8	-	-	-	***8.0-12.0***	***4.0+***	***5.8-1.8+***
BH111a	13.78	0.0-8.5	8.5	13.8-5.3	-	-	-	***8.5-20.0***	***11.5+***	***5.3-(-6.2)+***
BH112	14.90	0.0-8.0	8.0	14.9-6.9	8.0-9.5	1.5	6.9-5.4	***9.5-20.0***	***10.5+***	***5.4-(-5.1)+***
BH113	14.67	0.0-7.4	7.4	14.7-7.3	-	-	-	***7.4-16.0***	***8.6+***	***7.3-(-1.3)+***
BH114	14.58	0.0-6.5	6.5	14.6-8.1	6.5-9.0	2.5	8.1-5.6	***9.0-20.0***	***11.0+***	***5.6-(-5.4)+***
BH115	15.19	0.0-6.5	6.5	15.2-8.7	6.5-9.0	2.5	8.7-6.2	***9.0-15.0***	***6.0+***	***6.2-0.2+***

[1]Ground Level - elevation from Hydrock data, or where not surveyed inferred from topographic survey plan (Appendix 4).
[2]Bold+Italic = base of unit not proven (end of borehole).
[3]Depths to base of the unit presented are as logged by Hydrock – See section 3.2.3 for additional notes on / interpretation of the London Clay / Lambeth Group interface in BH101, BH106 and BH110 where the Lambeth Group deposits have (or are interpreted to have been- BH110) penetrated

See Table 3.2 in Section 3.4 for details relating to groundwater strikes/observations.

3.2.1. Made Ground & Existing Historic Waste (HstW)

Made ground, comprising the historic waste, was proven to 4.4m – 11.0mbgl (9.4m-5.3mAOD) across the majority of the Application Site area, and was generally thicker to the north, coincident with the higher ground, but to just 4.4m bgl (9.4mAOD) at BH106 near the eastern boundary (potentially nearing the limit of the historic gravel extraction). A plan of the made ground distribution/ depths (by Hydrock) is presented at Appendix 4.

The made ground is the upper covering soils (topsoil etc) and underlying infill material (HstW) used to restore the former gravel workings. The HstW material generally comprised sandy gravelly clays / clayey sandy gravels consistent with ‘typical’ inert construction type wastes (cohesive and granular soil with no discernible pattern laterally or vertically) with variable quantities of brick and concrete, ash, clinker, glass etc, and lesser quantities of organic material (again with no real discernible pattern).

Potential contamination was observed in the made ground material, as discussed at Section 3.3 and in Section 4.

3.2.2. Superficial Deposits (Kempton Park Gravel)

The made ground overlay deposits consistent with remnants of the Kempton Park Gravel (KPG) at ten (10no.) locations (and otherwise directly overlay the London Clay).

These are the deposits mined by the historic extraction activities at the Site.

The KPG generally comprised sandy gravels with pockets / layers of gravelly clay, and was generally 1 – 2.5m thick, but up to 4.0m thick at BH106 toward the east boundary (where thinner made ground was identified), and encountered to a depth of 8.4 – 13.0mbgl (4.9 – 6.9 mAOD).

3.2.3. Bedrock Deposits (London Clay and Lambeth/Thanet)

The made ground /HstW and / or KPG was underlain by clays consistent with the London Clay. The London Clay was encountered from 7.4m – 10.8mbgl (4.9m – 7.3m AOD).

Generally, the exploratory holes terminated in the London Clay at depths of 15 – 20mbgl; however, where penetrated (BH101, BH106), the London Clay had a proven thickness of 10.4 – 19.1m (and >19.5 in BH110 although see review notes below), with the base at 20.4 – 27.5mbgl ((-)3.9 – (-)13.7 mAOD) in BH101 and BH106 respectively. This is reasonably consistent with published borehole logs available on the BGS database (Section 2.3).

Lambeth Group (LMB) was identified at BH101 and BH106, underlying the London Clay at 20.4m – 28.4mbgl ((-)3.9 – (-)11.9mAOD) at BH101 and from 27.5m bgl ((-)13.7mAOD) to the base of the borehole (30.0mbgl) at BH106.

The LMB was also potentially encountered from around 22.5m / (-)8.1mAOD in BH110 as a 2.5m thick sand layer identified from 22.5 – 25.0mbgl.

Thanet Formation (ThSD) was encountered at BH101 only, below the LMB from 28.4mbgl ((-)11.9mAOD) to 33.0mbgl (end of borehole). The base of the Thanet/interface with the chalk below, was not proven.

On review of the borehole logs and soil descriptions, and with consideration of the consistency of the depths observed, it is considered that the London Clay / Lambeth interface is actually likely to be at:

- 23.5mbgl ((-)6.2mAOD) in BH101 - the description of the 3.1m of clay at the top of the LMB unit (as logged) appears similar to the London Clay above;
- 23.6mbgl ((-)9.8mAOD) in BH106 - more consistent with the first water strike identified at 21.5mbgl the deeper soils;
- 22.5mbgl ((-)8.1mAOD) in BH110 – there is a 2.5m thick sand layer from 22.5 – 25.0mbgl attributed to London Clay on the on the log which may be LMB.

The proposed adjusted levels above for the London Clay / LMB interface are more consistent across the Site area ((-)6.2mAOD to (-)9.8mAOD) as might be expected (as logged, the elevation of the interface varies quite dramatically from (-)3.9mAOD (BH101) and (-)13.7mAOD (BH106)).

On the basis of the adjusted depths the thickness of the London Clay would range between 12.7 – 16.2m. In either case, both the as-logged LC thickness (10.4m - >19m) or adjusted thickness (12.7m – 16.2m) would provide a significant degree of protection to the aquifers below the London Clay.

The thickness of the London Clay within the Application Site area appears to be some 6m thicker than was proven at boreholes to the north of the Site (from BGS records).

3.3. Contamination Observations

Aside from the general presence of made ground (inert waste – soils with brick and concrete, ash, clinker, glass, and wood etc.) the significant visual and olfactory evidence of potential contamination may be summarised as:

- Potential asbestos containing materials (ACMs) were frequently identified –
  - At 101 (no.) out of 168 (no.) investigation locations (boreholes and trial pits over both rounds of investigation);
  - Generally, as random isolated or as sporadic / occasional pieces within a ground layer and occasionally as more frequent / concentrated occurrences;
  - Generally comprising asbestos cement products but also including (in much lesser quantities) AIB, lagging and insulation materials, paper and bitumen products – in variable condition and in some cases described as in a condition that was 'difficult to pick'; and
  - Asbestos fibres and microscopic debris were also frequently detected.
- Hydrocarbon type contamination (primarily odours) was noted only relatively rarely in the made ground across the Site (at TP138, TP14, TP13, TP126 and TP10);
  - A dense black oil and strong odour (described as organic on the log) was noted in the groundwater at 12.0mbgl at BH107 during drilling. No evidence of potential contamination was found in groundwater sampling at this location; however, it should be noted that the well installation was above this observed 'contamination' with clay soils between the base of the well and the oil (i.e. a potential barrier to the upward movement of contamination in the ground); and
- Potential spent oxide (gas works) wastes were identified at 1 (no.) location (TP74 on the eastern side of the Site), manifesting as a dark blue colouration and "strong sulphuric / gas-like odour" at 1.45 – 1.7mbgl.

Aside from the potential oil noted at 12.0mbgl in the KPG in BH107 no other evidence of contamination within the groundwater was noted during drilling works.

During the supplementary SI; of the fragments of potential ACM submitted for identification, 17% were not ACM, and 54% were chrysotile cement, and 6% was Amosite AIB (next most frequent type).

All the above are discussed in detail in Section 4.

3.4. Groundwater Level Observations and Data

'Groundwater' (technically leachate but see Section 1.5) was generally first encountered / recorded in the made ground (with the exception of BH106) between 3.5m and 8.0m bgl (8.1 – 11.3 mAOD), with corresponding standing levels (after 30mins) of between 3.2m – 7.6m bgl (10.2 – 12.2 mAOD).

Groundwater strikes were also noted at depth in the London Clay at BH101 and BH106 – with standing levels after 30 minutes at 18.1 and 20.2mbgl ((-)1.57 and (-)6.41mAOD) respectively.

The water strike observations during drilling and the monitoring well installation details are summarised in Table 3.2.

It is noted that where wells have been installed in the KPG these are within remnant sand and gravel deposits between the made ground and the London Clay – it is expected (and borne out by the site data) that whilst the wells screen-out the waste body the water in the well will be in close hydraulic connectivity with that in the overlying waste.

Table 3.2. Groundwater Strike Observation and Borehole Installation Details.

BH Ref	GL[1] (mAOD)	Water Strike		RWL[2] (mbgl)	Strike in Unit	Position relative to inferred Hydraulic Grad.	Installation Details (mbgl)	
		mbgl	mAOD				Screen Interval	Screened unit
BH101	16.53	7.0	9.53	6.1	MG	Upgradient	-	
		20.4	-3.87	18.1	LC/LMB		20.0-28.4	Just below KPG, thru LC & LMB
BH102	16.05	8.0	8.05	5.5	MG	Upgradient	8.5-10.0	KPG
BH103a	17.40	6.0	11.40	5.6	MG	Upgradient / cross	1.0-9.0	MG (waste)
BH104a	15.70	5.9	9.80	4.9	MG	Upgradient / cross	8.4-10.4	KPG
BH105	17.68	7.0	10.68	6.4	MG	cross	10.0-11.8	KPG
BH106	13.79	21.5	-7.71	20.4	LC	cross	20.5-27.5	LC
		27.4	-13.61	20.2	LC/LMB	cross	-	
BH107	17.85	8.0	9.85	7.6	MG	cross	2.0-11.0	MG (waste)
BH108	18.24	8.0	10.24	7.2	MG	cross	11.1-13.0	KPG
BH109	14.69	4.4	10.29	3.9	MG	cross	2.0-7.4	MG (waste)
BH110	14.37	4.3	10.07	4.1	MG	cross	-	
		19.7	-5.33	13.8	LC	cross	22.5-27.5	LC, sand at 22.5-25.0 (possible LMB)
BH111a	13.78	3.5	10.28	3.2	MG	Downstream / cross	2.0-7.5	MG (waste)
BH112	14.90	4.8	10.10	4.5	MG	cross	10.0-20.0	LC, just below KPG
BH113	14.67	4.4	10.27	3.7	MG	cross	1.0-7.4	MG (waste)
BH114	14.58	4.7	9.88	4.4	MG	Downstream / cross	-	
		19.1	-4.52	-	LC	Downstream / cross	10.0-20.0	LC, just below KPG
BH115	15.19	5.5	9.69	5.0	MG	Downstream / cross	6.5-9.0	KPG

[1]Ground Level elevation from Hydrock data or inferred from topographic survey plan (Appendix 3).
[2]Water Resting Level after 30 mins.

3.4.1. Groundwater Level Monitoring Data

Groundwater level monitoring data was reported for 8 (no.) monitoring visits between the 15th February 2019 and 28th October 2019. The data is summarised in Tables 3.3 and Table 3.4.

Table 3.3. Summary of Groundwater Monitoring Data.

BH Ref	GL[1] mAOD	Screened Interval			Monitored Groundwater Levels (mbgl)			
		mbgl	mAOD	Unit	Min	Max	Typical Level[2]	Typical Level[2] (mAOD)
BH101	16.53	20.0-28.4	(-)3.47-(-)11.87	LC / LMB	21.0	24.9	22.2	-5.7
BH102	16.05	8.5-10.0	7.55-6.05	KPG	4.9	5.2	5.1	11.0
BH103a	17.4	1.0-9.0	16.4-8.4	MG	5.6	7.3	5.7	11.7
BH104a	15.7	8.4-10.4	7.3-5.3	KPG	4.7	5.4	4.9	10.8
BH105	17.68	10.0-11.8	7.68-5.88	KPG	4.8	7.3	6.9	10.8
BH106	13.79	20.5-27.5	(-)6.71-(-)13.71	LC	5.3	20.6	11.4	2.3
BH107	17.85	2.0-11.0	15.85-6.85	MG	6.8	7.6	7.0	10.8
BH108	18.24	11.1-13.0	7.14-5.24	KPG	7.1	7.9	7.4	10.9
BH109	14.69	2.0-7.4	12.69-7.29	MG	4.1	7.2	4.3	10.4
BH110	14.37	22.5-27.5	(-)8.13-(-)13.13	LC (LMB)	6.2	8.0	6.3	8.1
BH111a	13.78	2.0-7.5	11.78-6.28	MG	3.1	3.7	3.2	10.5
BH112	14.90	10.0-20.0	4.9-(-)5.1	LC	4.8	5.6	5.4	9.5
BH113	14.67	1.0-7.4	13.37-7.27	MG	4.1	4.5	4.2	10.4
BH114	14.58	10.0-20.0	4.58-(-)5.42	LC	4.1	4.2	4.1	10.5
BH115	15.19	6.5-9.0	8.69-6.19	KPG	4.6	5.1	4.8	10.4

[1]Ground Level elevation from Hydrock data or inferred from topographic survey plan (Appendix 3).
[2]'Typical Level' = average water level in the well over the 8 (no.) rounds, excluding obvious outliers.

Table 3.4 sorts the data from Table 3.3 by response zone to better demonstrate water patterns.

Table 3.4. Summary of Groundwater Monitoring Data (by response zone).

BH Ref	GL[1] mAOD	Screened Interval			Monitored Groundwater Levels (mbgl)			
		mbgl	mAOD	Unit	Min	Max	Typical Level[2]	Typical Level[1] (mAOD)
Well response zone in the made ground								
BH103a	17.4	1.0-9.0	16.4-8.4	MG	5.6	7.3	5.7	11.7
BH107	17.85	2.0-11.0	15.85-6.85	MG	6.8	7.6	7.0	10.8
BH109	14.69	2.0-7.4	12.69-7.29	MG	4.1	7.2	4.3	10.4
BH111a	13.78	2.0-7.5	11.78-6.28	MG	3.1	3.7	3.2	10.5
BH113	14.67	1.0-7.4	13.37-7.27	MG	4.1	4.5	4.2	10.4
Well response zone in the KPG								
BH102	16.05	8.5-10.0	7.55-6.05	KPG	4.9	5.2	5.1	11.0
BH104a	15.7	8.4-10.4	7.3-5.3	KPG	4.7	5.4	4.9	10.8
BH105	17.68	10.0-11.8	7.68-5.88	KPG	4.8	7.3	6.9	10.8
BH108	18.24	11.1-13.0	7.14-5.24	KPG	7.1	7.9	7.4	10.9
BH115	15.19	6.5-9.0	8.69-6.19	KPG	4.6	5.1	4.8	10.4
Well response zone in the London Clay but installed from immediately below the KPG								
BH112	14.90	10.0-20.0	4.9-(-)5.1	LC	4.8	5.6	5.4	9.5
BH114	14.58	10.0-20.0	4.58-(-)5.42	LC	4.1	4.2	4.1	10.5
Well response zone in the deeper London Clay and LMB								
BH101	16.53	20.0-28.4	(-)3.47-(-)11.87	LC / LMB	21.0	24.9	22.2	-5.7

Table 3.4. Summary of Groundwater Monitoring Data (by response zone).								
BH Ref	GL[1] mAOD	Screened Interval			Monitored Groundwater Levels (mbgl)			
		mbgl	mAOD	Unit	Min	Max	Typical Level[2]	Typical Level[1] (mAOD)
BH106	13.79	20.5-27.5	(-)6.71-(-)13.71	LC	5.3	20.6	11.4	2.3
BH110	14.37	22.5-27.5	(-)8.13-(-)13.13	LC (LMB)	6.2	8.0	6.3	8.1

[1]Ground Level elevation from Hydrock data or inferred from topographic survey plan (Appendix 3).
[2]'Typical Level' = average water level in the well over the 8 (no.) rounds, excluding obvious outliers

It is noted that wells installed in the KPG have their response zones entirely within the KPG (as logged) but are screened from directly or closely below the overlying made ground (historic waste) in groundwater that will be in very close connectivity with the water (groundwater / leachate) in the historic waste. Given the discontinuous nature and limited thickness of the KPG deposits (remnant after historic extraction processes) it would not be possible to have response zones significantly separated from the overlying made ground.

