



Oakford Homes Limited

# Former Arundel Gas Works

Further Site Investigation & Outline Remediation Strategy

29780-R02(00)

## RSK GENERAL NOTES

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**Project No.:** 29780

**Title:** Further site assessment and outline remediation strategy: Former Arundel Gas Works, Ford Road, Arundel.

**Client:** Oakford Homes Limited

**Date:** 7<sup>th</sup> April 2022

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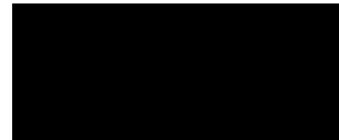
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# 1 INTRODUCTION

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## 1.1 Commissioning

RSK Environment Limited (RSK) was commissioned by Oakford Homes Limited to carry out additional site investigation in relation to a proposed residential development at the former Arundel gas works, located off Ford Road in Arundel. The project was carried out to an agreed brief as set out in RSK's proposal (Ref. 29780-T02, dated November 21, and e-mail to Soilfix dated 10<sup>th</sup> December 2021).

RSK's service constraints are shown in [Appendix A](#).

## 1.2 Project Background and Objectives

The site comprises a former town gas works that was operational from the 1840s until the 1950s. All of the above ground structures were subsequently demolished. Following numerous ground investigations to assess the sites contamination status, remedial works were undertaken by Celtic en Globe during 2020 in order to render the site suitable for a 'commercial open space' end-use.

On completion of the remedial works Oakford Homes acquired the former gas works from National Grid Property Holdings with the intention on redeveloping the site with residential apartment blocks. The objectives of this investigation were,

- Review the available information and identify any data gaps that require additional assessment in relation to land contamination and foundation design;
- Undertake further intrusive works to address the data gaps and characterise the current condition of the site;
- Identify potential environmental risks that would impact the proposed development, and provide outline remedial measures that would mitigate these risks or further assessment if necessary;
- Identify and geotechnical constraints to the proposed development; and
- The report shall be compliant with current guidance in order to support the discharge of relevant planning conditions.

## 1.3 Scope of works

The scope of this assessment has been developed in accordance with relevant British Standards and authoritative technical guidance as referenced through the report. The assessment of the contamination status of the site is in line with the technical approach presented in Land Contamination Risk Management (LCRM) (Environment Agency, 2021) – which supersedes CLR11 Model Procedures for Land Contamination – and in general accordance with BS 10175: 2011 + A2 2017 (BSI, 2017). It is also compliant with relevant planning policy and guidance.

The scope of the intrusive investigation has been designed in line with the recommendations of BS5930:2015+A1:2020 Code of practice for ground investigations (BSI, 2020), which maintains compliance with BS EN 1997-1 and 1997-2 and their related standards. It has also been developed in general accordance with BS 10175: 2011 + A2 2017.

The scope of works for the assessment has included the following:

- Review of existing reports and development of an initial conceptual site model;
- intrusive investigation comprising two deep boreholes using a cable percussive rig to 25 m depth, in-situ testing for geotechnical purposes;
- intrusive investigation comprising six shallow window sampler boreholes to 3 m depths, in-situ soil test for geo-environmental purposes, and return visits for vapour and groundwater monitoring;
- generic quantitative risk assessment (GQRA) of relevant contaminant linkages and refinement of conceptual site model;
- outline remedial measures for the site;
- interpretation of ground conditions and geotechnical data to provide preliminary recommendations with respect to foundations and infrastructure design; and
- production of this factual / interpretative report.

## **1.4 Existing reports**

The following reports detailing previous works at the site were made available for review:

- Ford Road, Arundel – Environmental Liability Assessment Report (for British Gas), WS Atkins Environment, document ref. E5347/LR860.NL/gp, dated April 1994;
- Ford Road, Arundel – Environmental Assessment Site Investigation Factual Report Final (for Lattice Property), document ref. A71430/GTG.2000078/R003rev1, dated December 2000. This report includes, as an appendix, a report by Harrison & Company, dated July 1993, entitled 'Desk Study on a Disused Gas Works at Ford Road, Arundel, West Sussex for British Gas (South Eastern) plc. Report No. C604a';
- Ford Road, Arundel – Environmental Groundwater Monitoring Letter Report, (for Lattice Property), document ref. A71430/GTG.2000078/R004rev0/mg, dated July 2001;
- Ford Road, Arundel – Land Contamination Site Investigation and Generic Quantitative Risk Assessment (for National Grid Property Holdings Limited), document ref. 5104362/GTG.20100923/Arundel 2011/R001v0, dated September 2011;
- Ford Road, Arundel – Detailed Quantitative Risk Assessment Report (for National Grid Property Holdings Limited), document ref. 5104362/GTG.20100923/Arundel DQRA 2012/R002v1, dated October 2012;
- Geo-environmental assessment, produced by RSK, report ref 29870-R01, dated June 2019;

- Supplementary site investigation factual report produced by Celtic en Globe, report ref R1820/20/5043, dated December 2020;
- Remediation implementation and verification plan rev 2, produced by Celtic en Globe, report ref R1820/21/5045, dated March 2021;
- Controlled waters risk assessment contained within Appendix C of the remediation implementation and verification plan; and
- Remediation verification report rev 1, produced by Celtic en Globe, report ref R1820/21/5111, dated September 2021.

Pertinant information from these reports have been summarised within Section 3.

RSK have assumed that as part of the site acquisition agreement, Oakford Homes have full contractual reliance upon the information contained within these reports.

It must be noted that all of the reports written prior to 2019 were issued by National Grid Property Holdings as redacted documents with all associated opinions and interpretation blanked out.

## **1.5 Limitations**

This report is subject to the RSK service constraints given in [Appendix A](#) and limitations that may be described through this document.

## 2 SITE DETAILS

### 2.1 Site location

Site location details are presented in **Table 1** and a site location plan is provided on [Figure 1](#).

**Table 1 Site location details**

|                                                 |                              |
|-------------------------------------------------|------------------------------|
| <b>Site name</b>                                | Former Arundel gas works     |
| <b>Full site address and Post Code</b>          | Ford Road, Arundel, BN18 9DX |
| <b>National Grid reference (centre of site)</b> | TQ014,067                    |

### 2.2 Site description

The site boundary and current site layout are shown on [Figure 2](#).

The site covers an area of c. 0.47 hectares and is currently undeveloped. All of the former gas works infrastructure has been removed from above ground, and a capping layer comprising a granular type 1 material has been placed across the majority of the site as part of recent remedial works. The only exception is the eastern corner which is covered by tarmac. A culverted field drain bisects the site from northeast to southwest.

The site is surrounded by a wire mesh fence with a padlocked gate located along the northern boundary.

### 2.3 Surrounding land uses

The site is located in Arundel, within a mixed residential and agricultural setting. Immediate surrounding land uses are described in **Table 2**.

**Table 2 Surrounding land uses**

|              |                                                                                                                                                                                                                              |
|--------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>North</b> | An electrical substation and a dirt access track are located along the northeastern boundary of the site. Agricultural land is located further to the northeast east. Ford Road and a cemetery are located to the northwest. |
| <b>East</b>  | Agricultural land is located directly east. The River Arun is situated ~50 m to the east.                                                                                                                                    |
| <b>South</b> | Agricultural land.                                                                                                                                                                                                           |
| <b>West</b>  | Residential properties are located to the west / southwest of the site.                                                                                                                                                      |

### 2.4 Development plans

It is understood that Oakford Homes are looking to redevelop the site with two separate apartment blocks containing 38 units, and that the development will be set at a raised

level predominantly with open air parking or amenity space beneath (given the flood risk potential). The development proposals do not include for private gardens although areas of communal soft landscaping are included.

It is understood that give the depth of made ground and presence of a shallow groundwater table on the site a piled foundation will be adopted for the apartment blocks (see Section 3).

Copies of the proposed development plans area included in Appendix B.

## **3 PREVIOUS SITE ASSESSMENTS**

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Relevant information for the previous site assessment is summarised in the following sections.

### **3.1 Site history**

#### **3.1.1 On-site**

The site was operated as a gas works from the 1840s until the mid-20<sup>th</sup> Century. The gas works contained up to four gas holders which were operational at different times. A retort house, including chimney/ tank, a boiler house, condensers, governor compound, liquor/ tar tanks, and associated offices and stores were situated along the northeastern boundary of the works. A tar tank was situated in the northern corner of the site, where evidence of soils heavily impacted with petroleum hydrocarbons / tar contamination was noted during the previous site investigations. A plan showing the historical layout of the gas works is presented as [Figure 3](#).

By 1994 only an electrical substation (located along the northeastern boundary), valve pits, toilet, and concrete base of a tank remained on the gas works. All of these with the exception of the substation have been decommissioned / removed from the site. Remedial works have subsequently been undertaken during 2021, which are further discussed in Section 4.

#### **3.1.2 Off-site**

By the mid 19<sup>th</sup> Century, the site was largely surrounded by agricultural land with a public baths located ~100 m to the southwest and an iron works ~120 m to the southwest. The existing residential properties located directly to the west of the site were constructed towards the end of the 19<sup>th</sup> Century. By the 1950s the iron works had expanded west, and further residential properties had been constructed to the northwest. The iron works closed by the 1970s and the buildings were used as an agricultural engineering works. At the same time the public baths had closed and been infilled. The iron works have subsequently been subject to remedial works and redeveloped into residential properties.

### **3.2 Ground conditions**

The published geological records for the area indicate that the site is directly underlain by a natural geological succession comprising Alluvial (raised marine) Deposits, which are further underlain by the Spetisbury Chalk Member, which is part of the White Chalk Subgroup. Based on the published data and intrusive investigations carried out on the site, the geological success beneath the site has been summarised within **Table 3**.

**Table 3: Geological succession beneath the Site**

| Geological unit                                                                                                                                                                       | Description (Atkins)                                                                                                                                                                                          | Proven thickness (m)                                                    |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|
| Made Ground                                                                                                                                                                           | Variable across the site, but generally comprised firm, sandy, gravelly clay and fine to medium, gravelly, clayey sand with frequent brick, chalk and flint gravels and fragments of clinker, coal and metal. | Absent to 4.5 m                                                         |
| Alluvium                                                                                                                                                                              | Stiff, silty, very gravelly clay or clayey gravel.                                                                                                                                                            | 0.70 m to 6.30 m                                                        |
| Spetisbury Chalk Member (White Chalk Subgroup)                                                                                                                                        | Structureless fine chalk composed of gravels and chalk cobbles in a soft off-white/grey clay matrix.                                                                                                          | >3.80 m to >7.60 m<br>(base not proven by previous investigation works) |
| <b>Note:</b> During the Atkins' 2011 investigation, the base of the Made Ground was not proven at TP108B (>2.5 m), TP111 (>2.3 m), VP202 (>1.0 m), VP203C (>1.2 m) or VP204 (>1.3 m). |                                                                                                                                                                                                               |                                                                         |

### 3.2.1 Contamination status

Numerous investigations were carried out on the site to characterise the ground conditions and risks to human health and groundwater which included extensive testing of the soils, groundwater as well as vapour monitoring. Visual and olfactory observations made during the site investigations identified gas related contamination including tar / hydrocarbon staining, pockets of free product, ash, clinker. However, the chemical test results and assessment of the risk were largely redacted from the reports produce prior to 2019.

The contamination status of the site was summarised within the remediation strategy which stated *'The various investigations carried out to date have generally identified widespread low-level gasworks contamination within the Made Ground, with more elevated concentrations recorded towards the north and east of the site associated with the identified former gasworks features. Further deeper contamination encountered within the Alluvium and Chalk has also been found to be focused in the north eastern area of site where sources of non aqueous phase liquid (NAPL) may be present. A summary of identified contamination is provided below,*

- *Inorganic and organic contaminated shallow soils across the whole of the site; and*
- *Hydrocarbon / NAPL impacted soils and perched water in the gasworks process areas in and around former structures (mainly in the north and east, but with localised impact in other areas of the site).'*

### 3.2.2 Former gas holders and foundations

Various substructures associated with the process buildings and gas holders remain in-situ.