In summary, wells installed with response zones through the made ground or the KPG had resting water levels between in the made ground / waste body at 10.4m – 11.7m AOD, broadly consistent with the water strikes observed during drilling.

Given the general consistency in levels, it is considered that there is good hydraulic connectivity throughout and between the made ground / historic waste and the KPG (as would be expected).

On this basis there is no meaningful distinction between leachate in the historic waste or groundwater in the KPG.

Wells installed with response zones in the London Clay *but* from just below the base of the KPG (BH112 and BH114) have resting water levels in the made ground and consistent with the shallow water strike observations and with no water strikes noted in the London Clay. It is likely that the water in the wells represents water from the made ground and KPG which has entered the installation.

The 'typical' water level in BH114 was 10.5mAOD, consistent with wells installed in the made ground / KPG – suggesting this well is in relatively good connection with the groundwater in those units. The water level in BH112 (9.5mAOD) however is outside of the range of levels observed in the made ground, suggesting this well may not have as good a hydraulic connection or that water is escaping the well.

In summary, for the wells with response zones installed in the deeper London Clay and LMB, including across the LC and LMB (BH101, BH106 and BH110), water in the wells may represent groundwater in the deeper aquifer however the following comments are made (Table 3.5):

Table 3.5. Notes on Groundwater in Deeper Boreholes.			
Ref	Screen Unit	Strikes	Water Level Notes
BH101	Across the LC and LMB	MG, base of LC/ top of LMB	Monitored levels (typically around 22mbgl) are consistent with the RWL for the deeper strike and sit within the LMB
BH106	LC, possibly LMB	LC/LMB interface. Not in MG / KPG.	Monitored levels variable but generally in LC. Inconsistent with BH101/BH110. Indicates shallow water contribution
BH110	LC, possibly LMB	In MG and LC	Monitored levels deeper than shallow strike, and shallower than deeper strike. Suggests water is representative of

			deeper aquifer, but the levels inconsistent with BH101/BH106, which indicates shallow water contribution.

Although the water levels in the deeper wells (BH101, BH106 and BH110) may suggest contributions from the shallower aquifer, as the groundwater monitoring was by low flow techniques and if limited or no drawdown of levels occurred during the monitoring (not recorded in the sampling data) then the water samples could still be representative of the groundwater in the deeper aquifer body.

3.4.2. Groundwater Connectivity, Hydraulic Gradient, and Flow Direction

As noted in Section 3.4.1, it is considered that there is good hydraulic connectivity throughout and between the made ground / historic waste and the KPG (as would be expected in an unlined site with no engineered liners / attenuation layers.

Table 3.6 Location of Boreholes Relative to Hydraulic Gradient	
Upgradient	BH102, BH103A, , BH104A
Cross-gradient	BH105, BH107, BH108, BH109. BH112 & BH113
Down-gradient	BH111, BH114, BH115

The actual 'groundwater' flow in the shallow water body (superficial aquifer and historic waste body) and the levels are likely to be complex and highly dependent on the specific local ground conditions. However, there is a general trend/hydraulic gradient in water levels from north to south (11.0mAOD to 10.5mAOD, gradient around 1:900), with a very minor east to west component with a gradient of 1:4000. This would be consistent with a general flow direction expected along the Lee Valley.

A plan showing the groundwater contours is presented as Figure 4 of the HRA and generally at Appendix 2.

In the deep aquifer (BH101, BH106 and BH110) the levels are very different between the locations (-5.7, +2.3 and +8.1 mAOD respectively). Given the very different nature of the units into which the response zones are installed this is not unexpected. It is considered the groundwater levels are too divergent to consider them representative of equivalent water bodies – and by extension that it is not possible to draw any conclusion about the groundwater flow direction in the deeper aquifer bodies from this data. For the purpose of the HRA, this is not considered further given there is no discernible continuity between the shallow water and that in the deep aquifer.

The groundwater Source Protection Zone map indicates a SPZ encroaching into the southeast corner of the Site, which extends westward around 250m south of the Site (Appendix 4). Further SPZs are to the north and northeast. On the basis of the SPZ mapping pattern (based on the modelling of the groundwater flow around the protected abstractions) the groundwater flow in the deeper aquifer (primarily in the chalk) in the area of the Site would probably be generally toward the southeast.

The water levels in each water body indicate no significant hydraulic connection between the shallow and deep aquifers, as expected given the London Clay between the made ground / KPG and the deeper aquifer (Lambeth, Thanet and Chalk).

With regard to surface waters, the water level of Ponders End Lake (c.10.8mAOD) is consistent with groundwater, therefore hydraulic connectivity with the lake is likely, however the expected groundwater flow is from north to south so groundwater from the Site is likely to have no or at most minimal impact on the lake surface water (but the reverse could, in principle, be true).

The water level in the RLN canal is similar but appears to be slightly *higher* than the groundwater level in the vicinity of the site (c.11mAOD vs 10.8mAOD). Whilst there may be some level of connectivity it is noted that canals were usually lined so this is likely to be limited (and must necessarily be so for the RLN to act as a canal with distinct water levels either side of the locks). Further, given that the water level in the canal is slightly higher than the site groundwater any limited 'leakage' would be out of the canal rather than into it.

It is further noted that if the groundwater at the Site was in connectivity with that in the canal (with the site water contributing to the quality of that in the canal) a significant (fairly high) degree of dilution would be expected to occur within the canal.

4. SOURCE TERM - CONTAMINATION CONDITIONS (MADE GROUND / HISTORIC WASTE)

4.1. General

This section presents a review of the contamination data from the site investigation presented by Hydrock. The discussion presented below characterises the Source Term in terms of concentrations of priority pollutants in solid wastes and the concentrations encountered in the water body at the Site. An exploratory hole layout plan is included in Appendix 4. The laboratory reports are also included in Appendix 4.

4.1.1. Soil

In total two hundred and seventy-one (271no.) samples were submitted for laboratory analysis - 48no. from the first round of site investigation and 223no. from the second round.

- All the samples were of the made ground except for one (1no.) sample at 6.6mbgl in BH115 which was from the very top of the KPG;
- 254no. were submitted for asbestos screening and quantification;
- 89no. asbestos fragments were submitted for laboratory bulk ID testing;
- 141no. were submitted for analysis for heavy metals and organic analytes;
- 54no. were submitted for TPH CWG and BTEX testing; and
- 12no. were submitted for VOC tests, and 10 (no.) for SVOCs.

4.1.2. Water

Groundwater samples were obtained on five (5no.) occasions and surface water on one (1no.) occasion during the Hydrock investigation, and tested for the following:

- Organic/Inorganics: pH, Electrical Conductivity (EC), Sulphate (SO4), Chloride, Fluoride, DOC, Hardness, Bromate, Ammonium (reported as total Ammoniacal Nitrogen as N and/or Ammonia as NH_3), Nitrate (N, NO_3), Nitrite (N, NO_3), Cyanide, and Total Phenols;
- PAH: (USEPA-16 or 'select' including Naphthalene, Anthracene, Fluoranthene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(a)pyrene, Indeno(123-cd)pyrene, Dibenz(a,h)anthracene, Benzo(ghi)perylene);
- Metals (dissolved): Aluminium, antimony, arsenic, barium, boron, cadmium, chromium (III), chromium (VI), cobalt, copper, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, selenium, silver, sodium, tin, vanadium, zinc;
- TPH CWG and BTEX; and
- VOC/SVOC.

4.2. Summary of Laboratory Data (Soil)

The sections below summarise soil chemical data, with commentary on distributions and other noteworthy features, in so far as the potential for ongoing leaching of contamination of contaminants from the HstW.

The site investigations did not include analysis for leachable concentrations of contaminants from the made ground / historic waste, therefore in the absence of such data and in order to describe the contamination conditions in context the data have been compared against a reasonable 'benchmark' concentration (BMC) based on recognised background concentrations of a contaminant or other industry screening Levels using

Inert WAC, parkland-type Public Open Space (POSpark) and Commercial land (Comm) assessment criteria for human health, where available (Appendix 6). These are deemed appropriate screening levels simply to provide a qualitative framework to assess whether the made ground / historic waste is considered 'contaminated' for the development at this stage.

It is however noted that these are not all directly applicable to the controlled waters assessment, but are used simply as a basis to described the degree of contamination.

4.2.1. Fraction of Organic Carbon

The fraction of organic carbon (FOC) in the made ground soils / HstW varied from 0.0022 (0.22%) to 0.073 (7.3%), the modal FOC was 0.013 (1.3%), indicative of low organic matter content generally.

4.2.2. Organic/Inorganic Analytes

In summary, the following results of note are identified:

- **Water-soluble SO_4:** Minimum 0.022 g/l, maximum 4.3 g/l, generally <2 g/l;
- **Cyanide (free):** Typically, <1 mg/kg, 1-2 mg/kg in two (2no.), and 79mg/kg at one (1no.) location.

A (1no) elevated cyanide concentration of 79mg/kg was identified on the west boundary at TP126 at 2.0mbgl, on the opposite side of the Site from the potential spent oxide/gas works waste material at TP74 (east boundary). No analysis of soils at TP74 was undertaken as they were deemed unsuitable for testing.

The cyanide concentration at TP126 exceeds the SoBRA Acute (oral) screening criteria for children (24mg/kg) which has been adopted for a Tier 1 BMC (based on a POSpark land use scenario), but not the adult criteria (2100mg/kg).

The fraction of organic carbon (FOC) in the made ground soils / HstW varied from 0.0022 (0.22%) to 0.073 (7.3%), the modal FOC was 0.013 (1.3%).

4.2.3. Metals

Metal concentrations were mostly low, with sporadic elevated concentrations of arsenic, boron, cadmium and chromium III. The metal concentrations are summarised in the table below with comparison to the Tier 1 screening criteria / BMC. The distributions are discussed further below.

Table 4.1. Summary of Metal Concentrations.

Determinand	Benchmark (mg/kg)		Measured Conc (mg/kg)		No. >Benchmark		Comment
	Comm	POS_{park}	Min	Max	Comm	POS_{park}	
Arsenic	640	170	7.8	110	0	0	Generally, <30 mg/kg
Beryllium	12	63	0.38	7.2	0	0	Generally, <2 mg/kg
Boron	240000	46000	0.6	130	0	0	Generally, <12 mg/kg
Cadmium	190	532	<0.2	380	2	0	Generally, <3 mg/kg
Chromium VI	33	220	<1.2	<1.2	0	0	Not detected (see note below)
Chromium III	8600	33000	20	790	0	0	Generally, <50 mg/kg
Copper	68000	44000	19	8700	0	0	Generally, 200 mg/kg to 1000 mg/kg
Lead	2300	1300	19	19000	6	17	4no >2500 mg/kg, 2no >14000 mg/kg

Table 4.1. Summary of Metal Concentrations.							
Determinand	Benchmark (mg/kg)		Measured Conc (mg/kg)		No. >Benchmark		Comment
	Comm	POS_{park}	Min	Max	Comm	POS_{park}	
Mercury (Elem/inorb)	58/1100	30/240	<0.3	310	2/0	2/1	Generally, <3 mg/kg.
Nickel	980	800	1.5	990	1	1	Generally, <80 mg/kg.
Selenium	12000	1800	<1.0	35	0	0	Generally, <1 mg/kg
Vanadium	9000	5000	17	210	0	0	Generally, <50 mg/kg
Zinc	730000	170000	68	27000			Generally, <2000 mg/kg

In the text of their report, Hydrock identified Chromium VI, however on examination of the data there appears the data for Chromium III was misconstrued. There was in fact no significant concentrations of Cr VI detected.

Copper, lead and zinc concentrations were frequently relatively elevated compared with what might be expected in 'normal' soils, however only lead concentrations (infrequently) exceeded the BMC.

There are no obvious patterns laterally or correlation with depth of these elevated concentrations.

In addition;

- Cadmium exceeded the Comm BMC (190mg/kg) in 2no. samples - 380 and 320 mg/kg at TP01 and TP85 (much higher levels than anywhere else). The locations are not near each other;
- Mercury exceeded BMC in 2no. samples out of 141 tested - the POSpark BMC (all forms) and Comm BMC for elemental mercury at TP07 (round 1) and the POSpark elemental mercury BMC at BH104 (the locations are not near to each other).

4.2.4. Poly-Aromatic Hydrocarbons (PAH)

PAH concentrations were generally low across the Site with elevated concentrations identified in relatively few samples. The PAH distributions are summarised in the table below and discussed further below.

Table 4.2. Summary of PAH Concentrations.							
Determinand	Tier 1 BMC (mg/kg)		Measured Conc (mg/kg)		No. >BMC		Comment
	Comm	POS_{park}	Min	Max	Comm	POS_{park}	
Naphthalene	190	1200	<0.05	53	0	0	Generally, <1 mg/kg
Acenaphthylene	83000	29000	<0.05	2.9	0	0	Generally, <1 mg/kg
Acenaphthene	84000	29000	<0.05	35	0	0	Generally, <1 mg/kg
Fluorene	63000	20000	<0.05	40	0	0	Generally, <2mg/kg
Phenanthrene	22000	6200	<0.05	250	0	0	Generally, <5 mg/kg
Anthracene	520000	150000	<0.05	68	0	0	Generally, <3mg/kg
Fluoranthene	23000	6300	<0.05	230	0	0	Generally, <12mg/kg
Pyrene	54000	1500	<0.05	190	0	0	Generally, <10mg/kg
Benzo(a)anthracene	170	49	<0.05	79	0	2	Generally, <5 mg/kg
Chrysene	350	93	<0.05	74	0	0	Generally, <5 mg/kg
Benzo(b)fluoranthene	44	13	<0.05	66	2	13	9no >16 mg/kg, most <5
Benzo(k)fluoranthene	1200	370	<0.05	35	0	0	Generally, <3 mg/kg

Table 4.2. Summary of PAH Concentrations.							
Determinand	Tier 1 BMC (mg/kg)		Measured Conc (mg/kg)		No. >BMC		Comment
	Comm	POS_{park}	Min	Max	Comm	POS_{park}	
Benzo(a)pyrene	35	11	<0.05	63	4	13	Generally, <5 mg/kg
Indeno(1,2,3-cd) pyrene	500	150	<0.05	33	0	0	Generally, <3 mg/kg
Dibenz(a,h) anthracene	3.5	1.1	<0.05	11	6	16	Generally, <1 mg/kg, 2 >10
Benzo(ghi)perylene	3900	1400	<0.05	44	0	0	Generally, <3mg/kg
Total PAH	100[1]		<0.8	1230	20		20 >100 mg/kg (inert WAC)

1. *Based on inert WAC Total PAH 100mg/kg*
2. *No. of samples > 100mg/kg Total PAH*

Total PAH was generally low (<30mg/kg) with 20no. out of 141no. samples >100mg/kg (Inert WAC BMC).

There is no clear spatial pattern either laterally or with depth to the elevated concentrations.

The highest concentrations of the individual species were in the higher molecular weight species. Naphthalene (and the other lower molecular weight species) was generally low, with the exception of 1no. elevated concentration at TP126 (53mg/kg) but still well below the BMC. This doesn't appear to correlate with other elevated PAH values but does coincide with relatively elevated TPH and elevated cyanide.