Four gas holders were constructed on the site, two of which were encountered during site investigation in the western and southern areas of the site. The base of the gas holder to the west was encountered at depths ranging from 0.55 m and 1.5 m bgl and comprised a

200 mm to 300 mm concrete base. The gas holder had been infilled with a variety of waste materials including wood, timber, brick, scrap metal, plastic, steel pipes, steel drums, car parts, glass bottles, coal, railway tracks and cast iron along with pockets of reworked natural ground.

A former tank base within the southeast corner of the site and comprised a 150 mm mass concrete slab at surface level underlain by two rows of red bricks. The base of the foundation was not proven.

### **3.3 Environmental Setting**

#### **3.3.1 Aquifer characteristics**

The site is underlain by a Principal aquifer associated with the White Chalk sub-group. It was reported that this may be partially confined by the overlying Alluvium.

Monitoring data recorded groundwater to be present at a depth in the order of 2.00 mAOD at high tide dropping to approximately 0.00 m AOD at low tide (~1.5 m to 3.5 m bgl). Suspected perched water was also noted within a number of trial pits ranging from 1.3 to 2.65 mbgl.

Tidal monitoring undertaken in July during the 2011 Atkins investigation indicated that there was significant tidal variation in the groundwater level at the site (up to approximately 2.00 m variance). Groundwater beneath the site is therefore anticipated to be affected by saline intrusion. The direction of groundwater flow was inferred to be towards the River Arun located to the east

#### **3.3.2 Vulnerability of groundwater resources**

The site has been classified by the EA website to overlie the following:

- Bedrock Aquifer (White Chalk Sub-group): Principal Aquifer, i.e. layers of rock or drift deposit that have high intergranular and/or fracture permeability (usually providing a high level of water storage). They may support water supply and/or river base flow on a strategic scale; and
- Superficial Aquifer (Alluvium): Secondary A Aquifer, i.e. permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers.

The soils beneath the site are classified as having a High Leaching Potential (H1) - Soils which readily transmit liquid discharges because they are either shallow, or susceptible to rapid by-pass flow directly to rock, gravel or groundwater.

#### **3.3.3 Licensed groundwater abstraction**

There are ten current licensed groundwater abstractions within a 2.0 km radius of the site. Of these, only one is located within a 1.0 km radius located approximately 730 m to the northwest of the site and operated by 'Arundel Estates T/A Chalk Springs Fishery' for 'Aquaculture: Fish Farm/Cress Pond Throughflow' purposes.

The nearest public water supply borehole is located 1,096 m to the northeast of the site and is operated by Southern Water Services Limited.

In terms of aquifer protection, the EA generally adopts a three-fold classification of source protection zones (SPZ) for public supply abstraction wells.

- Zone 1 or 'inner protection zone' is located immediately adjacent to the groundwater source and is based on a 50-day travel time from any point below the water table to the source. It is designed to protect against the effects of human activity and biological/chemical contaminants that may have an immediate effect on the source;
- Zone 2 or 'outer protection zone' is defined by a 400-day travel time from a point below the water table to the source. The travel time is designed to provide delay and attenuation of slowly degrading pollutants; and
- Zone 3 or 'total catchment' is the area around the source within which all groundwater recharge is presumed to be discharged at the source.

Information available on the EA website indicates that the site does not lie within a currently designated groundwater Source Protection Zone. The closest SPZ (Inner Zone) is located approximately 683 m to the north west of the site.

#### **3.3.4 Surface watercourses**

The nearest identified surface watercourse to the site is the River Arun located 50 m to the east site. The stretch of the watercourse closest to the site is known to be tidally influenced and flows in a southerly direction towards the English Channel.

The EA classification of the water quality in the stretch of the Arun nearest to the site is listed as an 'Unclassified Tidal River' with respect to river quality.

In 1994, Atkins reported that the tidal stretch of the River Arun adjacent to the site is classed as Estuary Class A (Good Quality) based on an assessment of biological, aesthetic and water quality.

The base flow of the River Arun is likely to be recharged by groundwater in the shallow aquifer in the site area.

#### **3.3.5 Site drainage**

A culverted field drain runs beneath the central portion of the site from northeast to southwest, and connects to a drainage direct to the northeast. This drainage ditch flows east to a sluice gate on the bank of the River Arun.

#### **3.3.6 Landfilling**

The closest landfill to the site is 'Penfold Works' located ~90m to the southwest which accepted inert, commercial and household waste between 1960 and 1962. The former landfill site appears to have been redeveloped to comprise garden areas associated with housing along Ford Road.

With respect to the former Penfold Works landfill, the preceding Atkins reports notes the following:

*'The Environment, Tourism and Leisure Department of Arun District Council have limited records of a landfilling operation in the area immediately to the south west of the study site. This was essentially infilling of the former baths in the 1950s and 1960s.'*

*Materials used included bottles, timber, ash and pottery. The Council's records do not state the exact depth or volumes of wastes involved but it is believed that the maximum depth of waste is approximately 3.0 m. This area and the land further south-west (the site of Tortington Ironworks between 1899 and the early 1960s) has since been developed for 40 houses with gardens. The Council stated that a site investigation was carried out prior to development. A total of 500 m<sup>3</sup> of topsoil was removed owing to the presence of copper, nickel, lead and zinc. The site investigation report concluded that there was "no major contamination threat".*

Two other historic landfills were identified within a 250 m radius (planning consent zone) of the Site, these are:

- Fagins Den landfill was situated approximately 144 m to the northeast of the site where Wheelrights Close is currently located; and
- Canada Road landfill was situated approximately 163 m to the northwest of the site where the recreation ground off Canada Road is currently located.

The Fagins Den landfill accepted inert, commercial and household waste between 1960 and 1962. Likewise, the Canada Road landfill accepted the same waste streams between 1947 and 1973.

## **4 REMEDIAL WORKS**

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### **4.1 Remediation Strategy**

Based on the findings of the previous investigation a remediation strategy was developed by Celtic en Globe. The strategy was based on providing a site suitable for 'commercial storage end use', which considered the risk to the following receptors,

- Future site users – females of working age (16 to 65) in a commercial setting but without any buildings on-site (open space);
- Adjacent site users – residential properties located to the northeast of the site; and
- Controlled waters – these are the Principal Chalk aquifer (groundwater) and River Arun (surface water).

A human health and groundwater detailed quantitative risk assessment (DQRA) was carried out as part of the strategy followed by an options appraisal in order to identify the most appropriate remedial techniques where a potential pollutant risk was identified. A summary of the report's findings is provided below.

#### **4.1.1 Risk to human health (site users and adjacent site users)**

The previous had identified the presence of residual gas works related contamination on the site where it was stated that a capping layer would be placed across the site to prevent commercial site users coming into direct contact with the impacted soils.

The principal risk to human health was considered to be from the off-site migration of hydrocarbon vapours impacting the neighbouring residential properties. Two sets of assessment criteria were therefore developed as part of the remediation strategy using the Environmental Agencies CLEA model. Firstly, soil assessment criteria in relation to the risk to on-site users for an open storage scenario, and secondly much more stringent criteria in relation based on residential values for the migration of vapour off-site.

It was proposed that the soils along the boundary next to the residential property shall be assessed against more stringent criteria during the remedial works to determine the risk from vapours.

#### **4.1.2 Risk to controlled waters**

The results of groundwater monitoring were initially compared against environmental water quality standards (EQS) for transitional estuarine environments, which was considered appropriate given the closest identified receptor was the tidally influenced reach of the River Arun. The assessment identified elevated concentrations of, nickel, petroleum hydrocarbon, cyanide, and ammonia above the EQS values. The exceedances were recorded in the area of the former process buildings located along the northeastern boundary. The concentrations along the eastern boundary of the site were below the EQS values.

The groundwater results were not included within the remediation strategy report, however, results for a single round were provided within Celtics 2020 supplementary

ground investigation. On examination of these results the highest concentrations of petroleum hydrocarbons were recorded at BH101d and BH204 both located in the northern corner of the site, which confirms the statements made in the remediation strategy. For reference the results from these boreholes have been reproduced in **Table 4**, below.

**Table 4 Concentration of hydrocarbons in the groundwater**

| Determinant           | BH101d (mg/l) | BH204 (mg/l) |
|-----------------------|---------------|--------------|
| Benzene               | 12.9          | 0.034        |
| Toluene               | 4.95          | 0.0063       |
| Ethylbenzene          | 0.077         | 0.038        |
| M&P Xylene            | 0.695         | 0.065        |
| O Xylene              | 0.328         | 0.050        |
| TPH Aliphatic C5-C6   | <0.001        | <0.001       |
| TPH Aliphatic C6-C8   | <0.001        | <0.001       |
| TPH Aliphatic C8-C10  | <0.001        | <0.001       |
| TPH Aliphatic C10-C12 | <0.001        | <0.010       |
| TPH Aliphatic C12-C16 | <0.001        | 3.1          |
| TPH Aliphatic C16-C21 | <0.001        | 7.8          |
| TPH Aliphatic C21-C35 | <0.001        | 3.2          |
| TPH Aliphatic C5-C35  | <0.001        | 14           |
| TPH Aromatic C5-C7    | 13            | 0.035        |
| TPH Aromatic C7-C8    | 5             | 0.0063       |
| TPH Aromatic C8-C10   | 1.2           | 0.21         |
| TPH Aromatic C10-C12  | 2             | 0.20         |
| TPH Aromatic C12-C16  | 4             | 1            |
| TPH Aromatic C16-C21  | 1.9           | 2.5          |
| TPH Aromatic C21-C35  | <0.01         | 1            |
| TPH Aromatic C5-C35   | 27            | 4.9          |

In order to further assess the risk to the River Arun a detailed risk assessment was undertaken by Celtic, which is presented in [Appendix C](#) of the remediation strategy report.

Theoretical DQRA criteria was derived for soils, soil pore water (leachate) and groundwater beneath the site using modelling software. It was reported that the measured groundwater concentrations for benzene, fluoranthene and naphthalene slightly exceed the remedial targets. However, the models do not take into account the influence of tidal variations on the groundwater flow which lead to dilute and dispersion of the contaminants in the groundwater.

The groundwater assessment concluded that *'Dissolved phase concentrations of potential contaminants in the groundwater may be assumed to meet compliance before discharge to the tidal water body and groundwater remediation per se would offer little benefit. The high groundwater flows induced by the tidal fluctuations would, in any case, make available remedial options ineffective.'*

*Consideration could be given to reducing near surface potential contaminant sources in the northern site area.'*

A search of the local authority planning records revealed that the Environment Agency had been consulted on the proposed remediation strategy including the groundwater DQRA. The EA confirmed (in letter ref HA/2021/123131/01-L01, dated 1<sup>st</sup> May 2021) that had no objection to the strategy to redevelop the site for an 'open storage' end-use. However, it was stated that the risks to groundwater would need to be reconsidered as part of any subsequent redevelopment.

#### **4.1.3 Proposed remediation strategy**

Following an options appraisal, the following remediation techniques were selected for the site:

- Excavation and segregation of grossly impacted soils from the made ground and underlying natural soils for treatment;
- Soil stabilisation of impacted soils - This was selected as the principal remediation technique to reduce the leachability of the contaminated soils and improve groundwater quality beneath the site, despite the controlled water assessment concluding that there is no risk to the River Arun;
- Removal of any visible free product (none aqueous phase liquid NAPL) either via the removal of soils or using a pump and treatment system for any perched groundwater encountered – This was focused within the northeast corner of the site where the most impacted soils / groundwater were encountered during the investigations;
- Excavation and turnover of ground outside those identified for specific remediation on a 10x10 grid in order to locate and segregate for treatment any other contaminated soils encountered;
- Verification testing on a 10x10 m grid, which is increased to 20 m<sup>3</sup> where gross contamination is identified; and
- Installation of a granular capping layer across the site.

The site was split into four different zones based on the anticipated levels of contamination and proximity to the neighbour residential properties. In each zone a description was provided within the remediation strategy on any specific areas of gross contamination would need targeting, and a more detailed summary of the remedial works that would be required using the selected techniques outlined above. The four zones identified were,

- 1) Orange (Eastern portion of the site 1200 m<sup>2</sup>) – Up to 1.6 m of made ground was recorded in this area, but the levels of contamination were found to be low. The made ground was to be turned over and any impacted materials segregated for treatment prior to backfill.

- 2) Red (northeastern boundary 1300 m<sup>3</sup>) – This area contained the most gas works infrastructure and contamination. Area to be turned over up to 2m depth, and made ground segregated for treatment. Structures to be removed where they impede access to gross contamination, and any unsuitable material will be removed off-site for disposal. Water treatment plant will be used to remove free product in perched water if encountered.
- 3) Green- (central area of the site 1000 m<sup>3</sup>) – Contains gas works infrastructure and sporadic contamination. Made ground to be turned over to 1.2 m for segregation and treatment. Any structures that impede access to gross contamination shall be removed.
- 4) Yellow (western boundary 220 m<sup>3</sup>) – represents a 5 m strip along the boundary next to the adjoining residential properties. However, there was a 2-3 m standoff from the boundary to prevent any land stability issues to the properties. The made ground to 1 m depth to be turned over and segregated for treatment. Verification samples were to be assessed against more stringent criteria for a residential end-use due to the risk of vapours to off-site properties.

A plan showing the zoning of the remediation areas is presented as [Figure 4](#).

## 4.2 Verification of the remedial works

The remediation works were carried out by Celtic from June to August 2021, details of the actual works carried out in each zone are summarised in **Table 5**, below.

**Table 5 Summary of remedial works undertake**

| Area   | Description of Remedial Works                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|--------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Orange | <ul style="list-style-type: none"> <li>Site levels were reduced in area of gas governor – no evidence of impacted soils was noted in this material and therefore it was stockpiled for re-use. Testing confirmed suitability for re-use;</li> <li>Old car tyres were removed from concrete structures and sent off-site for disposal;</li> <li>The base of a former gas holder was found at ~2 m AOD. No evidence of contamination was noted around the gas holder and therefore it was left in-situ; and</li> <li>Surface water connection were found that connect to the buried culvert. These were removed / sealed.</li> </ul> |

|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|--------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Red                      | <ul style="list-style-type: none"> <li>• Prior to placement of the water treatment plant the underlying soils were excavated. A small amount &lt;0.5 m<sup>3</sup> was encountered and stockpiled for later treatment;</li> <li>• Former cast iron pipes were removed were encountered;</li> <li>• A former gas holder (D1 and D2, see <a href="#">Figure 5</a>) was encountered in this area and contained tar stained timber. This was removed for off-site disposal;</li> <li>• The gas holder was constructed of brick with a concrete base. Part of the brick work was broken out;</li> <li>• Much visual evidence of impacted soils were noted in and surrounding the gas holder (E1 and E2) which were placed in the gas holder and subject to soil stabilisation;</li> <li>• A unknown pot end gas pipe was encountered in this area and had to be repaired during the remedial works;</li> <li>• A second gas hold (F1 to F3) was encountered in this area and contained heavily contaminated (tar stained) materials. The impacted soils were subject to soil stabilisation; and</li> <li>• Soils further east were less impacted but lots of foundations encountered some of which were removed to access contaminated area.</li> </ul> |
| Green                    | <ul style="list-style-type: none"> <li>• The foundations of a former gas hold was encountered and remains in-situ. It is reported that the remains are present at ~2.5 m AOD. A small amount of black stained material &lt;0.5 m<sup>3</sup> was encountered and removed for treatment (soil stabilisation);</li> <li>• A brick foundation was encountered to the north of the gas holder and was excavated to the same level of the gas holder;</li> <li>• The soils surrounding these features were found to be natural; and</li> <li>• All of the excavated soils were re-used in this area following validation testing.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Yellow                   | <ul style="list-style-type: none"> <li>• Made ground was found to extend to 1.2 m. No evidence of gross contamination was encountered and therefore the soils were tested to confirm their suitability for re-use and backfilled.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| All (Soil stabilisation) | <ul style="list-style-type: none"> <li>• Prior to carry out soil stabilisation any oversize materials such as wood, metal and plastic was removed mechanically and disposed of off-site;</li> <li>• The impacted soils were mixed with 4% Ordinary Portland cement (OPC) and 8% pulverized fuel ash (PFA) following a bench scale feasibility test;</li> <li>• Samples were retrieved at a frequency of one sample per 250m<sup>3</sup> for leachability and durability testing; and</li> <li>• Stabilised materials were placed in cells D1, D2 and D4, E1, E2, E4 and E5, F1 and F2.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| All (Capping layer)      | <ul style="list-style-type: none"> <li>• A 300 mm capping layer was placed across the site and comprised quarried aggregates conforming to type 1 material.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |

In summary the made ground was turned over across the entire site and where evidence of gross contamination was noted these soils were segregated for treatment through soil stabilisation prior to being backfilled. Material that could not be treated was sent off-site for disposal but this was limited to tar stained wood, tyres, metal, brick and concrete. Only small quantities of perched water were encountered during the works and there was no evidence of NAPL in the groundwater, therefore no groundwater treatment was carried out.

It was reported that groundwater monitoring was undertaken during the course of the remedial works, and that the results did not show any particular trend. On review of the results, elevated concentrations of petroleum hydrocarbons were recorded at BH101d, BH201 and BH202 throughout the monitoring.

Soil validation sampling was carried out at the frequency outlined within the remediation strategy. All of the samples were compliant with the adopted assessment criteria for an 'open storage' end-use, and the more stringent criteria along the western boundary.

It must however be noted that assessment criteria adopted for the remedial works is not suitable to safeguard the proposed development, and the risks would have to be reassessed in light of the current development proposals.

### **4.3 Conceptual Site Model**

The following conceptual site model has been developed for the site based on the remedial works carried out on the site and proposed end use. The risk classification has been undertaken in accordance with CIRIA C552 (Rudland et al., 2001), a summary of which is included in [Appendix C](#).

**Table 6 Conceptual site model**

| Potential source                                                                                                                                              | Potential receptor                                                               | Possible pathway                                    | Likelihood    | Severity                                                                                                                        | Potential risk | Justification                                                                                                                                                                                                                                                              |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|-----------------------------------------------------|---------------|---------------------------------------------------------------------------------------------------------------------------------|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| On-site former gas works – gas works related contamination included metals, PAHs, asbestos, cyanide, phenols, petroleum hydrocarbons and ammoniacal nitrogen. | Future site users (residential apartment blocks with communal soft landscaping). | Direct contact<br>Inhalation soil dust<br>Ingestion | Highly Likely | Medium                                                                                                                          | High           | Impacted soils remain on-site and pose a risk to site users in areas where they may be exposure in soft landscaped areas.                                                                                                                                                  |
|                                                                                                                                                               |                                                                                  | Inhalation of vapours                               | Highly likely | Medium                                                                                                                          | High           | Impacted soils and groundwater remain on the site.                                                                                                                                                                                                                         |
|                                                                                                                                                               |                                                                                  | Inhalation of ground gas                            | Unlikely      | Medium                                                                                                                          | Low            | The findings of the previous investigation indicate that the made ground generally comprised of inert non-biodegradable materials the risk from risk ground gas is therefore considered to be low.<br><br>The principal risk is considered to be from hydrocarbon vapours. |
|                                                                                                                                                               | Adjacent site users                                                              | Inhalation of vapours                               | Unlikely      | The remedial works carried out were designed to ensure there was no risk to off-site users from vapours. No linkage identified. |                |                                                                                                                                                                                                                                                                            |
|                                                                                                                                                               | Vegetation                                                                       | Direct contact                                      | Likely        | Minor                                                                                                                           | Low            | Possible risk from phytotoxic chemicals.                                                                                                                                                                                                                                   |

| Potential source                                  | Potential receptor                                                    | Possible pathway                                                                                                                                                                | Likelihood    | Severity                                                                                                                                                                                                                                                                                                                      | Potential risk | Justification                                                                                                                                                                               |
|---------------------------------------------------|-----------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                   | Water supply pipes<br>Building materials                              | Direct contact                                                                                                                                                                  | Highly likely | Minor                                                                                                                                                                                                                                                                                                                         | Moderate / low | Organic chemicals are presented that could cause deterioration of water supply pipes or concrete structures.                                                                                |
|                                                   | Controlled waters (Chalk aquifer and River Arun)<br>Future site users | Leaching from the unsaturated zone.<br>Lateral migration                                                                                                                        | Unlikely      | Groundwater DQRA concluded that there was no risk to the River Arun. Remedial works comprised soil stabilisation of grossly impacted soils to future reduce the leachability of contaminants to improve groundwater quality. – No linkage identified.                                                                         |                |                                                                                                                                                                                             |
|                                                   |                                                                       | Disturbance to the ground / vertical migration of contaminants into the saturated zone due to construction of piled foundations.<br>Migration of vapours along pile foundations | Likely        | Medium                                                                                                                                                                                                                                                                                                                        | Moderate       | Depending on the pile technique theoretically this could create a pathway for contaminants to migrate into the underlying groundwater or for vapours to migrate into the proposed building. |
| Off-site (infilled public baths to the southwest) | Future site users                                                     | Lateral migration of ground gas                                                                                                                                                 | Unlikely      | Historic record indicate that the public baths were infilled with inert (non-biodegradable) wastes. Furthermore, there is no preferential pathway for any gas to migrate onto the site. The shallow groundwater table in the area would severely limit any migration of gas in the unsaturated zone. – No linkage identified. |                |                                                                                                                                                                                             |

| Risk matrix |                | Consequences |              |              |              |
|-------------|----------------|--------------|--------------|--------------|--------------|
|             |                | Severe       | Medium       | Mild         | Minor        |
| Probability | Highly likely  | Very high    | High         | Moderate     | Moderate/low |
|             | Likely         | High         | Moderate     | Moderate/low | Low          |
|             | Low likelihood | Moderate     | Moderate/low | Low          | Very low     |
|             | Unlikely       | Moderate/low | Low          | Very low     | Very low     |

Potentially complete contaminant linkages with a potential risk of moderate to low or higher identified in in **Table 6** comprise:

- Risk to future site users, water supply pipes, vegetation and building structure from direct contact with gas works related contamination;
- Risk to future site users via the inhalation of vapours; and
- Risk to controlled water and future site users through the adoption of piled foundations.

These potentially complete contaminant linkages need to be assessed further through appropriate site investigation.

## **4.4 Data gaps and uncertainties**

Key data gaps and uncertainties identified in the CSM at desk study stage include:

- Chemical test results were redacted in investigation carried out prior to 2019;
- The extent of buried structures / former gas works infrastructure that remain on-site; and
- Current concentrations of contaminants within the underlying groundwater.

## 5 PRELIMINARY GEOTECHNICAL CONSTRAINTS

### 5.1 Design class

BS EN 1997-1 defines three different Geotechnical Categories that structures may fall into, which are summarised as follows:

- Category 1: Small and relatively simple structures for which it is possible to ensure that the fundamental requirements will be satisfied on the basis of experience and qualitative geotechnical investigations; with negligible risk;
- Category 2: Conventional types of structure and foundation with no exceptional risk or difficult ground or loading conditions; or
- Category 3: Structures or part of structures, which fall outside limits of Geotechnical Categories 1 and 2. Examples include very large or unusual structures; structures involving abnormal risks, or unusual or exceptionally difficult ground or loading conditions; structures in highly seismic areas; structures in areas of probable site instability or persistent ground movements that require separate investigation or special measures.

Based on the information provided above on the proposed development and in view of the anticipated ground conditions, a Geotechnical Category of 2 has been assumed for the purposes of designing the geotechnical investigation. This should be reviewed at all stages of the investigation and revised where necessary.

### 5.2 Preliminary geotechnical hazards assessment

A summary of commonly occurring geotechnical hazards associated with the anticipated geology outlined in Section 5.1 **Error! Reference source not found.** above is given in **Table 7** together with an assessment of whether the site may be affected by each of the stated hazards.