Benzo(a)anthracene (BaA), benzo(b)fluoranthene (BbF), benzo(a)pyrene (BaP) and dibenz(ah)anthracene (DiA) occasionally exceeded POS BMC (15 no. out of 141 no. samples) and rarely exceeded commercial BMC (6 no. samples).

4.2.5. Total Petroleum Hydrocarbons (TPH and BTEX)

Fifty-three (53no.) samples were analysed for TPH and BTEX. It is presumed to include targeted samples thought likely to have elevated TPH, which could influence the observed distributions and potentially have the effect of increasing the perceived hydrocarbon impact, rather than reducing it. In summary:

- Total (aro+ali) TPH concentrations were variable but generally relatively low;
  - 30no. samples <500mg/kg (Mineral Oil - C_{10}-C_{40} - Inert WAC BMC);
  - Of the 23no samples >500mg/kg, 13no are >1000mg/kg – including 1no sample >6000mg/kg (22103 mg/kg at TP138);
- No spatial or vertical patterns were identifiable in the concentration distributions;
- The TPH species were dominated by longer chain aromatic and aliphatic species (largely >EC16);
- No individual TPH CWG species exceeded Tier 1 BMC based on POSpark or Comm;
- The Hazard Index (HI) was 1.69 for 1no. sample (TP138, 0.6mbgl) which also had, notably, the highest total TPH (22,103mg/kg) dominated by the >EC21 aliphatic & aromatic species;
- The TPH Hazard Index was <1 (max 0.58) in all other samples;
- The elevated TPH concentrations at TP138 did not correlate with particularly elevated PAH (just 117 mg/kg Total PAH and no individual species > BMC or otherwise notably elevated); and
- BTEX species were <LOD in all but 3 (no.) samples. Those detected are well below BMC (27mg/kg) and Inert WAC (6mg/kg), and were associated with the highest TPH concentrations.

4.2.6. VOC and SVOC Concentrations

VOCs were analysed for in 12no. samples and SVOCs in 10no. samples. All were generally <LOD, however where VOC/SVOC was detectable this generally coincided with elevated TPH:

- 1.3.5-trimethylbenzene (4.6 µg/kg) and 1,2,4-trimethylbenzene identified in 1no. sample at BH112 (sample Total TPH 1167mg/kg, and p+m xylene detected, 14 µg/kg);
- Anthraquinone, 2no locations (BH107, 4.6 µg/kg at 7.6m, and BH115, 5.8 µg/kg at 3.1m);
- Dibenzofuran, 7no samples: BH107 at 7.6m (6.8 µg/kg) and BH115 at 3.1m (6.8 µg/kg), and BH112 (1.9m and 6.7m), BH113 (6.3m), and BH115 (1.3m and 6.6m) at 0.3-1.4µg/kg;
- Dibenzofuran was not detected in just 3no. samples (BH107, 9.1m; BH112, 3.2m; TP07, 1.5m; and
- VOCs were not analysed for the samples with the highest total TPH concentrations.

Anthraquinone is not significantly toxic (much lower toxicity than anthracene) and may be generated from oxidation of anthracene. The occurrences correlate with relatively elevated anthracene concentrations. Dibenzofuran is a relatively non-toxic compound, and may be obtained from coal tar. Both species are oxygenated PAH.

The apparent correlation of the dibenzofuran and anthraquinone concentrations (albeit in a small sample set) suggest a related source, and the correlation to the PAH distribution and the potential relationship of the latter to anthracene may suggest their distribution is related to the general presence of PAH.

It is considered that the risk assessment for these species should defer to the assessment for the PAH species as they are likely to be related, and the latter are the more toxic / main risk driver.

Dibenzofuran was detected in the groundwater. Anthraquinone was not but it has very low solubility.

4.2.7. Asbestos

Asbestos is not considered to be a significant risk factor to controlled waters within the Hydrogeological Risk Assessment, however as asbestos is one of the primary contaminants of concern generally, the findings of the analysis are summarised below:

The following observations with regards to potential Asbestos Containing Materials (ACMs) are made:

- Potential ACMs were identified at 101no of 168no boreholes/trial pits (over both rounds of SI);
- Generally random isolated or sporadic/occasional singular pieces; and
- Generally asbestos cement products but also including AIB, lagging/ insulation materials, and bitumen products. In some cases, materials were "significantly degraded / disaggregated".

89no potential ACM fragments were sent for identification, of which 74no (83%) were confirmed asbestos:

- 48no (65%) were chrysotile cement products and a further 5no (6.8%) were amosite or crocidolite containing cement products;
- 8no (10.9%) were amosite or chrysotile insulation board / tile;
- 6no (8.2%) were chrysotile, amosite of chrysotile and crocidolite lagging type insulation;
- 5no (6.8%) were chrysotile paper or fabric;
- 2no (2.7%) were chrysotile bitumen.

Asbestos fibres were detected in 150no out of 254no samples screened (59%). Asbestos detected was dominantly chrysotile (55%) or amosite/amosite and chrysotile (34.9%). 65% of the samples quantified were <0.001%, with a further 24% <0.01% and just 6% > 0.1%.

4.3. Summary of Soil Contamination and Distribution

The soil test results are generally consistent with construction and demolition type waste materials, with localised inputs of ‘other’ waste materials – and is consistent with deposition from multiple similar sources of the time period over a number of years. The waste deposit (HstW) shows discernible concentrations of priority pollutants, with the potential to leach from the waste to underlying groundwater.

However, there is no clear pattern to the contamination in the made ground/ HstW, not in the soil types and, overall, the made ground / HstW comprised generally quite similar (but heterogeneous on the smaller scale) materials throughout.

Similarly, there are no clear spatial patterns to the chemical or asbestos contamination.

Most potential chemical contaminants were below the BMC (commercial or park) – or where there were exceedances these were rare or sporadic. The following exceeded BMC (POSpark and / or Comm):

- Cyanide - 1no sample
- Metals – Lead (frequently elevated, rarely exceeding BMC), Cadmium (rarely), Mercury (rarely);
- PAH - BaA, BbF, BaP and DiA. 20no of the 141no samples exceed the Total PAH Inert WAC criteria (100mg/kg);
- TPH - No individual TPH species exceeded BMC in any sample, but the Hazard Index was >1 (1.69) in 1no sample which also had by far the highest total TPH concentration (22,103mg/kg);
- 23no samples exceed the 500mg/kg inert WAC criteria for Mineral Oil (total TPH C_{10}-C_{40});
- BTEX was well below the BMC, including inert WAC.

4.4. Summary of Laboratory Data (Groundwater)

Hydrock undertook groundwater sampling from the installed wells on five (5no.) occasions between February 2019 and June 2020:

- Round 1: 12/02/2019 – 15/02/2019
- Round 2: 27/02/2019 – 03/03/2019
- Round 3: 19/11/2029
- Round 4: 18/02/2020
- Round 5: 08/06/2020

It is noted that the monitoring was dominantly undertaken in autumn/winter/early spring months likely to be generally wetter with higher infiltrations rates (if there is an appreciable difference) and therefore potentially worst-case conditions if site generated leachate is an issue. One round was also undertaken in summer. It is understood that the samples were all taken by low-flow methods.

There is no obvious pattern or variation with the levels of contaminants seasonally.

As discussed previously, wells BH101, BH106 and BH110 are expected to represent the groundwater in the deeper aquifer body below the London Clay or within the lower parts of the London Clay.

Installations in Historical Waste
The following boreholes are installed in the Historical Waste

BH103A, BH107, BH109, BH111 and BH113 with the well response zone in the waste body

4.4.1. Installations in KPG (Residual Aquifer)

The following boreholes have installation in the KPG. Note within the site boundary, it has not been possible to find a location downstream of the waste, wholly within the sand and gravel. From the historical plans, presented in Appendix 4 it can be seen that historic extraction activities extended to and beyond the Application Site boundary.

The following existing wells are installed in the KPG

- BH102, BH104A, BH105, BH108, BH112, BH114 and BH115 with the response zone in the KPG or in the London Clay but from immediately below the KPG and thought very likely to be representative of water in the KPG.

4.4.2. Location of Boreholes Relative to Hydraulic Gradient

The table below summarises the location of the boreholes in relation to the inferred hydraulic gradient.

Table 4.3 Location of Boreholes Relative to Hydraulic Gradient	
Upgradient	BH102, BH103A, , BH104A
Cross-gradient	BH105, BH107, BH108, BH109. BH112 & BH113
Down-gradient	BH111, BH114, BH115

Whilst potential differences between the chemical quality of the water in the made ground / historic waste body (leachate) and that in the KPG (groundwater) have been considered it is noted that –

- The KPG is a remnant deposit which is discontinuous across the Site (historic extraction) and where present it is a relatively thin layer between the made ground and the underlying London Clay;
- There is hydraulic connectivity between the made ground and the KPG due to the lack of engineered attenuation layers, natural aquicludes, geological barriers etc.;
- The London Clay presents an underlying hydraulic boundary;
- It follows that there is likely to be minimal difference between the water (quality) in the KPG and the made ground (waste body) – this borne out by the site data.

The chemical data are included in Appendix 4. The sections below provide a summary of groundwater contaminant distributions, with reference to any specific features or patterns in the data.

4.4.3. Assessment Criteria

A preliminary screening of the concentrations has generally been made against the following screening criteria, as appropriate (Appendix 6):

- Water Framework Directive Environmental Quality Standards (EQS) for freshwater;
- Bioavailability adjusted EQS – using the M-BAT tool;
- 'Secondary' EQS – other UK Standards / other Non-UK Standards;

- Groundwater Threshold Levels (GWThr);
- Drinking Water Standards (DWS); and
- Inert WAC thresholds (Inert WAC BMC).

4.4.4. EC, Cl, SO4, NO3, Hardness

EC and Cl^- were generally below EQS levels (1880 µS/cm and 250 µg/l, respectively) except at BH102 (upgradient) at the northern end of the Site where they were marginally elevated (2300 - 3800 µS/cm and 260 – 340 µg/l, respectively). Otherwise, the levels were broadly consistent between the water body in the made ground and KPG and between the overall shallow water body and the deeper aquifers.

Sulphate (SO_4^{2-}) ranged from 9470 – 731000 µg/l in the shallow water body and from 27600 – 444000 µg/l in the deeper aquifer (EQS 400000 µg/l). The highest concentration was recorded in BH111 (down-gradient).

Within the shallow water body, the levels are broadly consistent between those wells installed in the waste and those installed in the KPG. Sulphate levels may in part be a regional effect related the London Clay. Overall considered unlikely to represent a significant risk.

Nitrate and nitrite were generally low in the shallow aquifer. Nitrate was typically <4mg/l compared to the GWThr (4 – 26 / 37.5 mg/l) and DWS (50 mg/l) but with occasional or localised relatively moderate exceedances at BH111 (1.18 - 65.4 mg/l), BH112 (1.14 – 6.13 mg/l), (BH114 (18.5 - 38.1 mg/l) and BH115 (16.1 - 71.1 mg/l), located downgradient. Nitrite was similarly distributed – with just occasional / localised exceedances of the DWS (500 µg/l). Nitrate and nitrite were also generally low in the deep aquifer.

Nitrate / nitrite concentrations were generally higher in the downgradient boreholes.

4.4.5. Ammoniacal Nitrogen / Ammonia / Ammonium

Ammonium (as NH_4) was reported for all samples. Ammoniacal nitrogen (as N) and ammonia (as NH_3) were also reported for a sub-set of samples but were all determined by the same method and all the values represent the total nitrogen as NH_4^+ and NH_3 expressed as mg/l N, NH_3 or NH_4^+. At the pH encountered however, the equilibrium is such that NH_4^+ will be the dominant form.

Ammonium was generally above the EQS adopted for initial appraisal (1100µg/l – based on WFD *Schedule 3 Table 7*, see Section 4.5), GWThr (208 - 1632µg/l) and DWS (500µg/l).

In the shallow water body, the overall range was 32-170,000µg/l with no obvious distinction between those in the waste body and those in the KPG (the highest and lowest values were in the KPG).

A general trend of concentrations being higher toward the north / upgradient (BH103A, BH105, BH107 largely >15,000µg/l, highest at BH102 >50,000µg/l), and lowest in the south / downgradient was observed, however. The lowest concentrations were at BH111 (490 - 1200µg/l), BH114 (540 - 770µg/l) and BH115 (<15 - 670µg/l) at the southern end of the Site and downgradient – including the only levels below the EQS/ GWThr.

There is no obvious on-site source evident in the soil data, for example organic matter content is low @1.3%.

The pattern of concentrations decreasing from the north end (upgradient) of the Site to the south / downgradient (with the expected hydraulic gradient) suggests a dominantly off-site source and limited (or no) addition from on-site sources.

A potential source from the sewage works formerly to the north (upgradient) is noted, however this may be considered speculative since potential source materials would have been removed by the gravel extraction works. Ammonium can also result from local fertilizer use (e.g. within the golf course) and sewage discharges (e.g. the campsite, noting the historical discharge consent), or (more likely) waste-water / more general industrial pollution in the wider urbanised area and Lee Valley – also noting the Site is in an NVZ this is likely a regional characteristic.

In the deep aquifer, ammonium was more moderate, ranging 1400-16,000µg/l (above the EQS/GWThr/DWS). Concentrations were lowest at BH101 (1400-8300µg/l) in the LMB and BH106 (2200-9200µg/l. 16,000µg/l was identified at BH110 in all 5no rounds of sampling, **which is higher than the concentrations in the shallow aquifer in this region of the Site.**

There is no spatial correlation apparent to the distribution pattern of the concentrations identified in the deep and shallow aquifer. Therefore, it is considered that the concentrations in the deep aquifer are unlikely to be directly related to those in the shallow aquifer, noting also the London Clay between them.

4.4.6. Phenols

Phenol concentrations were <0.05 – 6.7 µg/l across the whole data set, with all concentrations below EQS and the upper GWThr value. It appears that the higher levels may be a sampling or laboratory artefact.

Overall, it is considered that the concentrations identified are unlikely to represent a significant risk.

4.4.7. Cyanide

Free and complex cyanide were generally < LOD, however free cyanide was detected in 2no samples (2µg/l in 1no of 4no samples at BH102, possible error) and at 2µg/l in 1no sample at BH111 (of 5no). None are close to the elevated soil cyanide (TP126) or potential spent oxide (TP74). More localised effects could be present in the vicinity; however, the groundwater data do not indicate a wider pervasive issue.

Overall, cyanide is not considered to present a significant risk to controlled waters.

4.4.8. Metals

Dissolved metals concentrations were generally low and below the adopted EQS, GWThr and DWS screening levels, or only sporadically or locally exceeding a screening criterion. The exceptions to this are boron and manganese. Copper, nickel and zinc were also frequently greater than the (unadjusted) EQS levels but below the M-Bat adjusted bioavailable EQS (PNEC). The key distributions are summarised in Table 4.3 and discussed further below.

Table 4.3. Summary of Selected Metal Concentrations in Groundwater Samples.

Determinand	Screening Levels (µg/l)				Measured Concentrations (µg/l)	
	EQS	GWThr	PNEC	DWS	Min	Max
Arsenic	50	26 - 106		10	0.4	18
Boron	2000	750		1000	820	15000

Cadmium	0.25	0.054-0.53 / 3.75		5	<0.02	0.87
Cobalt	3				<0.2	4.7
Copper	1 (bio)	0.56-2.12 / 1500	38.3	2000	0.6	100 / 34
Iron	1000				15	4500
Manganese	123		850	1000	1.2	3300
Mercury	0.07	0.026 - 0.106 / 0.75		1	0.0055[1]	0.0055[1]
Nickel	4	2.06-8.48 / 15	22.6	20	1.1	18
Lead	1.2	0.619-2.54 / 7.5	9.7	10	< 0.2	4.2
Zinc	10.9	5.62-23.1	33		1.1	120
1= all results are at MRV						

4.4.8.1.Arsenic

Concentrations of Arsenic are below the EQS and GWThr and exceeds the DWS on one occasion. Concentrations range between 0.16 – 18ug/l including results from shallow and deep aquifers.