**Table 7 Summary of preliminary geotechnical risks that may affect site**

| Hazard category                             | Hazard status based on desk study findings and proposed development |                                           | Engineering considerations if hazard affects site                          |
|---------------------------------------------|---------------------------------------------------------------------|-------------------------------------------|----------------------------------------------------------------------------|
|                                             | Could be present and/or affect site                                 | Unlikely to be present and/or affect site |                                                                            |
| Sudden lateral changes in ground conditions | <input checked="" type="checkbox"/>                                 | <input type="checkbox"/>                  | Likely to affect ground engineering and foundation design and construction |
| Shrinkable clay soils                       | <input checked="" type="checkbox"/>                                 | <input type="checkbox"/>                  | Design to NHBC Standards Chapter 4 or similar                              |

| Hazard category                                                                    | Hazard status based on desk study findings and proposed development |                                           | Engineering considerations if hazard affects site                                             |
|------------------------------------------------------------------------------------|---------------------------------------------------------------------|-------------------------------------------|-----------------------------------------------------------------------------------------------|
|                                                                                    | Could be present and/or affect site                                 | Unlikely to be present and/or affect site |                                                                                               |
| Highly compressible and low bearing capacity soils, (including peat and soft clay) | <input checked="" type="checkbox"/>                                 | <input type="checkbox"/>                  | Likely to affect ground engineering and foundation design and construction                    |
| Silt-rich soils susceptible to rapid loss of strength in wet conditions            | <input checked="" type="checkbox"/>                                 | <input type="checkbox"/>                  | Likely to affect ground engineering and foundation design and construction                    |
| Running sand at and below water table                                              | <input checked="" type="checkbox"/>                                 | <input type="checkbox"/>                  | Likely to affect ground engineering and foundation design and construction                    |
| Karstic dissolution features (including 'swallow holes' in Chalk terrain)          | <input checked="" type="checkbox"/>                                 | <input type="checkbox"/>                  | May affect ground engineering and foundation design and construction – refer to Section 4.1.2 |
| Evaporite dissolution features and/or subsidence                                   | <input type="checkbox"/>                                            | <input checked="" type="checkbox"/>       | May affect ground engineering and foundation design and construction                          |
| Ground subject to or at risk from landslides                                       | <input type="checkbox"/>                                            | <input checked="" type="checkbox"/>       | Likely to require special stabilisation measures                                              |
| Ground subject to peri-glacial valley cambering with gulls possibly present        | <input type="checkbox"/>                                            | <input checked="" type="checkbox"/>       | Likely to affect ground engineering and foundation design and construction                    |
| Ground subject to or at risk from coastal or river erosion                         | <input checked="" type="checkbox"/>                                 | <input type="checkbox"/>                  | Likely to require special protection/stabilisation measures                                   |
| High groundwater table (including waterlogged ground)                              | <input checked="" type="checkbox"/>                                 | <input type="checkbox"/>                  | May affect temporary and permanent works                                                      |
| Rising groundwater table due to diminishing abstraction in urban area              | <input type="checkbox"/>                                            | <input checked="" type="checkbox"/>       | May affect deep foundations, basements and tunnels                                            |
| Geological faults, fissures and break lines                                        | <input type="checkbox"/>                                            | <input checked="" type="checkbox"/>       | May affect ground engineering and foundation design and construction                          |
| Underground mining including shafts and adits (e.g. coal, mineral)                 | <input type="checkbox"/>                                            | <input checked="" type="checkbox"/>       | Likely to require further assessment including potentially special stabilisation measures     |
| Effects of extreme temperature (e.g. cold stores or brick kilns/furnaces)          | <input type="checkbox"/>                                            | <input checked="" type="checkbox"/>       | Likely to affect ground engineering and foundation design and construction                    |

| Hazard category                                                                                               | Hazard status based on desk study findings and proposed development |                                           | Engineering considerations if hazard affects site                          |
|---------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------|-------------------------------------------|----------------------------------------------------------------------------|
|                                                                                                               | Could be present and/or affect site                                 | Unlikely to be present and/or affect site |                                                                            |
| Existing sub-structures (e.g. tunnels, foundations, basements, and adjacent sub-structures)                   | <input checked="" type="checkbox"/>                                 | <input type="checkbox"/>                  | Likely to affect ground engineering and foundation design and construction |
| Filled and made ground (including embankments, infilled ponds and quarries)                                   | <input checked="" type="checkbox"/>                                 | <input type="checkbox"/>                  | Likely to affect ground engineering and foundation design and construction |
| Adverse ground chemistry (including expansive slags and weathering of sulphides to sulphates)                 | <input checked="" type="checkbox"/>                                 | <input type="checkbox"/>                  | May affect ground engineering and foundation design and construction       |
| Site topography                                                                                               | <input type="checkbox"/>                                            | <input checked="" type="checkbox"/>       | May affect ground engineering and foundation design and construction       |
| Note: Seismicity is not included in the above table as this is not normally a design consideration in the UK. |                                                                     |                                           |                                                                            |

### 5.2.1 Chalk

In view of the prevailing ground conditions, with Chalk at shallow depth beneath the site, it is normal practice to consider the potential risk of ground subsidence related to the presence of swallow holes and other natural chalk solution features or man-made cavities.

Based on the Edmund's risk assessment model for natural dissolution features referred to in CIRIA Report C574 (Lord et al. 2002), the site falls into the 'moderate anticipated subsidence risk' category. However, with reference to Edmund's database of known natural and man-made chalk solution features there are no such features in the immediate vicinity of the site.

## 6 SITE INVESTIGATION STRATEGY & METHODOLOGY

### 6.1 Introduction

RSK carried out intrusive investigation works and subsequent monitoring of boreholes between 7<sup>th</sup> February 2022 and 17<sup>th</sup> February 2022.

### 6.2 Objectives

The specific objectives of the investigation were as follows:

- To determine the risk from hydrocarbon vapours;
- To establish the current condition of the groundwater beneath the site; and
- To characterise the deep ground conditions for pile design.

### 6.3 Investigation strategy

The ground investigation was carried out using intrusive ground investigation techniques in general accordance with the recommendations of BS5930:2015+A1:2020, which maintains compliance with BS EN 1997-1 and 1997-2 and their related standards. Whilst every attempt was made to record full details of the strata encountered in the boreholes, techniques of hole formation and sampling will inevitably lead to disturbance, mixing or loss of material in some soils and rocks.

The techniques adopted for the investigation were chosen with consideration of the objectives and site constraints, which are described below.

The investigation strategy involved the formation of six shallow boreholes to a maximum depth of 3 m bgl which were positioned within the footprint of the proposed buildings in order to assess the risk from vapours, and drilling two deep boreholes to 25 m depth using a cable percussive rig. An exploratory hole location plan is shown on [Figure 2](#).

The constraints to the investigation were as follows:

- Presence of existing culvert beneath the site; and
- A foundation was encountered whilst drilling BH01, which required chiselling to break through the brick / concrete.

Details of the investigation locations, installations and rationale are presented in **Table 8**.

**Table 8 Exploratory hole and monitoring well location rationale**

| Investigation type                    | Number | Designation     | Monitoring well installation | Rationale examples below                              |
|---------------------------------------|--------|-----------------|------------------------------|-------------------------------------------------------|
| Boreholes by cable percussive methods |        | BH101 to BH102. | Groundwater                  | To confirm the geological succession beneath the site |

| Investigation type                       | Number | Designation    | Monitoring well installation | Rationale examples below                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|------------------------------------------|--------|----------------|------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                          |        |                |                              | and obtain geotechnical test data for pile design.<br>The boreholes were positioned to provide spatial coverage of the site.<br>Groundwater wells were installed in both boreholes, with the response zones located in the underlying chalk to allow for future monitoring.                                                                                                                                                                                                                                                             |
| Boreholes by windowless sampling methods |        | WS201 to WS206 | Vapour monitoring            | To characterise the shallow ground conditions and install shallow wells in the made ground for future vapour monitoring.<br>WS201 and WS202 were posited to target the northern corner of the site where the highest concentrations of contaminants were previous recorded, and in the foot print of one of the proposed apartment blocks<br>WS203 was positioned towards the off-site residential properties and within the footprint of a apartment block.<br>WS204 to WS206 were located in the area of the second apartment block.. |

### 6.3.1 Implementation of investigation works

The exploratory holes were logged by an engineer in general accordance with the recommendations of BS5930:2015+A1:2020 (which incorporates the requirements of BS EN ISO 14688-1, 14688-2 and 14689-1).

The monitoring well construction and associated response zones are detailed on the exploratory hole records in [Appendix D](#).

The soil sampling and analysis strategy was designed to characterise each encountered soil strata, permit an assessment of the potential contaminant linkages identified and investigate the geotechnical characteristics. In addition, samples were taken to allow for geo-environmental and geotechnical testing to be undertaken.

Soils collected for laboratory analysis were placed in a variety of containers appropriate to the anticipated testing suite required. They were dispatched to the laboratory in cool boxes under chain of custody documentation. Samples were stored in accordance with

the RSK quality procedures to maintain sample integrity and preservation and to minimise the chance of cross contamination.

Selected samples were placed in polythene bags for headspace screening with a photo-ionisation detector (PID) fitted with a 10.6 eV bulb. The PID screening results are presented on the exploratory hole records.

## **6.4 Monitoring programme**

### **6.4.1 Vapour monitoring**

Vapour monitoring was carried out on the 11<sup>th</sup> February and 17<sup>th</sup> February at WS201, WS202, WS203, WS205 and WS206. These wells were selected as they are located within the footprints of the proposed apartment blocks. Monitoring was carried out on two occasions to ensure consistency of results.

The wells were initially purged using a gas analyser and screened for volatile organic compounds using a PID. The wells were left to recharge for at least an hour before vapour samples were taken using summa canisters. These were sent to a UKAS registered laboratory (Element) under a chain of custody and were scheduled for petroleum hydrocarbons, which is the principal contaminant of concern for gas works in respect to vapours.

### **6.4.2 Groundwater monitoring and sampling**

The new wells installed by RSK were purged a week prior to carrying out to carry out groundwater monitoring on the 17<sup>th</sup> February 2022. Samples were retrieved from BH101 and BH102, as well as the three wells that remained on the site from previous investigations BH202, BH104 and BH105. These wells were selected in order to assess the concentrations within the groundwater up-gradient and down-gradient of the site as well as target the northern corner.

Depths to groundwater and any NAPL were recorded using an electronic interface probe during the visit. It must be noted that the presence of NAPL was not detected.

Groundwater samples were retrieved using a United States Environment Protection Agency (USEPA) approved low-flow purging and sampling methodology. Water samples were dispatched to the laboratory in cool boxes under chain of custody documentation.

The groundwater monitoring records are presented in [Appendix E](#). BH202 is referenced as BH101a on the monitoring data and chemical results, due to a mix up with the numbering.

## 6.5 Laboratory testing

Laboratory testing was undertaken at a UKAS accredited laboratory with ISO17025 and MCERTS accredited test methods were specified where applicable for contamination testing and as shown in the laboratory test certificates appended.

### 6.5.1 Chemical analysis of soil samples

The programme of chemical tests undertaken on soil samples obtained from the intrusive investigation is presented in **Table 9** with the laboratory testing results contained in [Appendix F](#).

**Table 9 Summary of chemical testing of soil samples**

| Stratum                                      | Tests undertaken                                                                                                                                   | No. of tests |
|----------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|--------------|
| Made ground                                  | Asbestos screening, heavy metals, speciated PAHs, petroleum hydrocarbons split into criteria working group, total phenols, free and total cyanide. | 6            |
| Existing tarmac (eastern corner of the site) | Speciated PAH and % of coal tar (for waste disposal purposes).                                                                                     | 1            |

### 6.5.2 Geotechnical analysis of soils

Where appropriate disturbed, bulk and undisturbed soil samples were taken for geotechnical classification testing with the depth and nature of samples detailed within the exploratory hole records.

Where appropriate, testing was undertaken in accordance with BS 1377:1990 Method of Tests for Soils for Civil Engineering Purposes or, where superseded, by the relevant part of BS EN ISO 17892:2014 Geotechnical investigation and testing - Laboratory Testing of Soil. Tests carried out in order to classify the concrete class required on-site have been undertaken following the procedures within BRE SD1:2005.

The programme of geotechnical tests undertaken on samples obtained from the intrusive investigation is presented in **Table 10**. The results and UKAS accreditation of tests methods are shown in [Appendix G](#).

**Table 10 Summary of geotechnical testing undertaken**

| Strata               | Tests undertaken                                    | No. of tests |
|----------------------|-----------------------------------------------------|--------------|
| Made ground          | BRE concrete classification for a brownfield site   | 4            |
| Alluvium             | Liquid / plastic limits                             | 3            |
|                      | BRE concrete classification for non-pyritic geology | 3            |
| White Chalk Subgroup | Liquid / plastic limits                             | 2            |
|                      | Saturation soil moisture content                    | 2            |
|                      | BRE concrete classification for non-pyritic geology | 3            |

### 6.5.3 Chemical analysis of groundwater samples

Groundwater were collected in containers appropriate to the anticipated testing suite required. The containers were filled to capacity and placed in a cool box to minimise volatilisation.

Chemical testing undertaken on water samples obtained during the monitoring programme is presented in **Table 11** with the laboratory testing results contained in [Appendix H](#).

**Table 11 Summary of chemical testing of water samples**

| Sample type                        | Tests undertaken                                                                                                                                                         | No. of tests |
|------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|
| Groundwater (White Chalk Subgroup) | Heavy metals, speciated PAHs, petroleum hydrocarbons split into criteria working group, total phenols, total cyanide, sulphate, ammoniacal nitrogen, and total hardness. | 5            |

## 7 SITE INVESTIGATION FACTUAL FINDINGS

The results of the intrusive investigation and subsequent geo-environmental and geotechnical laboratory analysis undertaken are detailed below.

### 7.1 Ground conditions encountered

The descriptions of the strata encountered, notes regarding visual or olfactory evidence of contamination, list of samples taken, field observations of soil and groundwater, in-situ testing and details of monitoring well installations are included on the exploratory hole records presented in [Appendix D](#).

The exploratory holes revealed that the site is underlain by a variable thickness of made ground over Alluvial Deposits (locally absent) with the White Chalk Subgroup encountered at depth. This confirms the findings of the previous site investigations.

For the purpose of discussion, the ground conditions encountered during the fieldworks are summarised in **Table 12** with the strata discussed in subsequent subsections.

**Table 12 General succession of strata encountered**

| Stratum                     | Exploratory holes encountered | Depth to top of stratum m bgl | Proven thickness (m) |
|-----------------------------|-------------------------------|-------------------------------|----------------------|
| Made ground (Capping Layer) | All                           | Ground level                  | 0.60                 |
| Made ground                 | All                           | 0.11 to 0.60                  | 1.40 to 3.10         |
| Alluvium                    | BH102, WS203 to WS205         | 1.40 to 2.00                  | 5.10 m               |
| White Chalk                 | BH101 and BH102               | 3.50 to 7.10                  | Proven to 25.0 m     |

#### 7.1.1 Made ground

A capping layer was encountered across the site with the exception of the southeastern corner where the site is covered by tarmac. The capping layer comprised a granular fill material underlain by a geotextile membrane which ranged in thickness from 0.11 m to 0.6 m. In generally the capping layer was over 0.3 m in thickness as described in the verification report.

The capping layer was underlain by a dark brown to brown / grey sandy clay with varying proportions of brick, concrete, ash, clinker and occasional chalk fragments. At BH101 a former brick structure was encountered to 3.5 m depth.

Possible reworked Alluvial Deposits were noted below the made ground at WS203 and WS206.

In-situ SPT testing recorded N60 values ranging between 9.6 and tests recording no penetration.

### 7.1.2 Alluvial Deposits

This stratum was encountered beneath the central eastern portions of the site towards the River Arun, and comprised an initial layer of firm orange brown very gravelly CLAY. At BH102 this was underlain (3.7 m depth) by a brown gravelly silty SAND.

A summary of the in-situ and laboratory test results recorded in the stratum are presented in **Table 13**.

**Table 13 Summary of in-situ and laboratory test results for Alluvium**

| Soil parameters                                                               | Min. Value | Max. Value    | Reference                  |
|-------------------------------------------------------------------------------|------------|---------------|----------------------------|
| Moisture content (%)                                                          | 14         | 20            | <a href="#">Appendix G</a> |
| Modified moisture content (%)                                                 | 31         | 67            | -                          |
| Liquid limit (%)                                                              | 51         | 61            | <a href="#">Appendix G</a> |
| Plasticity limit (%)                                                          | 25         | 26            | <a href="#">Appendix G</a> |
| Plasticity index (%)                                                          | 25         | 36            | <a href="#">Appendix G</a> |
| Modified plasticity index (%)                                                 | 7.35       | 17.3          | -                          |
| Plasticity term                                                               | High       | High          | <a href="#">Appendix G</a> |
| Volume change potential                                                       | Low        | Low           | -                          |
| SPT 'N60' values                                                              | 12         | 16.8 (51.6**) | <a href="#">Figure 6</a>   |
| Undrained shear strength inferred from SPT 'N60' values (kN/m <sup>2</sup> )* | 60         | 84            | -                          |
| Consistency term from field description                                       | Soft       | Firm          | <a href="#">Appendix D</a> |
| <b>Notes:</b> *derived using a Stroud Factor of 5.                            |            |               |                            |
| **Denotes value influenced by cobbles                                         |            |               |                            |

### 7.1.3 White Chalk

This stratum was encountered at a depth of between 3.1 m and 7.1 m below ground level and was described as an off white structureless chalk composed of a sandy gravelly SILT. Possibly becoming structured (based on SPT blow counts with N values above 10) between 7 and 9 m bgl. Chalk clasts were encountered towards the base of the boreholes.

A summary of the in-situ and laboratory test results recorded in the stratum are presented in **Table 14**.

**Table 14 Summary of in-situ and laboratory test results for White Chalk Subgroup unit**

| Soil parameters                   | Min. Value | Max. Value | Reference                  |
|-----------------------------------|------------|------------|----------------------------|
| Moisture content (%)              | 30         | 32         | <a href="#">Appendix G</a> |
| Bulk Density (Mg/m <sup>3</sup> ) | 1.47       | 1.89       | <a href="#">Appendix G</a> |
| Dry Density (Mg/m <sup>3</sup> )  | 1.11       | 1.45       | <a href="#">Appendix G</a> |
| Saturated moisture content (%)    | 32         | 53         | <a href="#">Appendix G</a> |
| SPT 'N60' values                  | 9.6        | 75.6       |                            |

| Soil parameters        | Min. Value | Max. Value | Reference |
|------------------------|------------|------------|-----------|
| Inferred density scale | Low        |            | :-        |

#### 7.1.4 Visual/olfactory evidence of soil contamination

A strong hydrocarbon odour and an elevated PID reading of 128 ppm was recorded in the made ground from 0.5 m bgl at WS201 located in the northern corner of the gas works. A slight hydrocarbon odour and a PID reading of 16ppm was recorded at WS202 posited further to the west. Low concentrations of VOC of below 5 ppm was recorded in the samples taken from the remaining exploratory points.

The presence of ash and clinker was recorded in the made ground across the site.

## 7.2 Groundwater

### 7.2.1 Groundwater levels

Groundwater strikes were recorded at ~6 m depth during the intrusive works. The groundwater levels recorded during monitoring carried out on the 17<sup>th</sup> February are summarised in **Table 15**, below.

**Table 15 Summary of groundwater levels**

| Monitoring well | Response zone stratum | Groundwater (m bgl) |
|-----------------|-----------------------|---------------------|
| BH101           | Chalk                 | 2.05                |
| BH012           | Chalk                 | 2.44                |
| BH202           | Chalk                 | 1.85                |
| BH104           | Chalk                 | 1.00                |
| BH105           | Chalk                 | 0.65                |

The levels reflect the groundwater within the underlying chalk / alluvial deposits that are known to be affected by tidal variations.

### 7.2.2 Visual/olfactory evidence of groundwater contamination

A strong hydrocarbon odour and discolouration was noted when retrieving the groundwater sample from BH202. No visual evidence of contamination was noted within the other boreholes.

## 8 GEO-ENVIRONMENTAL ASSESSMENT

### 8.1 Refinement of initial CSM

The ground investigation recorded a variable thickness of made ground with visual / olfactory evidence of hydrocarbon contamination in the northern corner of the site. The findings are consistent with those anticipated within the CSM and therefore there are no significant changes.

The potential pollutant linkages under consideration are:

- Risk to future site users, water supply pipes, vegetation and building structure from direct contact with gas works related contamination;
- Risk to future site users via the inhalation of vapours; and
- Risk to controlled water and future site users through the adoption of piled foundations.

### 8.2 Linkages for assessment

As described in LCRM (Environment Agency, 2021), there are two stages of quantitative risk assessment (QRA), Tier 2 generic (GQRA) and Tier 3 detailed (DQRA). The GQRA comprises the comparison of soil, groundwater, soil gas and / or ground gas results with generic assessment criteria (GAC) that are appropriate to the linkage being assessed. This comparison can be undertaken directly against the laboratory results or following statistical analysis depending upon the sampling procedure that was adopted. This assessment relates to LCRM Stage 1, Tier 2 generic quantitative risk assessment

Following the refinement of the CSM, the potentially complete contaminant linkages that require further assessment and the methodology of assessment are presented in **Table 16**.

**Table 16 Linkages for GQRA**

| Potentially relevant contaminant linkage                                                              | Assessment method                                                                                                                                                                                                                                                                 |
|-------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Human health and phytotoxic-related linkages</b>                                                   |                                                                                                                                                                                                                                                                                   |
| H1. Oral, dermal and inhalation exposure with impacted soil, soil vapour and dust by future residents | The result of the chemical testing have been compared against human health GACs in <a href="#">Appendix I</a> for a proposed residential end use without home-grown produce since the proposed end use includes residential apartment blocks with communal soft landscaped areas. |
| H2. Inhalation of hydrocarbon vapours.                                                                | The results of the vapour testing have been compared against RSK vapour and groundwater GAC for a residential end use presented in <a href="#">Appendix J</a> .                                                                                                                   |

| Potentially relevant contaminant linkage                                                    | Assessment method                                                                                                        |
|---------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|
| H3. Uptake of contaminants by vegetation potentially impacting plant growth (phytotoxicity) | Comparison of soil data to GAC in <a href="#">Appendix K</a> for phytotoxicity.                                          |
| H4. Organic contaminants permeating potable water supply pipes                              | Comparison of soil data to GAC in <a href="#">Appendix I</a> for plastic water supply pipes using UKWIR (2010) guidance. |
| <b>Controlled waters-related linkages</b>                                                   |                                                                                                                          |
| W1. Migration of dissolved phase contaminants to River Arun.                                | Qualitative assessment using results from this and previous site investigations.                                         |

## 8.3 Methodology and assessment of human health and phytotoxic-related linkages

### 8.3.1 H1. Oral, dermal and inhalation exposure with impacted soil by future site users

The results of the soil testing have been directly compared against RSK GACs for a residential end-use, these are much more stringent than the open storage criteria used to remediate the site. The following exceedances have been identified in the made ground,

- Fibrous asbestos (chrysotile) has been recorded at WS203;
- Elevated concentrations of PAH benzo-a-pyrene have been recorded above the assessment criteria of 5.3 mg/kg in four samples taken from WS201 to WS204 with concentrations ranging from 10 mg/kg to 180 mg/kg; and
- An elevated concentration of lead was recorded above the GAC of 310 mg/kg at WS201 with a concentration of 460 mg/kg.

On review of the validation testing carried out by Celtic it was noted that concentrations of PAHs were found to be elevated above RSK's GAC across the site, with locally elevated concentrations of lead.

It is considered that there is a risk to future site users from coming direct contact with impacted soils where they may be exposed to the contamination i.e. areas of soft landscaping. Remedial measures will be required to mitigate the risk.

### 8.3.2 H2. Inhalation of vapours

To assess the risk from vapours the following lines of evidence have been considered.

- 1) Visual observations and field results.
- 2) Assessment of vapour concentrations from monitoring wells.
- 3) Assessment of hydrocarbon concentrations in groundwater.