The highest concentration of 18ug/l was recorded in BH102, in KPG (upgradient) in March 2019. This is considered anomalous and not significant, the remainder of results being below 10ug/l. Disregarding this result the highest Arsenic concentration would be 9.53 ug/l in BH107, in waste (cross gradient).

There is no discernible pattern in the distribution of Arsenic with hydraulic gradient, with similar concentrations observed up and downgradient, with no clear trend with the groundwater flow direction.

The concentrations in the deeper aquifer range between 0.16 – 4.27 ug/l suggesting the deeper aquifers, are also impacted by arsenic, but generally at lower concentrations.

4.4.8.2.Boron and Manganese

Concentrations were generally high relative to the adopted screening criteria (EQS, GWThr and DWS) across the whole site area in both the shallow and the deep aquifer groundwater bodies.

The boron concentrations in the shallow water body ranged from 820 – 15000 µg/l with concentrations broadly comparable between the waste body and KPG, although with generally slightly higher levels in the KPG (including the highest levels 8000 – 15000 µg/l at BH102 upgradient).

Overall, the highest concentrations in the shallow aquifer were at the northern end of the Site (BH102, upgradient) and the lowest values (820 – 2300 µg/l) in the western / central area, but otherwise were generally around 4500 – 6000 µg/l, with no clear trend with the groundwater flow direction.

Boron concentrations were generally slightly higher in the shallow aquifer than in the deep aquifer but were of the same order of magnitude. There was no clear spatial pattern between the concentrations, and it is noted that none was significantly elevated levels in soils; i.e. no direct on-site (anthropogenic) source.

Manganese was frequently above the bioavailability adjusted EQS by a factor of 2 or 3 in both the shallow and deep aquifer. Within the shallow aquifer there was no obvious distinction between the wells installed in the waste body and those installed in the KPG. Spatially within in the overall shallow water body concentrations were lowest in the south (downgradient) of the Site (1.2 - 230µg/l), relatively moderate at the north end (upgradient) (680 – 920 µg/l) and relatively high (1000-3000 µg/l) through the middle (cross-gradient), with the highest concentrations (1800 – 3300 µg/l) at BH113 (cross-gradient). Concentrations in the deep aquifer were generally around 2000µg/l, but significantly lower (below the EQS) in BH101 (960-120 µg/l).

Manganese was not analysed in soils, but is an abundant element in natural soils – and has a similar potential to boron to be a regional / background issue. It is noted that the lowest concentrations for both boron and manganese (and concentrations below both EQS and DWS levels) were detected in BH101 which was installed into the LMB and on the monitored groundwater levels (Section 3.4) may be most representative of the deeper groundwater body.

4.4.8.3. Copper, Nickel and Zinc

Copper in particular, but to a degree also nickel and zinc were relatively elevated across the Site, or sporadically detected at elevated or slightly elevated levels compared to EQS. There was no clear distinction between wells installed in the waste body and those in the KPG and no clear spatial pattern in the overall shallow water body. Concentrations dominantly below the bioavailability adjusted EQS, GWThr and DWS levels and unlikely to represent any significant risk to controlled waters.

Zinc was above the screening criteria at BH115 and in 1no sample from BH109, with the distribution possibly indicating potential for localised moderately elevated concentrations, but not suggestive of any widespread or general contamination with the potential to migrate or present a risk to water resources.

It is noted that copper in soil was relatively elevated generally, however groundwater concentrations are not high (dominantly below the adjusted EQS, GWThr and DWS). The same applies for zinc (albeit more sporadically elevated in soils), and no clear pattern was evident to either distribution. Nickel concentrations in soils were low, so the groundwater nickel concentrations do not have an apparent on-site source.

Overall, copper, zinc, and nickel do not appear to be presenting a risk to the controlled water environment.

4.4.8.4. Lead

The highest concentration of Lead was at BH109 (cross gradient) at 4.2ug/l with a minimum at the method reporting value (MRV) of <0.2ug/l.

Concentrations were generally low or very low, with just 9no. samples exceeding the unadjusted EQS levels, all at different locations, within wells installed in the waste body, KPG and the deeper aquifer and not consistent across monitoring rounds. All samples were below the adjusted EQS, upper GWThr, and DWS, and with similar concentrations in the upper and lower aquifers.

It is considered that there is no evidence of significant contamination, or the potential for significant migration of contaminants – i.e. no evidence that the Site is a risk to the on-site groundwater or that the Site or site groundwater is a risk to the wider controlled waters environment.

There appears to be no variation in lead concentrations between up and downgradient boreholes.

Sporadic elevated lead concentrations (rarely very high) were detected in the Site soils – however the groundwater data does not appear indicate any particular risk to the controlled water environment.

4.4.9. Polyaromatic Hydrocarbons

Naphthalene (summarised in the Table 4.4 below) was detected across the wells in the shallow water body (both in the waste and KPG installed wells) and the deeper aquifer body at up to 26.2 µg/l, however high concentrations up to 371 µg/l were detected at BH108 (cross-gradient), compared to a EQS of 2 µg/l and GWThr of 1.01 – 4.24 µg/l and DWS (total PAH) of 0.1 µg/l.

Table 4.4. Naphthalene Concentrations in Groundwater Samples.

Location (rel to Hyd. Grad.)	Naphthalene Concentrations in Groundwater (µg/l)				
	Rnd 1 (Feb 2019)	Rnd 2 (Mar 2019)	Rnd 3 (Nov 2019)	Rnd 4 (Feb 2020)	Rnd 5 (Jun 2020)
Shallow water body – installed in the waste body					
BH103A (up)	< 0.01	1.7	< 0.01		
BH107 (cross)	1.18	1.7	0.59	1.03	< 0.01
BH109 (cross)	26.2	25.4	2.13	1.17	5.46
BH111 (down/ cross)	21.5	< 0.01	1.07	< 0.01	< 0.01
BH113 (down)	8.46	1.89	1.23	1.93	< 0.01
Shallow water body – installed in the KPG					
BH102 (up)	< 0.01	< 0.01	0.73	< 0.01	
BH104A (up)	< 0.01	19.1			
BH105 (cross)		< 0.01	0.88	0.77	
BH108 (cross)	371	357	0.57	< 0.01	233
BH112 (down)	7.41	0.86	1.12	< 0.01	
BH114 (down)	< 0.01	< 0.01			
BH115 (down)	16.5	2.63	0.99	< 0.01	< 0.01
Deep Aquifer					
BH101 (up)	2.16	< 0.01	< 0.01	< 0.01	
BH106 (cross)		< 0.01	1.49	< 0.01	< 0.01
BH110 (cross)	24.2	22.9	1.98	0.91	2.46

It is noted that there is generally a strong decrease in concentration over time with the exception of BH108 and to a degree BH109 (and BH104A but here there were only 2no samples taken early on and then no more). Concentrations at BH108, whilst variable remained very high throughout (over the full 5no. rounds).

The general decline over time suggests the source is limited / or potentially exacerbated by the drilling of the borehole (soil disturbance) with initially elevated values returning to the background concentrations.

There is a loose correlation between the groundwater naphthalene and the other lower molecular weight PAH up to anthracene, and to a lesser degree fluoranthene (but not to higher molecular weight PAH - see below). These also decrease over time and are generally below detection by the end of monitoring.

There is also a strong correlation between the naphthalene / lower molecular weight PAH concentration and elevated aromatic TPH (primarily EC_{12} – EC_{21}) (Appendix 4), as outlined below:

- By far the highest total PAH concentrations were also detected at BH108 –(cross-gradient) again variable but up to 6977 µg/l (identified on the first monitoring round);
- Regarding PAH concentrations, the overall concentrations strongly decrease over time at BH108 (and at other locations) with naphthalene becoming the dominant component;

- This suggests a similar depletion of the source at BH108 – with again the levels possibly initially exacerbated by the drilling disturbance, returning to much lower background levels thereafter; and
- The longer chain hydrocarbon species are not particularly mobile in groundwater which in combination with the strong decline in concentration may also suggest a localised source.

Within the shallow water body, no clear distinction is evident between the wells installed in the waste body and those installed in the KPG.
The higher naphthalene concentrations do tend to be in the south / downgradient of the Site but are still highly variable spatially – which suggests localised effects rather than pervasive contamination.

Higher soil PAH concentrations were also identified across this area too but tended to be the higher carbon number species, with naphthalene in particular not generally particularly elevated. It is considered that the groundwater naphthalene concentrations correlation with the groundwater TPH concentrations is much stronger, suggesting a TPH / petroleum hydrocarbon type source.

Overall, it is considered that the naphthalene, lower molecular weight PAH and aromatic TPH concentrations identified in the shallow aquifer are likely to represent relatively isolated / localised hydrocarbon sources (potentially exacerbated initially by the drilling operation) and not pervasive groundwater contamination – and are unlikely to represent either a significant risk from the Site to the on-site groundwater or from the groundwater to the wider controlled waters environment.

Within the deeper aquifer the naphthalene concentrations are generally much lower and also decline over time – these are also likely to represent localised effects (potentially also exacerbated by the drilling operation) and not pervasive groundwater contamination and are unlikely to represent a significant risk.

There is limited or no correlation between the naphthalene concentrations and the higher molecule weight PAHs (e.g. benzo(a)pyrene), which were rarely detected – possibly relating to their much lower solubilities or suggesting a different primary source for these compounds.

Higher molecular weight PAHs were very low or <LOD and where present were only detected in the first 2no monitoring rounds. Benzo(a)pyrene concentrations (summarised in Table 4.5) could again represent an initial exacerbation of the concentrations by the drilling operation than a fall back to <LOD levels.

Table 4.5. Benzo(a)pyrene Concentrations in Groundwater Samples.

Location (rel to Hyd. Grad.)	**Benzo(a)pyrene Concentrations in Groundwater (µg/l)**				
	Rnd 1 (Feb 2019)	**Rnd 2 (Mar 2019)**	**Rnd 3 (Nov 2019)**	**Rnd 4 (Feb 2020)**	**Rnd 5 (Jun 2020)**
Shallow Aquifer in Waste					
BH103A (up)	< 0.01	< 0.01	< 0.01	-	-
BH107 (cross)	< 0.01	**2.03**	< 0.01	< 0.01	< 0.01
BH109 (cross)	**0.34**	< 0.01	< 0.01	< 0.01	< 0.01
BH111 (cross/ down)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
BH113 (down)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Shallow Aquifer in KPG					
BH102 (up)	< 0.01	< 0.01	< 0.01	< 0.01	-
BH104A (up)	< 0.01	< 0.01	-	-	-
BH105 (cross)	-	< 0.01	< 0.01	< 0.01	-
BH108 (cross)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

BH112 (cross)	< 0.01	< 0.01	< 0.01	< 0.01	-
BH114 (down)	< 0.01	< 0.01	-	-	-
BH115 (down)	**0.29**	**0.55**	< 0.01	< 0.01	< 0.01
Deep Aquifer					
BH101 (up)	**2.01**	< 0.01	< 0.01	< 0.01	-
BH106 (cross)	-	< 0.01	< 0.01	< 0.01	< 0.01
BH110 (down)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

It is considered that there is no significant risk from the Site to the groundwater, or to the wider controlled waters environment from the higher molecular weight PAH species.

Concentrations are comparable up and downgradient with not spatial pattern evident.

4.4.10. Total Petroleum Hydrocarbons and BTEX

Elevated TPH concentrations were rare – high concentrations were only detected at 2 (no.) locations,–

- Up to 6977 µg/l at BH108 (cross-gradient) (correlated with naphthalene concentration as discussed above) – installed within the KPG deposits; and
- Up to 3000 µg/l at BH101 (installed within the deep aquifer, upgradient).

The species distributions were quite different however and the sources do not appear related – At BH108 (cross gradient and in-waste) the total concentration was dominated by EC_{12}-EC_{21} aromatic and at BH101 by EC_{21}-EC_{35} aliphatic.

In the shallow aquifer (where the potential for in-soil sources is feasible) very high concentrations (BH108, cross gradient) fell to much lower levels over the course of the monitoring (from 6799 µg/l to 170 µg/l).

Much lower concentrations of similar species were detected at BH109 (up to 265 µg/l total TPH) and BH107 (up to 281 µg/l), with very low concentrations at BH104A, upgradient (19 µg/l) and BH111, down/ cross gradient (25 µg/l) or below LOD.

Similar to naphthalene / lighter PAH species, these are considered representative of relatively localised sources, potentially initially exacerbated by the drilling operations that are depleted relatively quickly and are not likely to migrate significantly or represent wider contamination of the groundwater.

Very low concentrations of similar contaminants were also detected in BH110 in the deeper aquifer (as was naphthalene) but again this is not considered likely to represent significant contamination.

High concentrations of EC_{21}-EC_{35} aliphatic were detected in BH101 on the first 2no monitoring rounds, but subsequently below LOD. These species are very insoluble, and that they are not detected after the first monitoring rounds suggests a very localised, probably minor source. Therefore, they are not considered likely to represent a significant risk to groundwater.

Very low concentrations of EC_{21}-EC_{35} aliphatic species were also detected in the samples from the early monitoring rounds at BH106 (200 µg/l; and <LOD thereafter) and BH114 (180 µg/l). These are similarly not considered likely to represent a significant risk to controlled waters.

At BH107 in waste and cross-gradient, a dense black oil and strong odour (described as organic on the log) was noted in the groundwater at 12.0mbgl in the KPG (sandy gravelly clay). No soil or groundwater sample was taken during drilling / analysed from this depth to confirm the presence of hydrocarbons.

No evidence of contamination was noted in the soils at this depth, the made ground above (present to 11m) or in water above (the first water strike was at 8m). Only very low TPH concentrations were identified in the groundwater samples from BH107 (max 281 µg/l total TPH, comprising only aromatic EC_{21}- EC_{35}), which fell to <LOD on the last round. This, with consideration of the wider TPH distribution, is considered to indicate there is very unlikely to be a significant contamination issue associated with the observation.
BTEX and TPH was detected in the first two (2no.) rounds of groundwater testing at BH108. BTEX compounds included toluene (6.8 µg/l, round 1 only), ethylbenzene (51.7 µg/l and 4.6 µg/l), p & m-xylene (56.7 µg/l and 17.1 µg/l), and o-xylene (23.8 µg/l and 10 µg/l).

The concentrations are coincident with the highest total TPH concentrations (6977 µg/l and 5385 µg/l for rounds 1 and 2 respectively, primarily comprising C_{10}-C_{21}); with all species <LOD over the next 3 (no.) rounds. It is considered that the concentrations identified initially are in line with the wider TPH observations and are unlikely to represent a significant risk.

4.4.11. VOC and SVOC

Low concentrations of iso- and n-propylbenzene and 1,3,5- and 1,2,4 trimethylbenzene were detected at BH108 over the first one or two rounds (both February 2019). They were not detected anywhere else and were not detected in subsequent rounds at BH108 (February and June 2020).

- Isopropylbenzene: 5.5 µg/l 1st round only, <LOD thereafter;
- N-propylbenzene: 2.2 µg/l 1st round only);
- 1,3,5-Trimethylbenzene: 26.7 µg/l falling to 15.5 µg/l rounds 1 and 2 then <LOD thereafter; and
- 1,2,4-Trimethylbenzene: 52 µg/l falling to 37.9 µg/l then <LOD thereafter).