### Visual observations / field data

Visual observation made during the site works recorded hydrocarbon odours at WS201 and WS202. Elevated concentrations of volatile organic compounds were also recorded in the made ground at WS201 with the PID.

The monitoring wells were screened for volatile using a PID prior to sampling. A summary of field results are summarised in **Table 17**, below.

**Table 17 Summary of monitoring results**

|                 | 11 <sup>th</sup> Feb 2022 | 17 <sup>th</sup> Feb 2022 |
|-----------------|---------------------------|---------------------------|
| Monitoring well | Max PID (ppm)             | Max PID (ppm)             |
| WS201           | 851                       | 416                       |
| WS202           | 8.6                       | 39.4                      |
| WS203           | 158                       | 12.3                      |
| WS205           | 30                        | 19.8                      |
| WS206           | 0.4                       | 25.1                      |

The table shows that elevated concentrations of VOCs (above 10 ppm) were recorded in all of exploratory points, with the highest concentrations were recorded at WS201 and WS203.

### Vapour monitoring

The results of the vapour monitoring have been compared directly against RSKs vapour GACs presented in [Appendix J](#). Exceedances are summarised in **Table 18**, below

**Table 18 Exceedances against vapour GACs**

| Determinant                 | GAC (mg/m3) | Exceedances 11th Feb.                  | Exceedances 17th Feb.                                                                             |
|-----------------------------|-------------|----------------------------------------|---------------------------------------------------------------------------------------------------|
| Benzene                     | 1.59        | WS201 (132 mg/m3)<br>WS202 (6.9 mg/m3) | WS201 (536 mg/m3)<br>WS202 (40 mg/m3)<br>WS203 (5 mg/m3)<br>WS205 (9.9 mg/m3)<br>WS206 (31 mg/m3) |
| Aromatic hydrocarbon C8-C10 | 34          | WS201 (65 mg/m3)                       |                                                                                                   |

Exceedances of the vGACs were recorded at WS201 during both monitoring rounds, which corresponds with the field data. However, only two wells exceeded the vGAC for

benzene during the first round whereas all five wells recorded elevated concentrations during the second round. This may be due to differing climatic conditions or the influence of varying groundwater levels that may affect the movement of the vapours e.g. via hydraulic pumping.

#### Assessment of groundwater results

Inhalation exposure from VOCs within groundwater has initially been assessed through the direct comparison of groundwater data with the RSK GrAC presented in [Appendix J](#).

The GrAC for groundwater are based on indoor inhalation exposure to contaminants in the vapour-phase. Based on the conceptual model, a sandy loam soil has been selected and a groundwater depth of 0.65 m.

The assessment found that the concentration of aromatic carbon chain C12-C16 marginally exceeded the GAC of 5.75 mg/l at WS201 with a concentration of 7 mg/l. No other boreholes recorded elevated concentrations above the GACs.

#### Discussion of the results

The results of the assessment indicates that elevated concentrations of benzene were recorded across the site above the vGACs, with the highest concentrations being recorded in the northern corner, which corresponds with field observations. This was also the area highlighted in the previous site reports as being impacted by gross contamination.

Testing of the groundwater also recorded elevated concentrations of hydrocarbons in the northern corner at WS201, but not at any of the other boreholes. It is therefore considered that groundwater does not appear to be acting as a pathway for hydrocarbons. However, the tidal fluctuations may create a movement of vapours in the unsaturated zone via hydraulic pumping.

Remedial measures will be required to mitigate the risk to future site users from benzene vapours.

### **8.3.3 H3. Uptake of contaminants by vegetation potentially inhibiting plant growth (phytotoxicity)**

The chemical test results have been compared with the GAC presented in **Appendix K** for this linkage. The assessment has identified elevated concentration of lead above the GAC (based on a pH above 7), and therefore this linkage is likely to exist associated with phytotoxic effects.

### **8.3.4 H4. Organic contaminants permeating potable water supply pipes**

For initial assessment purposes, the results of the investigation have been compared with the GAC presented in [Appendix L](#) for this linkage, which are reproduced from *UKWIR Report 10/MM/03/21. Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites* (UKWIR, 2010).

The results indicate that a relevant linkage is likely to exist associated with organic contaminants and therefore pollutant polyethylene (PE) and/or polyvinyl chloride (PVC) water supply pipes are expected to be unsuitable for use on the development unless remedial measures are implemented that mitigate the risk.

It should be noted that at the time of this investigation the future routes of water supply pipes had not been established, hence the investigation and sampling strategy may not be fully compliant with UKWIR recommendations. Consequently, a targeted investigation and specific sampling/analytical strategy may be required at a later date once the route(s) of the supply pipe(s) are known. In addition, it is recommended that the relevant water supply company be contacted at an early stage to confirm its requirements for assessment, which may not necessarily be the same as those recommended by UKWIR.

## 8.4 Methodology and assessment of controlled waters-related linkages

### 8.4.1 W1 migration of dissolved phase contamination to River Arun.

The results of the groundwater monitoring carried out by RSK recorded elevated concentrations of petroleum hydrocarbon in the northern corner of the site at BH202, which corresponds with the findings of the previous investigations. However, no evidence of free product was noted during the field works. None of the other boreholes tested by RSK recorded elevated concentrations of hydrocarbons located along the eastern boundary.

To determine the impact of the remedial works on groundwater quality, the results from BH202 have been compared against testing carried out during and prior the remedial works. The four most mobile hydrocarbon fractions (as defined in CLAIRE 2017 guidance on petroleum hydrocarbon in groundwater) were selected as they pose the greatest risk to controlled waters. The findings are presented in **Table 19**, below.

**Table 19 Comparison of results from BH202.**

|                                                                                                                    | Monitoring dates |         |        |        |         |
|--------------------------------------------------------------------------------------------------------------------|------------------|---------|--------|--------|---------|
| Determinant                                                                                                        | 2/12/20          | 15/6/21 | 6/7/21 | 4/8/21 | 17/2/22 |
| Benzene (mg/l)                                                                                                     | 0.81             | 0.159   | <0.001 | 3.28   | 1.04    |
| Toluene (mg/l)                                                                                                     | 0.07             | 0.071   | <0.001 | 1.06   | 0.2     |
| Total Xylene (mg/l)                                                                                                | 0.002            | <0.001  | <0.001 | 0.036  | 0.004   |
| Ethylbenzene (mg/l)                                                                                                | 0.21             | 0.057   | <0.001 | 0.037  | <0.001  |
| Yellow = Pre-remediation, Orange = during remediation, Green = Post remediation and monitoring carried out by RSK. |                  |         |        |        |         |

The assessment shows that following an initial fall in the concentrations they exceed the pre-monitoring results by the end of the remedial works. This may have been due to the disturbance during the process of soil stabilisation of the impacted soils that caused a temporary peak in the concentration of hydrocarbons. The monitoring carried out by RSK

post remediation show that the concentrations have fallen again and are comparable with initial concentrations.

Further monitoring would be required to establish any continuing trend, however, the results suggest that the potential impact to controlled waters has not altered. The groundwater DQRA undertaken by Celtic and approved by the Environment Agency stated that the elevated concentrations of hydrocarbons recorded in the groundwater do not pose a risk to the River Arun. Other factors that should be taken into account are,

- None of the down-gradient wells (BH102, BH104, and BH105) recorded elevated concentrations of petroleum hydrocarbons above the analytical detection limit, suggesting that the impacted groundwater is localised; and
- The majority of the site will be covered in hardstanding as part of the proposed development with only minor areas of communal soft landscaping. At the present the site is covered in a granular capping layer. The hardcover will reduced any surface water infiltration and leachability of contamination within the unsaturated zone.

#### **8.4.2 Risk to principal chalk aquifer from piled foundations**

Theoretically the use of piled foundations could increase the risk to the deeper chalk aquifer / River Arun by creating an artificial pathway for hydrocarbon contamination. It may also create a pathway for vapours to migrate along. Therefore, a foundations work risk assessment will be required to select the most appropriate piling technique for this site.

## **9 CONCLUSIONS OF GEO-ENVIRONMENTAL ASSESSMENT**

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A small town gas works was operational on the site from the 1840s until mid-20<sup>th</sup> Century following which the above ground structures were demolished to ground level.

Numerous investigations were carried out on the site by other consultants that revealed ground conditions comprising a variable thickness of made ground up to 4.5 m depth. Visual and olfactory of gas works related contamination including, ash, clinker, tar staining and hydrocarbon odours were noted across the site but was concentrated across the northern portion of the site where the former process buildings were situated. The groundwater in the northern corner was also impacted with petroleum hydrocarbons. The made ground was underlain by Alluvial Deposits (absent to 6.3 m in thickness) with the White Chalk Sub Group at depth. Groundwater levels varied from 2.00 mAOD at high tide dropping to approximately 0.00 m AOD at low tide. Perched water was also noted on the site.

Remedial works were carried out last year by Celtic en Globe on behalf of National Grid Property Holdings to render the site suitable for a commercial 'open space' end-use. The works essentially comprised the treatment of any gross contamination identified using soil stabilisation and the provision of a capping layer. Very little contaminated materials were removed off-site. The remedial works were designed to ensure that there was no risk to neighbouring residential properties from hydrocarbon vapours. Also, a groundwater DQRA carried out at the time did not identify a risk to the River Arun located ~50 m to the east due to varying tidal fluctuations that would dilute / disperse any contamination.

RSK have undertaken additional investigation of the site to further characterise the sites current condition in relation to a proposal to redevelop it with a more sensitive landuse (two residential apartment blocks). The works consisted of the formation of six shallow boreholes to 3m depth and two deep boreholes to 25 m with the installation of vapour and groundwater monitoring wells.

The findings of the investigation indicated that the made ground still contains gas works related contamination (lead, PAHs, and asbestos) that would pose a risk to residential users, and vegetation where they may be exposed to these soils in proposed areas of communal soft landscaping.

Vapour sampling also identified elevated concentration of hydrocarbons (benzene) that pose a risk to future residential users, especially in the northeast corner where the concentrations were at their highest.

The contaminated soils are also not considered suitable for use of plastic water supply pipes due to the presence of organic contaminants.

In relation to groundwater, the investigation found elevated concentrations of petroleum hydrocarbons in the northeast corner which were similar to those recorded prior to the remedial works. No boreholes tested down-gradient identified the presence of petroleum hydrocarbons suggesting that the impacted groundwater is localised. The risk to controlled waters (River Arun) has not altered following the remedial works, and it is considered that the conclusions of the DQRA are still valid. However, the proposed

development will use a piled foundation solution that could theoretically create pathways for groundwater / vapours to migrate along. Therefore, a foundation works risk assessment will be required to ensure that the most appropriate foundation solution is adopted.

In summary, the ground investigation has identified potential risks that require remedial measures to safeguard the proposed development. Our conclusions are subject to approval by the Local Authority Environmental Health Department and Environment Agency.

## 9.1 Outline remediation strategy

The following complete pollutant linkages have been identified.

- Risk to future site users, water supply pipes, vegetation and building structure from direct contact with gas works related contamination in the made ground;
- Risk to future site users via the inhalation of vapours; and
- Risk to controlled water and future site users through the adoption of piled foundations.

Based on our current understanding of the proposed development the following mitigation measures are proposed.

### 1) Risk to future site users and vegetation via direct contact with contaminated soils

In areas of hardstanding the impacted soils will be encapsulated, however site users may be exposed to contamination in area of proposed soft landscaping. The development plans show that minor areas of communal soft landscaping around the periphery of the site.

It is considered that the risk may be mitigated through the adoption of a 450 mm clean cover system. However, given the level of contamination within the made ground a no-dig / capillary break layer as well as a visible marker layer should be placed at the base of the clean cover system.

### 2) Risk to future site users from hydrocarbon vapours

Due to the risk of flooding, the majority of the ground floor will be used for undercroft car parking that would naturally vent any vapours. However, where buildings are present, gas vapour protection measures should be incorporated into the design of the building. Any vapour membrane installed should comply with the CIRIA guidance C748 '*design of plastic membranes for vapours*'. The design of the protection measures should be carefully considered to take into account the impact of the tidal influences on the flow of gases, and to ensure that additional pathways are not created to the off-site residential properties.

Given the importance of these measures it is recommended that they are verified in accordance with the generally principals outlined within CIRIA document C735 '*verification of gas protection measures*'. The installation of any membrane should be carried out by suitability component NVQ qualified installer.

### 3) Risk to water supply pipes via direct contact with impacted soils / groundwater

The following measures are considered to be suitable to mitigate the risk from organic contaminants,

- Removal of made ground from the services trenches and backfill these with pea shingle;
- Adoption of barrier pipe which is resistant to chemical attack; and
- All service corridors leaving site should be sealed to prevent the off-site migration of vapours.

The local water authority should be contacted to confirm the requirements for water supply pipes.

4) Risk that additional contaminant pathways may be created by piled foundations

A foundation works risk assessment will be required in order to determine the most appropriate piling techniques to prevent the creation of preferential pathways for contamination to migrate along.

5) Re-use of site won-materials

It is considered that excavation of the made ground will be required to remove buried obstructions that would impede the piled foundations or other buried infrastructure, as well as create a suitable development platform.

The re-use of any made ground excavated should be considered within a detailed remediation strategy and should be chemically and geotechnically suitable for use. In relation to chemical suitability, the made ground as a minimum should be compliant to the DQRA assessment criteria produced by Celtic to ensure that it does not pose a risk to the underlying groundwater.

Any reuse of site-won material should be subject to a material management plan in line with the definition of waste code of practice (DoWCOP) or appropriate environmental exemption, to ensure regulatory approval.

### 9.1.1 Further works

The following additional reports are required,

- Detailed remediation strategy for the site;
- Method statement for the design and verification of vapour protection measures;
- Foundations works risk assessment to confirm selection of suitable piling technique;
- Materials management plan in relation to the re-use of site won-material; and
- Verification report upon completion of the remedial works.

## 10 GEOTECHNICAL ASSESSMENT

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### 10.1 Proposed development

The preliminary proposed development scheme at the time of writing comprises a residential development consisting of two separate apartment blocks containing 38 units, and that the development will be set at a raised level predominantly with open air parking or amenity space beneath. The development proposals do not include for private gardens although areas of communal soft landscaping are included.

### 10.2 Key geotechnical hazards / development constraints

The key risks identified from the available ground investigation data are discussed below:

- Potential for sudden lateral changes in ground conditions;
- Shrinkable clay soils within the Alluvium;
- Low bearing capacity soils within the made ground and underlying Alluvium;
- Silt-rich soils susceptible to rapid loss of strength on wetting;
- Potential for running sand within saturated granular horizons;
- Potential for dissolution with underlying chalk;
- High (tidally influenced) groundwater table;
- Potential for remnant sub structures;
- Made ground soils; and
- Adverse ground chemistry.

### 10.3 Foundations

#### 10.3.1 Foundation options

Given the variable depths of heterogeneous made ground, underlying Alluvium and a tidally influenced shallow ground water table, it is considered that the adoption of traditional spread foundations will not provide a feasible foundation solution to support the structural loads associated with the proposed residential apartments.

Similarly, the potential for low strength organic-rich cohesive soils within the Alluvium and recent non-engineered fill to be present may preclude the use of ground improvement techniques, such as vibro-replacement.

Therefore, it is considered that recourse to piled foundations is likely to provide the most suitable founding strategy for the proposed apartments.

#### 10.3.2 Piled foundations

Recommendations for the design and construction of pile foundations in relation to the ground conditions are set out in **Table 20**.

**Table 20 Design and construction of piled foundations**

| Design/construction considerations           | Design/construction recommendations                                                                                                                                                                                                                                                                                                                                                                     |                                                  |
|----------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------|
| Pile type                                    | The construction of both bored and driven piles is considered technically feasible at this site.                                                                                                                                                                                                                                                                                                        |                                                  |
| Possible constraints on choice of pile type  | Given: the close proximity of the site to a residential area; potential for pre-setting on obstructions; and contamination issues it is considered possible that pile driving may not be acceptable.                                                                                                                                                                                                    |                                                  |
| Temporary casing                             | Given the presence of groundwater strikes over the full depth of the investigation bored piles will require temporary casing throughout their depth. Alternatively, the use of continuous-flight-auger (CFA) injected bored piles or driven piles usually overcomes this issue.                                                                                                                         |                                                  |
| Soft superficial deposits                    | <p>For the purpose of assessing preliminary pile capacities the made ground have been presumed not to contribute to the load-carrying capacity for the piles.</p> <p>Where located within areas of potential tree influence, piles should be reinforced and designed in tension to resist the potential for uplift forces, alternatively the piles should be sleeved through the zone of influence.</p> |                                                  |
| Obstructions                                 | Due to previous land use, pre-pile probing should be conducted to ensure the pile locations are free from remnant sub structures.                                                                                                                                                                                                                                                                       |                                                  |
| Pile design parameters for Made ground soils | No support assumed for top 3.50 m due to made ground soils                                                                                                                                                                                                                                                                                                                                              |                                                  |
| Pile design parameters for                   | Pile design parameter                                                                                                                                                                                                                                                                                                                                                                                   | CFA                                              |
| Alluvium                                     | Shear strength                                                                                                                                                                                                                                                                                                                                                                                          | 30                                               |
|                                              | Adhesion factor                                                                                                                                                                                                                                                                                                                                                                                         | 0.50                                             |
| Undifferentiated Chalk                       | Shaft Resistance ( $\tau_{sf}$ )                                                                                                                                                                                                                                                                                                                                                                        | $0.80s_v'$ for $N > 10$                          |
|                                              | Base Resistance ( $kN/m^2$ )                                                                                                                                                                                                                                                                                                                                                                            | $Q_u = 200N$<br>$Q_{all} = 800 \text{ to } 1800$ |
| General parameters                           | Limiting concrete stress ( $kN/m^2$ )                                                                                                                                                                                                                                                                                                                                                                   | $7.5 \text{ N/mm}^2$                             |

The design resistance has been calculated in accordance with BS EN 1997-1 and the UK National Annex, using partial resistance factors for CFA bored piles, given in **Table 21**.

**Table 21 Partial resistance factors ( $\gamma_R$ )**

| Resistance                       | Set    |        |
|----------------------------------|--------|--------|
|                                  | DA1 C1 | DA1 C2 |
| Base - $\gamma_b$                | 1.0    | 2.0    |
| Shaft (compression) - $\gamma_s$ | 1.0    | 1.6    |
| Total (compression) - $\gamma_t$ | 1.0    | 2.0    |

The design procedure for piles varies considerably, depending on the proposed type of pile. However, for illustrative purposes **Table 22** gives likely working pile loads for traditional bored, cast-in-situ concrete piles of various diameters and lengths, based on the design parameters given in **Table 21**. The soil profile of BH102, which identified low strength clays of the Lowestoft Formation, has been considered to provide a conservative assessment.

**Table 22 Illustration of typical pile working loads for CFA bored cast-in-situ piles**

| Typical pile working loads (kN)               |               |        |        |        |
|-----------------------------------------------|---------------|--------|--------|--------|
| Depth of pile below existing ground level (m) | Pile diameter |        |        |        |
|                                               | 300 mm        | 350 mm | 400 mm | 450 mm |
| 10                                            | 130           | 156    | 184    | 208    |
| 12                                            | 206           | 246    | 288    | 332    |
| 14                                            | 293           | 349    | 406    | 465    |
| 16                                            | 381           | 452    | 525    | 600    |
| 18                                            | 469           | 556    | 644    | 735    |
| 20                                            | 557           | 659    | 764    | 871    |

It should be stressed that the above capacities do not take into consideration pile group effects which is more pronounced for a large number of closely spaced piles.

Notwithstanding the above, it is recommended that the detailed advice of a specialist-piling contractor be sought as to the most suitable type of pile for the prevailing ground conditions and as to their lengths and diameters to support the required design loads.

### 10.3.3 Foundation works risk assessment

Given the potential for ground and groundwater contamination beneath the site, it is anticipated that a foundation works risk assessment report will be required for the development.

### 10.3.4 Floor slabs

The Site is generally underlain by more than 600 mm of existing made ground. National House-Building Council (NHBC) standards require that ground floor slabs should be suspended in areas where made ground is greater than 600 mm in thickness.

## 10.4 Roads and hardstanding

In the 1 m to 1.5 m below the proposed finished ground level the exploratory holes have revealed a soil profile comprising heterogenous made ground. The potentially poorest sub-grade material within this profile is the cohesive elements of made ground.

In pavement design terms, the groundwater conditions are anticipated to comprise a high water table.

The estimated minimum, equilibrium soil-suction, California bearing ratio (CBR) value for the soils and groundwater conditions described above under a completed pavement is 2 %, based upon Table C1 in TRRL (1984) Report LR1132. However, given the recent programme of enabling groundworks understood to have been completed it is recommended that the sub-grade condition should be confirmed by testing at the final formation level by in situ CBR testing.

Given the variability with the made ground, the sub-grade soils can be regarded as frost-susceptible, based upon the criteria given in Appendix 1 of TRRL (1970) Report Road Note 29. When the sub-grade is frost-susceptible the thickness of sub-base must be sufficient to give a total thickness of non-frost-susceptible pavement construction over the soil of not less than 450 mm.

## **10.5 Excavations for foundations and services**

The made ground is heterogenous in nature and the likelihood is that it will not be self-supporting within excavations. It is therefore recommended that excavation support systems are made available during the groundwork stage of the development.

Man entry into any excavations should not be undertaken without provision of suitable shoring and support and dewatering or suitable regrading and battering of side slopes to safe angles. Confined spaces protocols for the Health and Safety of personnel should always be used where man entry into excavations is to be undertaken as low oxygen conditions may be present.

Groundwater has been recorded at shallow depth and is considered to be tidally influenced. Dewatering may therefore be required to facilitate foundation excavation.

Pumping from open sumps in non-cohesive soils should be avoided as this can result in instability and general loosening of the soils at the base of the excavation. It is likely that dewatering in non-cohesive soils will require the use of well-pointing systems.

Excavation should be possible using conventional site plant. Breakers may be necessary to remove any concrete obstructions within the made ground.

## **10.6 Chemical attack on buried concrete**

This assessment of the potential for chemical attack on buried concrete at the site is based on BRE Special Digest 1: Concrete in aggressive ground, which represents the most up-to-date guidance on this topic currently available in the UK.

The desk study and site reconnaissance indicate that, for the purposes of assessing the aggressive chemical environment of the site, the site should be considered as comprising brownfield ground unlikely to contain pyrite.

Based on testing results, **Table 23** gives the characteristic pH, water-soluble and total sulphate content values for soils from each of the geological units and groundwater encountered on-site.

**Table 23 Characteristic pH and water soluble sulphate**

| Stratum     | pH           | Water Soluble Sulphate (mg/l) |
|-------------|--------------|-------------------------------|
| Made ground | 7.9 to 10.3  | 27 to 1010                    |
| Alluvium    | 8.55 to 9.0  | 64 to 118                     |
| Chalk       | 8.46 to 9.13 | 63 to 339                     |

Based on the results above and following the steps outlined in the BRE guidance, the Design Sulphate Classes and Aggressive Chemical Environment for Concrete classifications are summarised in **Table 24**, on the basis of water soluble sulphate and total potential sulphate, respectively.

**Table 24 Concrete design class**

| Stratum     | Groundwater | Water Soluble Sulphate |          |
|-------------|-------------|------------------------|----------|
|             |             | DS Class               | AC Class |
| Made Ground | Mobile      | DS-2                   | AC-2     |
| Alluvium    | Mobile      | DS-1                   | AC-1     |
| Chalk       | Mobile      | DS-1                   | AC-1     |

The recommended ACEC Classification is therefore AC-2 with a Design Sulphate Class of DS-2.

## 10.7 Infiltration drainage

The high water table and potential for remnant contamination will preclude the feasibility of adopting traditional soakaway chambers to discharge surface water drainage. However, the adoption of shallow SUDs such as permeable paving may remain feasible with prior approval from the Environment Agency.