These compounds are related (structurally and by potential sources) and are considered likely to relate to the overall TPH concentrations at this location, and by the logic discussed previously, the concentrations are likely to have been initially aggravated, then falling back to actual background levels (<LOD). It is considered that the concentrations are unlikely to represent a significant risk to controlled waters.

Aside from the PAH species discussed in Section 4.4.7, dibenzofuran was detected in a number of samples – it is noted however that SVOC analysis was only conducted on a limited number of samples from the first round (February 2019) and fifth round (June 2020).

Dibenzofuran concentrations correlate to the low/mid molecular weight PAH species (acenaphthene and fluorene). It is likely that they have a similar overall distribution – i.e. related to relatively localised sources, concentrations exacerbated by drilling operations but then falling back to markedly very low levels.

A screening criterion of 7.3 µg/l was identified by a literature search. This is only exceeded at BH108 and BH109 on the first round and only at BH108 on the subsequent round.

Overall, it is considered that the dibenzofuran concentrations identified are very unlikely to represent a significant risk to controlled waters.

4.5. Summary of Laboratory Data (Surface Water)

Historic data (Table 2.3) indicates the Lee Navigation and Enfield Ditch (Pymmes Brook) watercourses have poor/moderate water quality with 'high' acid neutralizing capacity. In accordance with Schedule 2 Paragraph 1(1) of the Water Framework Directive, these would be considered 'Type 5' or 'Type 7' watercourses.

Hydrock undertook surface water sampling in June 2022 and provided laboratory data for 4 no. corresponding samples (refs. SW1 – SW4). It was understood that the samples were taken at 4 no. different locations along the River Lee Navigation (canal) above, at, and below the Site, however no record of the precise locations was offered. This somewhat limits the usefulness of the data; however, they still serve to characterise the general condition of water.

The results are presented in the following sections, with comparison to relevant EQS and DWS criterion, which are included in Appendix 6.

4.5.1. pH, EC, Cl, SO4, NO3, Hardness, Ammonium, Phenols and Cyanide

- No determinands exceed the EQS or DWS and are generally lower or much lower than the equivalent groundwater concentrations across the Site;
- pH ranged 7.9-8.1, EC ranged 480-620µS/cm, Hardness ranged 264-438mgCaCO3/l;
- Ammonium was 69-150µg/l (around a factor of 100 lower than the 'typical' groundwater levels);
- Sulphate concentrations are a similar order of magnitude/lower than the groundwater;
- Nitrate and nitrite are appreciably higher than the typical groundwater concentrations; and
- Cyanide and phenols were not detected.

There does appear to be a distinction between SW1 and SW2 compared to SW3 and SW4; for example –

- Conductivity, chloride, sulphate and hardness are higher in SW1 and SW2 vs. SW3 and SW4;
- Ammonium is appreciably higher in the SW3 and SW4.

This suggests that something is influencing the canal water chemistry in the region of the Site, although given that opposite trends in the chloride, sulphate and hardness concentrations vs. the ammonium concentrations it is not clear what.

It is also noted (with reference to Section 3.4.2) that the canal is likely to be lined and that water levels in the canal are slightly higher than the site groundwater levels in the region of the site meaning any 'leakage' is likely to be from the canal to the groundwater if at all, rather than vice versa.

Regardless it is noted that the canal concentrations are generally much lower than groundwater concentrations and below EQS levels, and this is considered indicative of the Site not having a significant impact on the canal.

Higher nitrate/nitrite levels in the canal (vs. the groundwater) are consistent through all samples indicating that there are other, possibly regional, influences on the water quality.

4.5.2. Metals

- Metal concentrations in surface water samples are all low and generally below EQS/ DWS;

- Copper is slightly above the EQS level, but well below the bioavailability adjusted EQS level; and
- Zinc and nickel are below the EQS, and well below the bioavailability adjusted EQS.

Compared to the groundwater concentrations –

- Boron and manganese were identified at high concentrations in the groundwater – this is not reflected in the surface water samples;
- Copper, nickel and zinc levels are broadly similar in the groundwater and surface water samples;
- Significant levels of dissolved lead and chromium were not detected in the surface water – but were also not detected in the bulk of the groundwater samples;
- Significant levels of dissolved cobalt were not detected in the surface water; and
- Cadmium that was generally not detected in the groundwater except at isolated locations / sporadically is detected at very low levels in all the surface water samples.

Where there is any pattern in the surface water sample concentrations then concentrations are higher in SW1 and SW2 vs. SW3 and SW4 – e.g. aluminium, boron, copper, iron and selenium. This is as per chloride, sulphate and hardness – but opposite to the trend in ammonium concentrations.

4.5.3. TPH, PAH and VOC

All PAH, TPH and VOC species were below the limits of detection.

4.6. Summary of Ground and Surface Water Contamination, Distribution, and Inferences

On the basis of the available information, and with consideration of the conceptual site (ground) model (CSM), it is considered that the Historic Waste (HstW) at the Site is unlikely to present a significant risk to controlled waters - neither the historic waste (soils) to the on-site groundwater, nor the on-site groundwater (or soils directly) to the wider groundwater environment or surface water environment.

Further, no significant difference in water quality is evident between the wells installed with the response zone in the waste body and those installed with the response zone in the KPG, It is considered that this is consistent with the ground model – i.e. with the KPG deposits being only discontinuous and relatively thin across the site, in good hydraulic connectivity with the waste body and hydraulically bounded by the London clay below.

Where any patterns are evident in the shallow water body water quality these are lateral rather than vertical: e.g. the ammonium concentrations appear to decrease from north (upgradient) to south (downgradient) across the Site but there is no clear distinction between the waters in the waste body and KPG. The potential contaminant distributions tend to suggest regional effects (metals, ammonium) or very localised effects including possible drilling artefacts (PAH, TPH) and nothing indicative of on-site impacts migrating off-site.

There is no evidence impact on the deeper groundwater (as would be expected with the London Clay barrier.

In general, contaminant concentrations in the surface water are lower or substantially lower than those in the groundwater and were all at levels below EQS, or M-BAT bioavailability adjusted EQS and DWS.

The inference is, that if the Site is having any impact on the water quality, it is very slight (and not exceeding any EQS etc) and regional factors likely to be more significantly influencing the surface water quality.

5. CONCEPTUAL SITE (GROUND) MODEL (BASELINE CONDITION)

The baseline ground model is presented in the previous sections and the ESSD report and may be summarised as:

- Made ground / historic waste across the site to 6.5 – 11.0mbgl consistent with infilling of the site with ‘inert construction and demolition type’ waste materials; overlying
- Relatively thin and discontinuous remnant KPG deposits, generally limited to 1.0 – 2.0m thick where present; in turn overlying
- London Clay from 7.4 – 10.8mbgl (5.3 – 7.3mAOD) and at least around 10 - 14m thick.
- Lambeth Group, Thanet Sand and Chalk at depth;
- A shallow water body within made ground (leachate) and remnant KPG (Secondary ‘A’ Aquifer) – with unconstrained hydraulic connectivity between the units and no clear distinction in water quality between the two units (i.e. no meaningful distinction between the groundwater in either unit);
- A significant thickness of London Clay (10-14m) underlying the Site/made ground, which will form a significant hydraulic break (aquiclude) between the shallow and deep-water bodies;
- A deeper groundwater body is present underlying the London Clay, within the Lambeth and Thanet (Secondary ‘A’ Aquifers) and in the Chalk (Principal Aquifer) at depth;
- The groundwater flow/hydraulic gradient in the shallow waterbody is interpreted to be generally from north to south, potentially with a very minor east to west component;
- The groundwater flow direction in the deeper aquifer is likely to be toward the southeast;
- There is an SPZ II encroaching into the southeast corner of the Site.
- The shallow water body (described above) is likely to be in contact with the wider shallow groundwater environment – primarily to the south with the groundwater flow direction. The groundwater flow will be blocked to the east by the reservoir and to the west by higher ground;
- The hydraulic connectivity with the River Lee Navigation canal and William Girling Reservoir is considered to be limited. There may also be some potential for connection to the lake to the north, but this up-hydraulic gradient (against the flow).

It is noted that on the basis of the site investigation data the existing made ground /HstW (Source Term) is not significantly impacting on the groundwater quality at the Site or the groundwater or surface water within the wider area of the Site.

In the context of the proposed development (Sections 1.2 to 1.4 and Appendix 1), ***it is considered that the basic ground model is materially unchanged in the post-operational phase*** – whilst a Cut & Fill scheme is proposed to facilitate creation of the required development platform and lake, this will entail relocation of recovered waste (made ground/HstW) within the Site boundary to other areas where similar made ground is already present and importantly, it will not include any excavation or deposition of recovered waste below the groundwater level.

It will also not materially relocate the made ground (contamination source) to areas that are not currently affected or to more sensitive areas (e.g. along the canal boundary).

The proposed depths / volumes re-used material will not significantly affect the general distribution of made ground soils across the Site; i.e. it will not significantly concentrate material or increase or decrease the depths of material at the Site in comparison to the current distribution, See Drawings WAVE-WHE-ZZ-XX-DR-S-0006 - Design Levels (P02) and WAVE-WHE-ZZ-XX-DR-S-0007 - Sections (P02), presented in Appendix 1

5.1. Source Term – Summary

The source-term for the Deposit for Recovery is the made ground / historic waste, (HstW), that will undergo a treatment process to remove geotechnically deleterious materials such as wood, metal, textiles, and ACM as far as practically possible. Recyclable inert materials such as concrete, brick, masonry and ceramics will be processed on-site to create aggregates for use in the construction works.

The source term can generally be described as soils (clay, sand and gravel) derived from construction wastes. The characteristics of the Source Term are essentially represented by the characterization of the made ground / HstW described in previous sections, however, the treatment process will include the removal of grossly contaminated soils, degradable materials such as wood, textiles, paper etc.

With regard to the current contamination characteristics, the data does not indicate any discernible pattern in the distribution of contamination or soil composition/ types (vertical or lateral) and overall, the made ground was generally quite similar (but heterogeneous on the smaller scale) throughout. Contamination identified (in soils) is summarised as follows:

- Metal concentrations were generally low with occasional / sporadic higher concentrations;
- Copper, zinc and lead concentrations were pervasive across the Site, but only lead occasionally exceeds the BMC;
- Moderate PAH levels were relatively common – again with higher values also occurring sporadically across the Site. The PAH distributions were generally dominated by the mid – higher chain length species. Naphthalene was high (relatively) at just 1 no. location – and was not generally correlated with the higher PAH concentrations;
- TPH concentrations were generally relatively low with higher concentrations occurring sporadically (probably representing localised ‘hotspots’);
- There was only weak correlation between TPH and PAH concentrations – high TPH levels generally did not coincide with high PAH levels. PAHs were generally more pervasive and likely to represent a more consistent distribution across the Site (although some no doubt also represent hotspots);
- BTEX and other VOCs were low or <LOD, and where present related to the petroleum hydrocarbon distribution. No chlorinated VOCs were identified;

- High (relatively) cyanide concentrations (79 mg/kg) were identified at 1 (no.) locations TP126 on the western side of the Site at 2.0mbgl and suspected spent oxide (described as dark blue silty sand with a strong gas like odour) was identified during the Site investigation at TP74 on the eastern side of the Site.

Based on the data and the age of the material (>50 years), it is considered unlikely that contamination levels will increase in the future as the waste mass degrades.

On the basis of the groundwater and surface water sampling and analysis undertaken the made ground /HstW does not appear to currently be having a significant impact on the controlled waters environment.

By extension, it is considered that the contamination present is unlikely to have significant potential to leach at levels likely to affect the controlled waters environment in the context of the development proposals.

5.1.2. Current and Historic On-Site and Close to Site Sources

A number of current and historic activities either on- or close to the Site were identified by the desk study review, as presented in Section 2, including:

- Historic railway sidings, creosote works, sewage treatment works, and gravel workings etc;
- Builders yard to the southeast, development of the Picketts Lock Centre to the west; and
- Current use as a golf course and campsite.

It is considered that where these may have had an impact, they would be reflected in the Site soils and / or in the groundwater conditions at the Site, which have been well characterised by the Hydrock SI.

Any residues of the older historic on-site activities – e.g. the creosote works, railway tracks – will have largely been 'overwritten' by the extraction and deposition processes, but could have left localised effects.

It is considered that the sewage works formerly present to the immediate north of the Site may have contributed to or affected the nature of the fill at the Site but that this will also be already accounted for in the soil conditions identified by the Site investigations. No potential contamination attributable to the current Site use has been identified.

The sewage works may have impacted on the groundwater conditions locally and the wider area including the subject site which is immediately down hydraulic gradient, and thus has been proposed as a potential source for elevated ammonium concentrations. If this were / is the case however it would be expected that the primary source (materials / soils directly associated with the sewage works) would have been largely removed by the gravel extraction works.

Within the wider area, the historic chemical and gas works sites etc may have affected (and be reflected in) the historic composition of the waste deposited, but will again be already accounted for by the conditions identified by the Hydrock investigation. Similarly, any associated impact on the groundwater quality at the Site would likely be a regional and would also be reflected in the current groundwater sampling results.

Overall, these off-site and regional potential contamination sources are not considered relevant or significant in the context of the current assessment. The dominant contamination signature is likely to be from the infilling of the subject site (which will overwrite to a large degree any previous site activities).

5.1.3. Groundwater (as a Source-Term)

The groundwater at the Site has been characterised by the various site investigations.

There are no potable water groundwater abstractions within 500m of the Site, and the abstractions within 1km exclusively source water from the Chalk or Thanet bedrock.

Whilst there are a number of contaminant species that are elevated above the adopted screening levels in the groundwater, these generally appear to be related to off-site / regional effects, or to be sporadic and not consistently related to site conditions.

Overall, the groundwater and surface water monitoring and risk assessments indicated that the Site groundwater was unlikely to have an impact on the wider controlled waters environment.

5.2. Pathways

With consideration of the geological, hydrogeological and hydrological setting and discussion with regard aquifer connectivity etc. in the previous sections the primary potential mechanisms / pathways for migration of potential contaminants from the Site are considered to be:

- Infiltration of rainfall and surface water run-off;
- Leaching of contaminants in the waste body;
- Vertical and lateral migration in the unsaturated zone to the saturated zone;
- Lateral migration in the groundwater, and migration between superficial and bedrock aquifers;
- Migration into Surface Water Receptors from the Groundwater;
- Migration within surface waters; and
- Man-made subsurface pathways.

It is noted that a number of pathways may be exacerbated or altered by the development – either during the process (construction phase) or post construction.

5.2.1. Infiltration of Rainfall and Surface Water Run-Off

Currently the Site is dominantly soft standing and this is expected to remain the case in the proposed development except for the Wave Pool itself the immediate surroundings.

It is expected that rainfall will be generally accounted for by infiltration and evapotranspiration.

Given the generally low rainfall for the region (Section 2.10) evapotranspiration is likely to be the dominant effect with minimal surface percolation through the soils likely to occur. This is supported by the generally minimal levels of perched waters encountered by the Site Investigation. Overall infiltration through the surface soils is therefore generally expected to be minimal.

New buildings and hardstanding added within a development can potentially result in increased / concentrated run-off and infiltration in some areas. However, this will be managed by the Site layout and drainage design (Appendix 1) and overall, it is expected that the development is likely in itself to reduce overall infiltration with the introduction of more hard standing and buildings etc. and a managed surface water drainage system that discharges to existing water courses. Overall, it is considered that this would not be significant in the context of the development.

Considering potential climate change effects, these are expected to potentially result in increased rainfall but in more concentrated events which is likely to result in increased run-off rather than increased infiltration.

5.2.2. Leaching of contaminants

No direct laboratory generated soil leachate data has been produced by the SI. However, the water quality data for the shallow water body (from the wells installed within the waste body and those in the KPG because of the close proximity, hydraulic connectivity and discontinuity and relative thinness of the remnant KPG) do represent the 'leachate' product – or rather a combination of the inflowing groundwater quality from the north plus the site contribution.

On the basis of the site investigation data, it has been concluded that the site is not having a significant impact on the shallow water body quality at the site, nor on the shallow groundwater in the wider region of the site (Section 4). By extension it is considered that the potential for significant new leachate generation (contamination derived from the site soils) is very limited.

Potential contaminant concentrations in the Site soils are generally low or only sporadically elevated and in particular the groundwater data indicate that leaching of contaminants from the Site soils is generally (very largely) minimal (not significant).

This is consistent with the type of fill identified (i.e. soils and 'inert type' construction and demolition type fill), and with the age of the fill - since it has been present since the 1950s / 60s and the most easily leachable components will have already naturally attenuated.

The potential for the leaching of significant contaminants from the existing site soils (waste) is therefore very low.

5.2.3. Migration in the Unsaturated Zone

The only significant water input to the Site will be rainfall (also note Section 5.4.1).

Rainfall in the region is low, and evapotranspiration from soil surfaces are likely to dominate during much of the year. This limits the potential for leachate generation in the unsaturated zone and also limits the driver for migration of that leachate.

Further, within the context of the proposed development rainfall/surface water run-off will be manged by the design of surface water drainage (SUDs - which will be approved through the planning process).

Lateral migration in the Unsaturated Zone is likely only over relatively short distances in perched water, potentially over low-permeability (clay) layers in the made ground.

The SI data did not indicate any significant perched waters, possibly in part due to minimal recharge from rainfall, so these are not expected to be major driver of leachate/migration.

5.2.4. Migration in the Groundwater and Between Aquifers

Groundwater flow in the shallow aquifer is expected to be generally north to south, with potentially a minor easterly component, but limited in the area of the Site due to geological factors.

The groundwater flow in the deep aquifer is poorly defined but likely toward the southeast on a regional level, however direct hydraulic continuity with / vertical migration to the bedrock aquifers is unlikely due to the London Clay interlayer acting as a hydraulic barrier (aquiclude), protecting the Thanet and Chalk.

Based on the above, the need to precisely define the groundwater flow in the deep aquifer is not considered to be required.

Monitoring wells installed by the Site Investigation are unlikely to provide a significant pathway between the upper and lower aquifer bodies. Regardless these must be decommissioned properly in line with Agency guidance when they are no longer required.

5.2.5. Migration into Surface Water Receptors from the Groundwater

The groundwater level at the Site and the water levels in the River Lee Navigation canal are similar, but slightly higher in the canal (11.0mAOD) versus the groundwater (c.10.8mAOD at east boundary).

Hydraulic connectivity between the groundwater and the canal is likely limited by the liner of the canal.

It is noted (with reference to Section 3.4.2) that the canal is likely to be lined, therefore limiting hydraulic connectivity between the groundwater and the canal. Also, with reference to Section 3.4.2 the water levels in the canal are slightly higher than the site groundwater levels in the region of the site meaning any 'leakage' is likely to be from the canal to the groundwater if at all, rather than vice versa.

Additionally, it is possible that the canal levels are artificially higher than they would otherwise naturally be by locks (the Site is just north of Picketts Lock) which would suggest any leaking of the canal lining would be outwards (i.e. from the canal to the groundwater).

Regardless, the water quality data do not suggest any significant impact or connectivity between the groundwater and canal.

5.2.6. Migration within Surface Water Systems

Any contamination entering the River Lee Navigation would migrate downstream. It would be expected however that there would be a high degree of dilution and that it would be hard to differentiate any effects downstream from those potentially through impact from other sites.

It is further noted that on the basis of the comparison of the groundwater and surface water monitoring data it does not appear that there is any significant discernible effect on the canal in the vicinity of the Site, and it follows that there would be none downstream that would be attributable to the Site.

Pymmes Brook is a relatively minor ditch / shallow water course, which will likely dominantly receive surface runoff which has had limited/no contact with the made ground soils. Surface water run-off is to be managed during construction by the Environmental Management System and by SuDs in the final build.

Migration of water between the Site and the William Girling Reservoir to the east is considered to be very unlikely due to the engineering construction of the reservoir, with the embankment puddle clay core toeing into the London Clay. Furthermore, the water levels in the reservoir are significantly higher than those the River Lee Navigation and the Site, so any flow would likely be out of the reservoir rather than into it.

5.2.7. Man-Made Subsurface Pathways

Piled foundations and ground improvement techniques are anticipated beneath the wave pool and associated structures.

It is accepted that a risk assessment will be required to assess the potential risk in accordance with current industry guidance, principally 'Piling and Penetrative Ground Improvement Methods on Land Affected by Contamination: Guidance on Pollution' available at CL:AIRE website. This risk assessment will be carried out and submitted the EA following finalisation of the foundation design.

It is not expected that soakaways that would concentrate infiltration of surface water run-off in particular areas of the Site will be used. It is expected that infiltration of water into the Site will be dominantly though the Site surface (similar to the current situation) or managed by lined attenuation basins.

Site investigation monitoring wells are considered to be unlikely to provide a pathway to the underlying aquifers, but must nonetheless be decommissioned in line with EA guidance once no longer required.

No significant underground utilities are known on-site. Irrigation apparatus may be in place for the maintenance of the golf course; however, these are likely to be shallow features (<1m bgl).

5.3. Receptors

On the basis of the review, the primary potential sensitive receptors that might be affected by the Site are:

- Shallow groundwater within the Made Ground/Secondary 'A' aquifer; and
- Off-site surface waters (River Lee Navigation, Enfield Ditch (Pymmes Brook), Ponders End Lake, and other lakes/reservoirs and connecting water courses downstream of the Site).

Potential receptors of River Lee Navigation, William Girling Reservoir, and deep aquifers below the London Clay are considered very unlikely to be affected (and will not be included in the CSM).

The Enfield Ditch (Pymmes Brook) is considered unlikely to be affected, but has been included in the CSM due to the potential for the site works to influence the water quality.

It is further considered that the receptors the same pre-, during and post- development.

5.3.1. Shallow Groundwater in the Made Ground and KPG

Shallow groundwater within the Made Ground body / the Secondary 'A' aquifer (KPG) is considered to be the primary groundwater receptor for contamination. Specifically, on-site and immediately beyond the Site.

The wider groundwater environment is not considered to be a significant receptor.

The Kempton Park Gravel (KPG) has been mined from the Site (only small residual KPG soils remaining), and replaced with HstW. No significant leachable contamination has been identified in the fill thus far.

Only re-engineered materials which conform to inert waste classification criteria are to be placed - inert wastes do not contain leachable hazardous or non-hazardous substances likely to cause pollution. In addition, no materials are to be laid below the water table, and no significant perched waters are expected.

5.3.2. Off-Site Surface Waters

The primary potential surface water receptors have been identified as River Lee Navigation Canal, Ponders End Lake to the north, and reservoirs, connecting water courses, and lakes downstream of the Site.

In summary, based on the data discussed in this report, it is considered that there is limited possibility for surface waters to be affected by any potential contamination at the Site.

The River Lee Navigation is likely protected by lining, and no evidence of degradation of the watercourse quality has been identified. Ponders End Lake is hydraulically upgradient. Downstream watercourse quality in wider area is likely to be influenced to a greater extent by regional factors.

6. HYDROGEOLOGICAL RISK ASSESSMENT

6.1. Nature of the hydrogeological risk assessment

EA guidance supports a tiered approach to risk assessment, the complexity of which should reflect the level of risk. The risk assessment herein utilises both a Tier 1 (qualitative) and Tier 2 (generic quantitative) approach on the basis of available information, and the comparison of SI data with a set of generic screening levels.

The Assessment uses a Source-Pathway-Receptor approach based on a robust Conceptual Site Model (CSM) If a complete Source-Pathway-Receptor linkage does not exist then there is no risk.

The Hydrogeological Risk Assessment (HRA) considers:

- The potential risks posed by the Site, in its current state;
- The Sensitivity of the surrounding water environment; and
- Hazards posed and the likelihood of the risk happening.

The factors are dependent on the geological, hydrogeological and hydrological settings which define the underlying Hydrogeological Conceptual Site Model.

6.2. Sensitivity of Location

The Site is considered to be of moderate sensitivity with regard to groundwater, due to its location overlying a Secondary A Aquifer associated with the remnant KPG, which has been largely mined as a result of previous extraction (1930 – 1950's).

There are surface water receptors in proximity to the Site but it has been shown there is limited, if any direct connectivity with the water body at the Site.

The south-eastern corner of the Site is located in an SPZ II, associated with abstraction from deeper aquifers in the Chalk and has been disregarded from the HRA due to the presence of the London Clay, providing an effective aquitard to downward migration of the groundwater and hence the potential for contamination.

6.3. Compliance Point

For the purpose of the risk assessment the compliance point is the water body (leachate/groundwater) in the saturated zone (@10-11m AOD) at the southern extent of the Site. In June 2025 two additional down gradient groundwater monitoring boreholes GBH102 & GBH103, were installed. These boreholes will be included as compliance points for future monitoring during the operational phase.

6.4. Proposed Assessment Scenarios

The HRA considers the following assessment scenarios

1. The baseline condition, based on the Site in its current state;
2. The operational phase (construction / development); and
3. Post operational phase (completed development)

The Source-Pathway-Receptor linkages for each scenario are presented in Tables 5.1- 5.3 below.

6.5. Tier 1: Qualitative Risk Assessment

Based on the data presented in the previous sections, it may be logically concluded that the contamination profile of the existing water body is representative of the concentrations resulting from in part leaching from the HstW – Source Term, and in part from off-site contributions in the wider groundwater of the London area.

The potential for on-going leaching from the source-term HstW is very low and the risk of an increasing contaminant load to groundwater is considered very low. This is on the basis of the low organic content and infrequency of biodegradable fractions within the HstW, i.e. no evidence of degrading vegetable matter and neutral pH conditions (6.8 – 7.9 Av 7.26).

It is concluded, qualitatively that the Source-Term subject of the DfR will not cause additional pollution to enter groundwater.

Waste acceptance, including chemical laboratory testing of recovered wastes, prior to permanent deposition will ensure the deposited material complies with appropriate criteria for the protection of controlled waters. The testing will

6.6. Tier 2 generic quantitative risk assessment

Whilst it has been shown that the Source Term does not present a significant risk to controlled waters in its current state the following the following priority substances have been considered further in the HRA on the basis that discernible concentrations have been detected in the water body (Section 4) at the Site.

6.6.1. Priority Substances

Arsenic and lead are considered hazardous and are considered as discernible concentrations have been detected in the water body at the Site, albeit at concentrations below the EQS / DWS and discernible concentrations have been detected in the Source Term. The relevant screening value used is the MRV (minimum reporting value)

Boron and ammonium, are considered non-hazardous and are present in discernible concentrations above the EQS and are considered to examine the potential for deterioration in the quality of the wate body at the Site. The screening assessment criteria for the non-hazardous substances is the appropriate EQS / DWS.

For each substance, the highest concentration observed during the monitoring has been used as the concentration in the source. Background concentrations in the aquifer are taken either from the monitoring data, or as the required assessment criteria (MRV or EQS etc.)

Outputs from the risk screening are presented in Appendix 9

6.6.2. Technical Precautions

As set out in the Tier 1 qualitative risk screening, it is concluded based on the proposed re-use of site-derived waste only that there will be no significant risks to the environment from the proposed development. Surface water flows from the development will be managed via an approved surface water management scheme. There will be no additional significant input to the existing waste or water environment.

6.6.3. Consideration of Dilution

The remnant KPG is considered the main groundwater receptor, this being overlain by cohesive and granular historic waste (HstW).

No waste recovery or deposition will be carried out sub-water table and there is no requirement for groundwater management during the operational phase.

Following waste deposition, the main pathway for pollutants to enter the groundwater is via percolation through the unsaturated zone. It is assumed conservatively that the compliance point for hazardous substances and for non-hazardous pollutants is in groundwater underlying the Site.

For the purposes of this HRA only dilution in the KPG is considered and the same model is used conservatively to represent both the operational and post operational scenarios.

Other than immediate dilution in the KPG aquifer no attenuation of hazardous substances or of non-hazardous pollutants is considered in the dilution calculations. As dispersion, retardation and degradation processes will reduce the concentrations of hazardous substances or of non-hazardous pollutants along the groundwater flow path prior to the groundwater reaching the surface water receptors downstream, it is considered that this assumption is conservative.

6.6.4. Calculation Methodology

As a conservative assumption it is assumed that all of the modelled substances are present the highest recorded concentrations at the outer edge of the current waste (HstW). Accordingly, these concentration values are used as model input parameters in a spreadsheet-based model which predicts the concentration of contaminants in the KPG aquifer at the compliance point taking into account immediate dilution in the aquifer.

For each of the priority environmental assessment limits (EALs) are proposed, which comprise the concentrations of substances above which it is considered there may be a discernible discharge of hazardous substances to groundwater or pollution of groundwater by non-hazardous pollutants based on recognized standards e.g. EQS, DWS.

In order to assessment the magnitude of the potential impact on groundwater quality from the re-use of site derived wastes, values, the predicted concentration of contaminants in the KPG aquifer at the compliance point are compared with the EALs.

The predicted concentration of contaminants in the KPG aquifer at the compliance point following immediate dilution is calculated as follows:

$$C_{aq} = \frac{(C_{iw} \times Q_{iw}) + (C_{bq} \times Q_{aq})}{(Q_{iw} + Q_{aq})}$$

C_{aq} is the predicted concentration in the aquifer (ug/l)

C_{iw} is the actual in waste value from the monitoring data (ug/l)

Q_{iw}	is the discharge to groundwater from the existing waste (m^3/s) which is calculated based on the assumed hydraulic conductivity of the waste multiplied by the measured hydraulic gradient
Q_{aq}	Is the groundwater flow (m^3/s)down gradient of the Site calculated based on assumed hydraulic conductivity in the KPG which is calculated based on the assumed hydraulic conductivity of the waste multiplied by the measured hydraulic gradient.

6.6.5. Model Parameters

The substances which comprise the source term in respect of the GQRA together with the source concentrations are listed in Appendix 9 at Table HRA App9-1.

For each of the substances included in the assessment the proposed EALs are presented in Table HRA App9-1.

The EAL for the hazardous substances arsenic and lead are set at the minimum reporting value (MRV).

The EALs for non-hazardous pollutants are set based on background groundwater quality and/or relevant water quality standards where available.

Where possible the input parameters are based on site-specific data or other relevant sources. Where no site-specific data are available professional judgement has been used to select appropriate parameter values based on relevant scientific literature. The model input parameters are presented in Table 6.1, Appendix 9 and in the spreadsheet.

Table 6.1 Input Parameters			
Parameter	**Unit**	**Value**	**Justification**
Assumed Hydraulic conductivity of HstW	m/s	1.00E-05	reasonably conservative assumption based on HstW being a mix of clay and sand. No attenuation layers present
Assumed Hydraulic conductivity of KPG Aquifer	m/s	1.00E-04	based on professional judgement / literature values.
Hydraulic Gradient in Hist W	m/m	1.11E-03	calculated from SI data
Hydraulic Gradient of KPG	m/m	1.11E-03	calculated from SI data
Thickness of waste below the rest groundwater level	m	5.00E+00	based on SI data and represents the max. thickness below resting water level.

In all cases the predicted concentration in the aquifer is lower than the Environmental Assessment Level, as summarised below and provided in Appendix 9 .

Arsenic - Hazardous	**Unit**	**Value**
Environmental Assessment Level for Arsenic	ug/l	5.00E+00
Predicted Conc in Aquifer **(Caq)**	ug/l	3.64E-01
Lead - Hazardous	**Unit**	**Value**
Environmental Assessment Level for Lead	ug/l	5.00E+00
Predicted Conc in Aquifer **(Caq)**	ug/l	1.64E+00

Boron - Non-Hazardous	**Unit**	**Value**
Environmental Assessment Level for Boron	ug/l	2.00E+03
Predicted Conc in Aquifer **(Caq)**	ug/l	7.45E+02

Ammonium- Non-Hazardous	**Unit**	**Value**
Environmental Assessment Level for NH4	ug/l	2.00E+03
Predicted Conc in Aquifer **(Caq)**	ug/l	2.91E+01

From the data and the predicted concentrations for hazardous and non-hazardous substances are significantly lower than the respective EAL's. It is therefore considered that there will be no discernible discharge of priority substances (both hazardous and non-hazardous) as a result of the permitted operations

6.7. Consideration of Leachate Squeeze

The Hydrock site investigation shows highly variable material within the upper HstW, in general, the sequence of material was found to be cohesive overlying sands and gravels. Groundwater ranged between 4.30m to 8.00m bgl and in all but two of the boreholes (BH104a & BH107) was located within granular made ground / HstW largely comprising sands and gravels.

In order to determine the if the additional surface pressure of the embankments could cause leachate squeeze due to the additional loading the data from the SI has been reviewed, geotechnically.

From a geotechnical and hydrogeological point of view, leachate generation can occur due to either consolidation of the material that contains the leachate or, a reduction in volume of a confined, fully saturated granular material. Consolidation only occurs within cohesive (fine grained) material such as clays and silts. It is the process of a mixture of porewater and air voids being squeezed out of a clay due to an added pressure. Therefore, the smaller the applied pressure, the smaller the reduction in volume of the material will occur.

Granular soils do not consolidate. They undergo immediate or nearly immediate settlement under an applied pressure by rearrangement of individual grains. Any groundwater within granular made ground/HstW is free to percolate through the non-saturated material above the current water levels and will therefore generally remain at a constant level.

Lateral leachate can be generated within discrete, confined granular horizons that are fully saturated and under hydrostatic pressure e.g. granular horizons confined by non-permeable cohesive soils above and below. If the granular horizon is fully saturated (e.g. all intergranular voids are full of leachate) then the leachate could theoretically move but only if there was a specific pathway within the granular material for it to migrate.

As detailed above, only two of the boreholes within the Hydrock report indicate groundwater levels within cohesive material. The vast majority of the boreholes (except BH113) indicate groundwater to sit within layers of granular HstW and KPG deposits with generally far more than 1.00m of granular material above the groundwater level. Therefore, this would allow a significant degree of settlement to occur before the surface pressure was transferred to the groundwater/leachate and cause it to migrate.

Therefore, the risk of ongoing leachate generation and migration is considered negligible across the Site.

For completeness, a simple calculation was undertaken using some of the bunds geometries to ascertain the potential applied vertical stress σ_z at a level of approximately 6.00m bgl which corresponds to the approximate average groundwater level across the site. A simplified 2:1 Stress Distribution Method was used which is considered appropriate for uniformly loaded embankments and bunds similar to the ones proposed.

For a uniformly loaded area, the vertical stress at depth z is approximated by spreading the load at a 2:1 slope:

$$\sigma_z = \frac{q \cdot A_0}{A_z}$$

Where:

q = surface pressure (kPa)

A_o = original loaded area

A_z = area at depth z, expanded by a 2:1 slope

Assuming a bulk unit weight of $18kN/m^3$ and using the maximum height of approximately 3.00m above existing ground level, this would give a uniform surface pressure (ignoring the bund side slopes) of 54kPa. Using the above equation, the vertical stress at 6.00m depth is reduced by approximately 10kPa to around 44kPa.

Given the SPT N values within the clay material were between 8-10 this would correspond to a very conservative undrained shear strength of around 24kPa.

Using basic Bearing Capacity equations approximating to a rectangular footing at 6.00m depth, the shear strength gives an allowable bearing capacity of 49kPa.

Assuming a M_v (coefficient of volume compressibility) of 0.2, this would effectively produce no appreciable settlement at the given load and depth.

Whilst it is recognised that these calculations are basic and generally used for predicting settlements for foundations, they provide a quick and simple check on potential settlement and hence potential leachate generation without using complex specialised software.

In summary, given the predominant material type being granular, the depth to groundwater being on average 6.00m bgl and the relatively low applied surface pressure of 54kPa, the risk of leachate generation and migration (e.g. leachate squeeze) is considered negligible.

6.8. Conceptual Site Model and Risk Assessments

On the basis of the available background information and discussion in the preceding sections, the Conceptual Site Model (CSM) and Risk Assessments are summarised in tabular form in Tables 6.2, Table 6.3, and Table 6.4.

Site cross sections North -South and West – East are presented at Appendix 2.

The CSM and Risk Assessments are considered for the following scenarios:

- The **current situation** based on the available background information and the Site investigation data and risk assessments set out in Sections 4 and 5 – which forms the basis of assessments for following scenarios in the context of the proposed development (Section 6.8.1/ Table 6.2);
- A **construction phase** assessment, considering factors during the Cut & Fill works (i.e. excavation, stockpiling/treatment, and relocation/placement of soils, and the processes used to achieve this, exposure of contaminated soils/hotspots; temporary landforms which may result in pooling of water, changes in run-off patterns, and/or increased infiltration; increased exposure of soils to water/infiltration and potential for increased leaching of contaminants (data suggests this will be minimal / not significant (Section 6.8.2/ Table 6.3); and
- The **Post Development** scenario, i.e. the new landform and development layout achieved through re-use of site soils in accordance with a Deposit for Recovery permit and WRP (Section 6.8.3/ Table 6.4). Post development it is considered that the risk profile of the Site is essentially the same as the current scenario. Placement of landscaping soils and inclusion of a surface water drainage system will potentially improve the risk scenario as surface water run-off will not interact with the made ground (expected to be limited anyway).

The Risk Assessment has been undertaken in accordance with EA guidance (R.13, R.14).

6.8.1. Current Situation

Table 6.2. Source-Pathway-Receptor Linkages – Current Site Setting / Land Use Scenario.				
Source(s)	**Pathway(s)**	**Receptor(s)**	**Risk**	**Justification / Comment**
Made ground	Infiltration of rainwater or surface water run-off; Leaching within the unsaturated zones; Vertical and lateral migration within the unsaturated zone; Migration to and within the shallow 'groundwater' body (leachate and groundwater in KPG)	Shallow Groundwater (in MG/KPG)	**Low**	Based on SI data, in particular groundwater data. No significant contamination of the shallow groundwater at the Site. Consequently, the risks are deemed to be low.
	As above plus Lateral migration within the shallow water body; Migration to the wider groundwater environment and / or Migrations to surface water receptors connected with the groundwater; and Migration within the surface water	Shallow Groundwater (in MG/KPG)	**Low / Very Low**	As above, and required migration (which will result in dilutions) of the contamination.
		Surface Waters	**Low / Very Low**	As above, and required migration (which will result in dilutions) of the contamination. No significant connectivity to off-site surface waters (River Lee Navigation, Reservoir, Lakes)
	Leaching to surface water run-off; migration in surface water	Surface Waters	**Very Low**	As above and run-off will only interact with very near surface soils over a short distance - over longer distances normal infiltration and evapotranspiration will be dominant.
Contaminated groundwater in MG/KPG	Lateral migration within the shallow water body (leachate or groundwater in KPG); Migration to the wider groundwater environment and / or Migrations to surface waters connected with the groundwater; and Migration with the surface water systems, Man-made pathways	Shallow Groundwater (in MG/KPG)	**Low / Very Low**	Based on SI data, the Site does not appear to be significantly impacting on the groundwater. Consequently, the potential contaminants are local off-site effects or (more likely) regional effects. Localised contamination within the groundwater (e.g. TPH, naphthalene and lead) non-pervasive or not migrating in any significant manner. Overall, the Site groundwater is unlikely to significantly impact the wider groundwater environment.
		Surface Waters	**Very Low**	Based on the SI data the Site does not appear to be having any significant impact on/connection with the canal. By extension there will also be no impact on the wider downstream surface waters. The lake is up- hydraulic gradient.

6.8.2. *Construction Phase Assessment*

Table 6.3. Source -Pathway-Receptor Linkages – Operational (Construction) Phase.

Source(s)	Pathway(s)	Receptor(s)	Risk	Justification / Comment
Made ground (this applies to both in-situ and relocated soils)	Infiltration of rainwater or surface water run-off; Leaching within the unsaturated zones; Vertical and lateral migration within the unsaturated zone; Migration to and within the shallow 'groundwater' body (leachate and groundwater in KPG)[1]	Shallow Groundwater (in MG/KPG)	**Low**	Based on SI data, in particular the groundwater data and risk assessments indicating no significant contamination of the shallow groundwater at the Site. The data and age of the made ground (since original placement at the Site, 1960s) also suggest limited potential for increased leaching. Consequently, the risks are deemed low.
	As above plus Lateral migration within the shallow water body; Migration to the wider groundwater environment and / or Migrations to surface water receptors connected with the groundwater; and Migration within the surface water[2]	Shallow Groundwater (in MG/KPG)	**Low / Very Low**	As above and required migration (which will result in dilutions) of the contamination.
		Surface Waters	**Low / Very Low**	As above, and required migration (which will result in dilutions) of the contamination. No significant connectivity to off-site surface waters (River Lee Navigation, Reservoir, Lakes)
	Leaching to surface water run-off; migration in surface water[3]	Surface Waters	**Low**	As above, but see Note 3. Stockpiles should be placed to minimise run-off to the canal etc. Otherwise, infiltration to be dominant pathway (as above). Assuming works are suitably managed, risk is low.
Contaminated groundwater in MG/KPG[2]	Lateral migration within the shallow water body (leachate or groundwater in KPG); Migration to the wider groundwater environment and / or Migrations to surface waters connected with the groundwater; and Migration with the surface water systems, Man-made pathways	Shallow Groundwater (in MG/KPG)	**Low / Very Low**	Based on SI data the Site does not appear to be significantly impacting groundwater quality. Proposed works are unlikely to significantly change this (see above) or the pathways and the overall risk is therefore unlikely to materially change (Low / Very Low).
		Surface Waters	**Very Low**	Based on SI data the Site does not appear to be significantly impacting the canal or downstream surface waters, or lake (up-gradient). The proposed works are unlikely to worsen the source term (likely to improve by remediation) or the pathways. The overall risk is therefore deemed Very Low.

[1]there is an increased potential for infiltration directly into made ground / concentrated infiltration in certain areas (e.g. pooling of water). All site operations will be controlled/managed by implementation of an EMS in accordance with the Environmental Permit.

[2]it is considered that these source/linkages will not be materially altered by the proposed works

[3]there is some potential for increased interaction of surface water run-off with the made ground during this phase and for factors that concentrate this within certain areas (e.g. pooling of water). The works however will be managed by the implementation of the EMS to minimise these effects and to avoid directing run-off to the surface water receptors (primarily the canal)

6.8.3. *Post Development*

Table 6.4. Hydrogeological RA/CSM – Post-development.

Source(s)	Pathway(s)	Receptor(s)	Risk	Justification / Comment
Made ground[1]	Infiltration of rainwater or surface water run-off; Leaching within the unsaturated zones; Vertical and lateral migration within the unsaturated zone; Migration to and within the shallow 'groundwater' body (leachate and groundwater in KPG)[2]	Shallow Groundwater (in MG/KPG)	**Low**	Based on SI data, in particular the groundwater data and risk assessments indicating no significant contamination of the shallow groundwater at the Site (or from the Site itself). The data and age of the made ground (since original placement at the Site) also suggest limited potential for increased leaching resulting from the scheme. Consequently, the risks are deemed to be low.
	As above plus Lateral migration within the shallow water body; Migration to the wider groundwater environment and / or Migrations to surface water receptors connected with the groundwater; and Migration within the surface water[3]	Shallow Groundwater (in MG/KPG)	**Low / Very Low**	As above and required migration (which will result in dilutions) of the contamination.
		Surface Waters	**Low / Very Low**	As above, and required migration (which will result in dilutions) of the contamination. No significant connectivity to off-site surface waters (River Lee Navigation, Reservoir, Lakes)
	Leaching to surface water run-off; migration in surface water[2]	Surface Waters	**Low**	As above and run-off will only interact with very near surface soils over a short distance - over longer distances normal infiltration and evapotranspiration will be dominant. Water to be managed by design of surface water drainage systems (SuDS)
Contaminated Groundwater in MG/KPG[4]	Lateral migration within the shallow water body (leachate or groundwater in KPG); Migration to the wider groundwater environment and / or Migrations to surface waters connected with the groundwater; and Migration with the surface water systems, Man-made pathways	Shallow Groundwater (in MG/KPG)	**Low / Very Low**	Based on SI data, the Site does not appear to be significantly impacting on the groundwater quality. Proposed works are unlikely worsen the source term (more likely to improve due to remediation) or the pathways. Overall risk is therefore deemed Low – Very Low.
		Surface Waters	**Very Low**	As above, no significant impact on the canal and wider surface waters in current situation, and proposed works are unlikely to significantly change this or the pathways. The overall risk is therefore deemed Very Low.

[1]this applies to both in-situ and relocated soils (It is not considered that there will be any material difference in the source over the Current Situation)
[2]whilst there will be changes to the landform and details of the Site usage it is considered that these will not materially affect the pathways over those present in the current situation
[3]it is considered that these linkages will not be materially altered from the current situation by the proposed works)
[4]on the basis of the above risk assessment the groundwater contamination is considered unlikely to materially change

6.9. Accidents and Consequences

The source term will be derived from the current Historical Waste, which has been characterised and demonstrated that in its current form does not pose a significant risk to the water environment. Wastes from external sources will not be accepted to Site.

Potential accidents, consequences, mitigation and emergency measures are detailed o identified will be associated with the operational phase and are listed below:

Table 6.5: Accidents, Consequence, Mitigation			
Potential Accident	**Consequence**	**Mitigation**	**Emergency Measures**
Re-use of unsuitable materials, following recovery	Release of hazardous substances to groundwater Harm to ecosystem Harm to human health	Robust waste acceptance procedures, based on laboratory testing and visual / olfactory inspections prior to re-use. Record keeping Use of tracking system for re-used waste.	Excavation of any placed waste that has the potential to release hazardous pollutants to groundwater, followed by further treatment or removal off-site.
Potential for gross contamination to be encountered during excavations	Release of hazardous substances to groundwater, Harm to ecosystems Harm to human health	Procedures will be in place (EMS) to implement in the event of gross unforeseen contamination.	Implement procedure, incl. cessation of activity. Temporary cover contam. Assess PPE and monitoring. Apply dust / odour supp. If required. Excavate appropriate. And remove off-site or take to quarantine area as appropriate.
Accidental spillages of fuel oils / hydrocarbons used in the operational phase	Release of hazardous substances to groundwater Harm to ecosystem Harm to human health	Procedures will be in place (EMS) to implement in the event of fuel / oil spills Spill kits available Storage in accordance with OSR (double bunded fuel tank with >110 % of storage volume)	Use of spill kit Disposal of spill kit and any contaminated soils / materials Record incident
Unauthorised tipping	Release of hazardous substances to groundwater Harm to ecosystems Harm to human health	Robust Site security will be implemented during the operational phase, including perimeter fencing, security gates, CCTV	In the unlikely event that the un-authorised tipping occurs, it will be removed from site to a suitably licensed facility for disposal.

7. CONCLUSION AND REQUIREMENT FOR FURTHER RISK ASSESSMENT

7.1. Summary of EA Guidance

The guidance states that a 'tiered approach' should be followed when completing a Hydrogeological Risk Assessment in support of an Environmental Permit (R.13).

The greater the risk of groundwater pollution, the more detailed the assessment is required to be. The risk assessment can be concluded once enough information to demonstrate that the activity does not pose a pollution risk to groundwater can be provided.

Environment Agency guidance on the protection of groundwater from landfills (Position Statement E1 – landfill location; R.14) states that:

- The EA will normally object to any proposed landfill site in groundwater SPZ I;
- For all other proposed landfill site locations, a risk assessment must be conducted based on the nature and quantity of the wastes and the natural setting and properties of the location;
- Where this risk assessment demonstrates that active long-term site management is essential to prevent long-term groundwater pollution, the Environment Agency will object to sites;
  - o below the water table in any strata where the groundwater provides an important contribution to river flow, or other sensitive receptors;
  - o within SPZ II or III;
  - o on or in a principal aquifer.

7.2. Site-Specific Considerations/Conclusions

- The Application Site is not within an SPZ I;
- The southeastern-most corner of the Application Site slightly impinges an SPZ II, however the large majority of the works (main excavation and fill areas) will not affect this area of the Site;
- The SPZ II is associated with the deeper aquifers, not in hydraulic continuity with the shallow water body;
- The site materials (source term) have been sufficiently characterised (data summarised at Section 4);
- Cut & Fill exercise of the deposited materials for reuse as a resource will include remediation of the materials (removal of deleterious/hazardous material) and engineered placement (compaction). This is likely to improve the condition of the material;
- No materials are to be excavated or placed below the water table;
- There is some potential for contamination hotspots, however it is considered that the remediation operation (controlled through planning) is capable of maintaining a watching brief and managing any such finds;
- Residual risk to using material unsuitable material (that exceeded the re-use criteria) – confirmation testing?
- Based on the current calculated volumes, there will be no requirement for the importation of material to make up levels, and therefore there is no possibility of 'rogue' loads to be brought into the Site; and
- Risk of accidents.

Based on the characterisation of site soils and water, in the context of the Tier 1 & 2 HRA and CSM (presented at Section 5) and the proposal (Section 1), there is a very low risk to controlled water receptors, and the deposit for recovery is considered to be appropriate for re-use (following appropriate remediation).

The re-use of site soils is considered low risk and importantly will not materially alter the CSM with respect to controlled waters. An Environmental Management System will be implemented during the works.

No further Risk Assessment is considered to be necessary at this stage. It is considered that ongoing groundwater monitoring (Section 7) is required to prove site compliance.

8. SURVEILLANCE/MONITORING

8.1. General

The application is for permanent deposit of waste materials as a recovery operation; the wastes being derived from re-use of existing made ground / HstW, following treatment, for an earthworks cut & fill exercise (see section 1.3 – 1.4) .

In accordance with EPR 2016 (R.15), requisite surveillance must be conducted at landfill sites. This includes appropriate leachate, groundwater, and surface water monitoring in order to detect any adverse impacts of the landfill site, and the implementation of Control Levels and Compliance Limits for water quality assessment.

All monitoring should be undertaken by suitably qualified and experienced technicians or consultants and all samples stored and transported in accordance with BS ISO 5667-11:2009 (R.16).

8.2. Compliance Point

For the purpose of the risk assessment the compliance point is the water body (leachate/groundwater) in the saturated zone (@10-11m AOD) at the southern extent of the Site. In June 2025 two additional down gradient groundwater monitoring boreholes GBH102 & GBH103, were installed. These boreholes are considered, as far as practically possible, downgradient of the waste.

8.3. Waste Acceptance

Robust Waste acceptance procedures will be implemented at the Site to demonstrate acceptability for re-use. With regard to demonstrating the recovered wastes will have no discernible impact on groundwater quality at the Site.

Re-used soils (Source-Term) will be tested for total and leachable concentrations of a number of priority pollutants. Leachate preparation will by the TCLP method

Groundwater quality compliance and assessment limits for groundwater and soil leachate are presented in Table 7.4 and are based on the observed concentrations, or appropriate water quality standard or with respect to hazardous substances the MRV as given in the UK Technical Advisory Group (UKTAG) on the Water Framework Directive, Technical report on Groundwater Hazardous, Substances publication will be applied to soil leachate concentrations.

Confirmation testing will be carried out in accordance with the frequency provided in Table 8.1. Assessment / Compliance Limits for groundwater, soil (waste) and soil leachate are provided at Appendix 6 Waste Acceptance.

8.4. Leachate Monitoring

The risk assessments indicate that significant new / additional contamination (new 'leachate') is not being generated by movement of water through the waste body – from either vertical infiltration of rainwater or lateral migration of 'groundwater' (i.e. there is no significant impact from the Site on the groundwater at the Site). In addition, no works are proposed below the water table and therefore there is no potential for significantly altering the potential leachability of materials by changing the location of the material (i.e. from above to below water table).

Consequently, it is considered that there is no requirement for leachate monitoring.

8.5. Groundwater Monitoring

On the basis of the HRA, the risk to groundwater is low or very low. However, due to the sensitivity of the Site location (secondary 'A' superficial aquifer, in/near SPZII) and proximity to the River Lee Navigation canal it is considered that groundwater monitoring should continue. It is not considered necessary to monitor groundwater in the deep aquifer, due to a lack of hydraulic connectivity between the made ground and underlying aquifers due to the presence of London Clay between.

It is necessary in accordance with LFD/LFTGN02 (R.17, R.18) to monitor groundwater quality and levels both up- and down-gradient, including one (1no.) up-gradient and two (2no.) downgradient monitoring wells.

Groundwater flow is interpreted to be generally north to south, with a potential minor westward component.

The proposed monitoring points are presented in Table 8.1

It has been assumed that the monitoring apparatus installed by Hydrock is still present and serviceable, otherwise new boreholes will be required.

Table 8.1. Proposed Monitoring Locations for Groundwater Compliance.

Borehole Reference	Relative Site Location	Rationale	Frequency
BH102	North (campsite)	Upgradient	Monthly for 3no. months during works; Quarterly thereafter until 12 months post-completion (assuming no breaches).
BH109	West boundary, northwest of wave pool	Upgradient of wave pool, cross gradient	
BH104A/BH106	East / northeast of wave pool		
BH111	South	Downgradient	
BH115	Southeast		
GBH102	South-east	Downgradient	
GBH103	South-west	Downgradient	

8.6. Surface Water Monitoring

On the basis of the risk assessments, it is considered that the risk to surface waters is very low, primarily due to lack of connectivity to off-site surface water receptors. It is therefore not considered necessary to sample Ponders End Lake, the River Lee Navigation or the William Girling Reservoir.

It is however proposed to monitor Enfield Ditch downstream of the works, within the Site boundary, with a control point Upgradient of the works area, to monitor the effects (if any) of the works on the water quality, as summarised in the table below:

Table 8.2. Proposed Monitoring Locations for Surface Water Compliance.

Location	Relative Location	Rationale	Frequency

Enfield Ditch (Pymmes Brook)	Upgradient of works areas	Quality of water leaving the Site and any influence of works on site, before other potential off-site contamination sources	One occasion prior to commencement Monthly for 3no. months during works; Quarterly thereafter until 12 months post-completion (assuming no breaches).
	Downgradient of works areas (within site boundary)		

The monitoring will track any potential issues during and after works, including winter months where run-off is typically greater and water table higher.

All surface water will be controlled within the works on site. A Surface water management plan will be included within the Environmental Management System.

8.7. Monitoring Parameters and Frequency

The proposed monitoring parameters are presented in the table below, based on EA guidance (e.g. LFD/LFTGN02), the material classification / the Site investigation observations, and the findings of the HRA:

Table 8.3. Monitoring Parameters.			
Receptor	**Parameters**	**Rationale**	**Frequency**
Groundwater	Water Levels pH, TOC, phenols, alkalinity, Cl, NH_4, SO_4, Cyanide, Metals (As, B, Ba, Cd, Cr, Cu, Fe, Hg, Mg, Mn, Mo, Ni, Pb, Sb, Se, Zn), TPH, naphthalene	Main risk factors, indicator 'species'	monthly for the first 3 months and then quarterly thereafter
Surface Water	Water level / flow / quality observations Chemical parameters as groundwater, plus TDS	Main risk factors, indicator 'species'	monthly for the first 3 months and then quarterly thereafter
Soil Leachate	pH, TOC, phenols, Cl, NH_4, SO_4, Cyanide, Metals (As, B, Ba, Cd, Cr, Cu, Fe, Hg, Mg, Mn, Mo, Ni, Pb, Sb, Se, Zn), TPH, naphthalene	Main risk factors, indicator 'species'	one every 1000m^3 of recovered waste deposited

Only MCERTS accredited laboratories should be used for the analysis. If adverse or unusual conditions are identified further sampling will be undertaken at the earliest practicable time to confirm the findings.

Groundwater samples will be collected monthly for the first 3 months and then quarterly thereafter.

Soil leachate testing will be carried out on at least one every 1000m^3 of recovered waste deposited.

A yearly hazardous substances suite would also be prudent, with one taken prior to the start of operations then on an annual basis, thereafter.

8.8. Control Levels and Compliance Limits

In order to comply with the Landfill Directive, it is necessary to set groundwater quality compliance limits (formerly 'trigger values'). The parameters are also proposed to be monitored at Enfield Ditch (Pymmes Brook). It is considered that the following parameters of concern should have thresholds:

Table 8.4. Control Levels and Compliance Limits

Receptor	Parameter (Dissolved)	Max Conc. (µg/l)	EQS (µg/l)	DWS (µg/l)	Control Level (µg/l)	Compliance Limit (µg/l)
Enfield Ditch	TDS	-	-	*n/a*	-	None
	Ammonium as NH_4	150	1,000	*n/a*	150	None
	Sulphate (SO_4)	94,600	400,000	*n/a*	400,000	None
	Naphthalene	<0.01	2	*n/a*	2	None
Ground-water	Ammonium as NH_4	170,000	*n/a*	500	170,000	255,000
	Arsenic	18	50	10	5	27
	Sulphate (SO_4)	731,000	*n/a*	-	731,000	1,096,500
	Cyanide (total)	16	*n/a*	50	16	24
	Copper	100	*n/a*	2,000	2,000	3,000
	Lead	4.2	*n/a*	10	10	15
	Zinc	120	*n/a*	-	120	180
	Naphthalene	371	*n/a*	-	370	555
Soil Leachate	Ammonium as NH_4	170,000	*n/a*	500	170,000	255,000
	Arsenic	18	50	10	5	27
	Sulphate (SO_4)	731,000	*n/a*	-	731,000	1,096,500
	Cyanide (total)	16	*n/a*	50	16	24
	Copper	100	*n/a*	2,000	2,000	3,000
	Lead	4.2	*n/a*	10	5	15
	Zinc	120	*n/a*	-	120	180
	Naphthalene	371	*n/a*	-	370	555

For hazardous substances, the Control Level will be the detection of any hazardous substance. Minimum reporting values (MRV) as set out on the government website at the following link.

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

For non-hazardous substances, Control Levels have been set at the maximum detected concentration for each parameter, based on the site investigation/monitoring data, or the DWS/EQS for groundwater and surface water, respectively, whichever is higher.

It is proposed that Compliance Limit values are initially be set for groundwater only, based in part on the control values and existing chemical data, at 50% above DWS/maximum concentration in order to demonstrate that no significant worsening of the local groundwater quality has occurred.

All data obtained should be analysed for increasing trends, and if three (3no.) consecutive increases or a sudden dramatic increase in a contaminant is evident, potential sources and any need for additional/revised risk assessment should be investigated, to determine any pollution risk to water receptors beyond the Site.

In the event of a breach of the control limits, additional sampling may be required as soon as is practicably possible after breach is identified, depending on the nature of the contaminant. Ongoing exceedances of the control limits will require investigation and potential implementation of mitigation measures.

The above is considered a conservative approach that is protective of wider groundwater environment. This should be reviewed in light of the monitoring data as this is collected.

9. REFERENCES

R.1. Norwest Holst Soil Engineering. Ground Investigation at Picketts Lock HPC. Ref: F13229, May 2004;

R.2. Hydrock Consultants Ltd. Desk Study Report, The Wave, London. Ref: WAV-HYD-DS-RP-GE-1000-S0-P1, September 2018;

R.3. Hydrock Consultants Ltd. Site Investigation Report, The Wave, London: Siteworks Phase 1 Area. Ref.: WAV-HYD-XX-XX-RP-GE-1000-S2-P02, November 2019;

R.4. Green Earth Management Company (GEMCO) Limited, Waste Recovery Plan, The Wave London, Ref 2309 R01 Issue 1, February 2025;

R.5. Department for Environment Food & Rural Affairs, Catchment Data Explorer, 2025, https://environment.data.gov.uk/catchment-planning/;

R.6. Department for Environment Food & Rural Affairs, Water Quality Archive, 2025, https://environment.data.gov.uk/water-quality/view/explore?search=&area=10-36&samplingPointType.group=F&loc=536572%2C196670&_limit=500;

R.7. Environment Agency: Flood Map for Planning (2025) https://flood-map-for-planning.service.gov.uk/;

R.8. Christian Aid, Scorched Earth, The impact of drought on 10 world cities, May 2022;

R.9. HR Wallingford, Updated projections of future water availability for the third UK Climate Change Risk Assessment, Technical Report, MAR6025-RT002-R05-00, July 2020;

R.10. Environment Agency, The state of the environment: water resources, May 2018;

R.11. Met Office, Climate Data Portal, Annual Precipitation Observations 1991-2020, 12km, https://climatedataportal.metoffice.gov.uk/datasets/f6ed302049894ee8b230215a3efa9c19_0/explore?location=51.602238%2C-0.018044%2C11.99;

R.12. Environment Agency, Proposed EQS for Water Framework Directive Annex VIII substances: ammonia (un-ionised), Science Report SC040038/SR2, February 2007;

R.13. GOV.UK Guidance: Groundwater Risk Assessment for your Environmental Permit, April 2018 https://www.gov.uk/guidance/groundwater-risk-assessment-for-your-environmental-permit#generic-quantitative-risk-assessment;

R.14. Environment Agency, The Environment Agency's approach to groundwater protection. Section E, Position Statement E1, Version 1.2, Feb 2018;

R.15. The Environmental Permitting (England and Wales) Regulations 2016;

R.16. BS ISO 5667-11:2009, Water quality. Sampling - Guidance on sampling of groundwaters, May 2009;

R.17. Council Directive 1999/31/EC on the Landfill of Waste (The Landfill Directive), June 2011;

R.18. Environment Agency, LFTGN02: Guidance on Monitoring of Landfill Leachate, Groundwater & Surface Water (2014);

R.19. Water Framework Directive

Figure 1

Site Location Plan

Figure 2

Application Site Boundary Plan

Figure 3

Sensitive Receptors Plan

Figure 4

Groundwater Contour Plan

Appendix 1

Development Masterplan Pack

Appendix 2

GEMCO Drawings

Appendix 3

Topographic Survey

Appendix 4

Site Investigation Information – Including Historical Plans

Appendix 5

Environmental Risk Assessment
(not presented in HRA)

Appendix 6

Waste Acceptance

Appendix 7

TCM Cert

Not presented in HRA

Appendix 8

Pollution Control
Not presented in HRA

Appendix 9

Environmental Assessment Levels & Dilution Calculations