# 11 GEOTECHNICAL CONCLUSIONS AND RECOMMENDATIONS

---

## 11.1 Geotechnical assessment

The key risks identified from the available ground investigation data are discussed below:

- Potential for sudden lateral changes in ground conditions;
- Shrinkable clay soils within the Alluvium;
- Low bearing capacity soils within the made ground and underlying Alluvium;
- Silt-rich soils susceptible to rapid loss of strength on wetting;
- Potential for running sand within saturated granular horizons;
- Potential for dissolution with underlying chalk;
- High (tidally influenced) groundwater table;
- Potential for remnant sub structures;
- Made ground soils; and
- Adverse ground chemistry.

Given the variable depths of heterogenous made ground, underlying Alluvium and a tidally influenced shallow ground water table, it is considered that the adoption of traditional spread foundations will not provide a feasible foundation solution to support the structural loads associated with the proposed residential apartments.

Similarly, the potential for low strength organic-rich cohesive soils within the Alluvium and non-engineered fill to be present may also preclude the use of ground improvement techniques, such as vibro-replacement.

Therefore, it is considered that recourse to piled foundations is likely to provide the most suitable founding strategy for the proposed apartments.

The made ground is heterogenous in nature and the likelihood is that it will not be self-supporting within excavations. It is therefore recommended that excavation support systems are made available during the groundwork stage of the development. Groundwater has also been recorded at shallow depth and is considered to be tidally influenced. Dewatering may therefore be required to facilitate foundation excavation.

The recommended AEC Classification is AC-2 with a Design Sulphate Class of DS-2.

The estimated minimum, equilibrium soil-suction, California bearing ratio (CBR) value for the soils and groundwater conditions described above under a completed pavement is 2 %, based upon Table C1 in TRRL (1984) Report LR1132. However, given the recent programme of enabling groundworks understood to have been completed it is recommended that the sub-grade condition should be confirmed by testing at the final formation level by in situ CBR testing.

The high water table and potential for remnant contamination will preclude the feasibility of adopting traditional soakaway chambers to discharge surface water drainage.

However, the adoption of shallow SUDs such as permeable paving may remain feasible with prior approval from the Environment Agency.

## **11.2 Recommendations**

Given the recent programme of enabling earthworks, it is recommended that in-situ CBR testing be conducted to confirm the current CBR design value for the site.

It is also recommended that a programme of groundwater monitoring be continued to ensure the full range of conditions are understood.

A foundation works risk assessment will be required to demonstrate that the proposed foundation strategy will not create pollution pathways for any residual contaminants to reach sensitive receptors.

Where levels are proposed to be altered as part of the proposed development it is recommended that these works be completed in strict accordance with an earthworks specification in order to prevent any issues with potential long term settlements.

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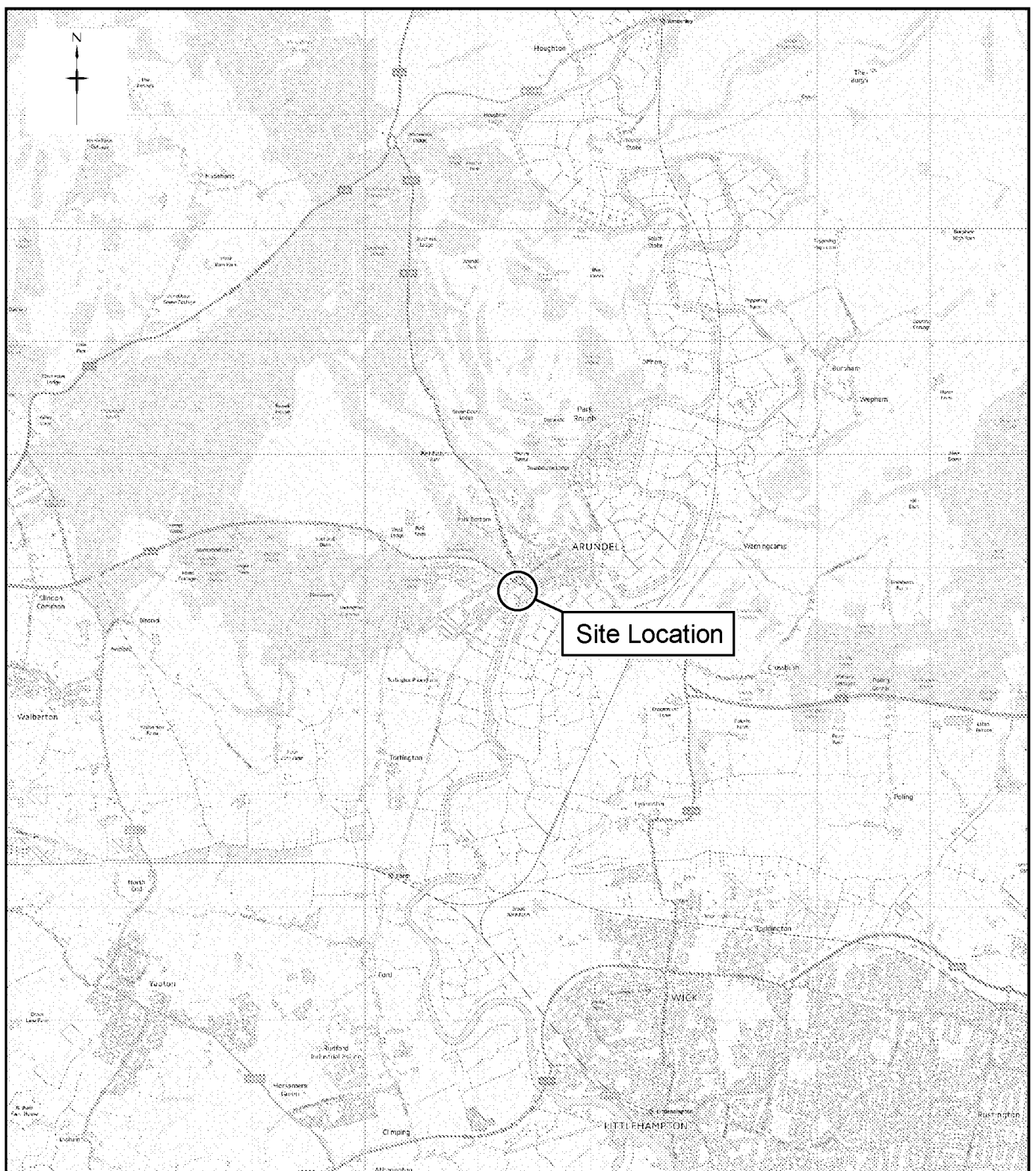
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## FIGURES

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## FIGURE 1 SITE LOCATION PLAN



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18 Frogmore Road  
Hemel Hempstead  
Hertfordshire  
HP3 9RT  
United Kingdom  
Tel: +44 (0) 1442 407500  
Fax: +44 (0) 1442 407500  
Email: info@rsk.co.uk  
Web: www.rsk.co.uk

Client

**OAKFORD HOMES**

Project Title

**FORMER ARUNDEL GASWORKS,  
FORD ROAD, ARUNDEL**

Drawing Title

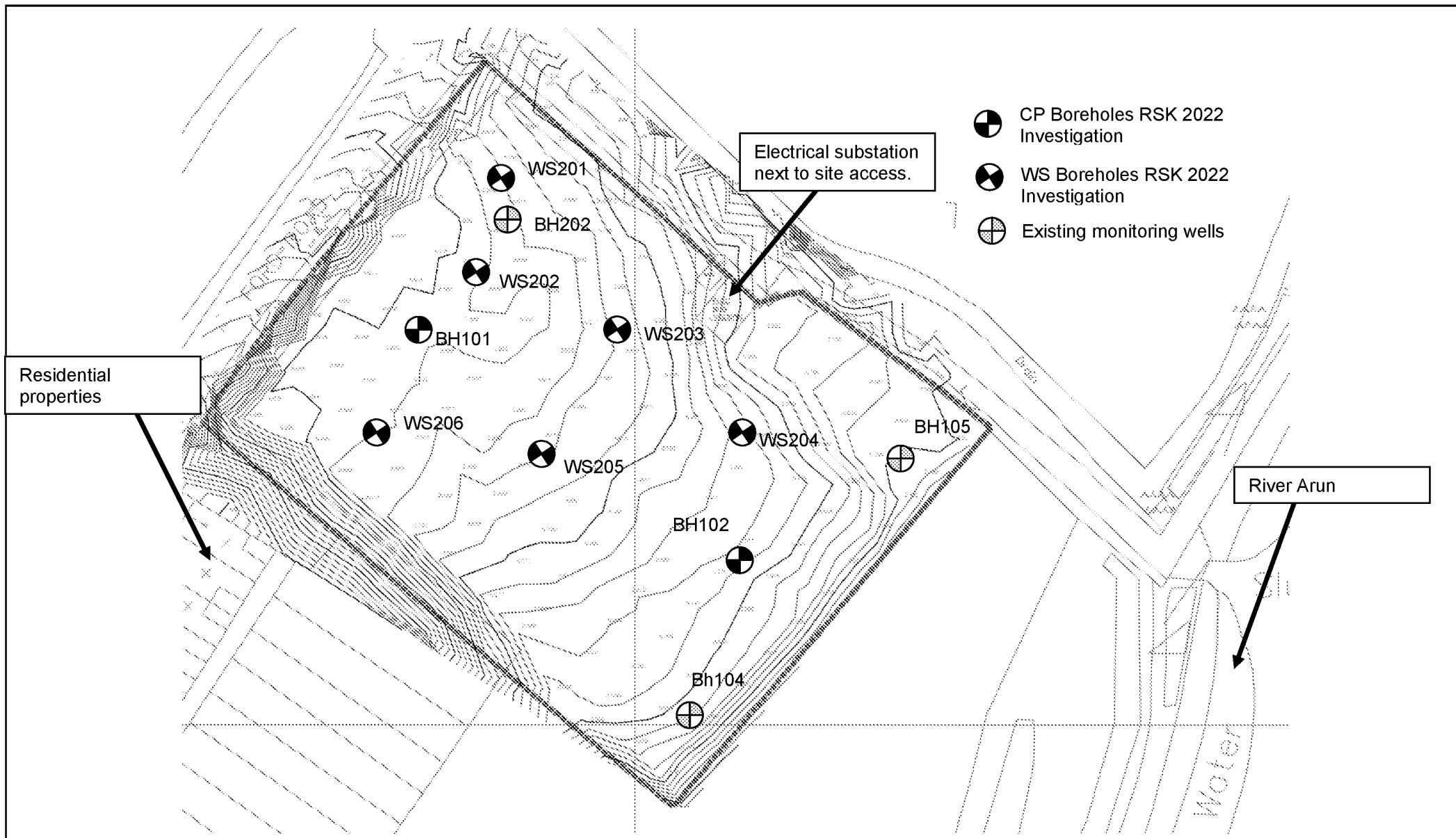
**SITE LOCATION PLAN**

| Rev        | Drawn | Date     | Checked | Date          | Approved | Date     |
|------------|-------|----------|---------|---------------|----------|----------|
| 01         | ASC   | 26.03.18 | AK      | 26.03.18      | AK       | 26.03.18 |
| Dimensions |       | Scale    |         | Original Size |          |          |
| m          |       | 1:50,000 |         | A4            |          |          |

| Project Number   | Drawing File    | Drawing Number |
|------------------|-----------------|----------------|
| 29780 - R01 (00) | 29780 - SLP.dwg | FIGURE 1       |



## **FIGURE 2 SITE LAYOUT AND EXPLORATORY HOLE LOCATION PLAN**



|                                                                                    |                                                     |                                |                      |
|------------------------------------------------------------------------------------|-----------------------------------------------------|--------------------------------|----------------------|
|  | <b>Site Layout / Exploratory Hole Location Plan</b> | <b>Client:</b> Oakford Homes   | <b>Figure No:</b> 2  |
|                                                                                    |                                                     | <b>Site:</b> Arundel Gas Works | <b>Job No:</b> 29780 |
|                                                                                    |                                                     | <b>Scale:</b> N.T.S            | <b>Source:</b> N/A   |

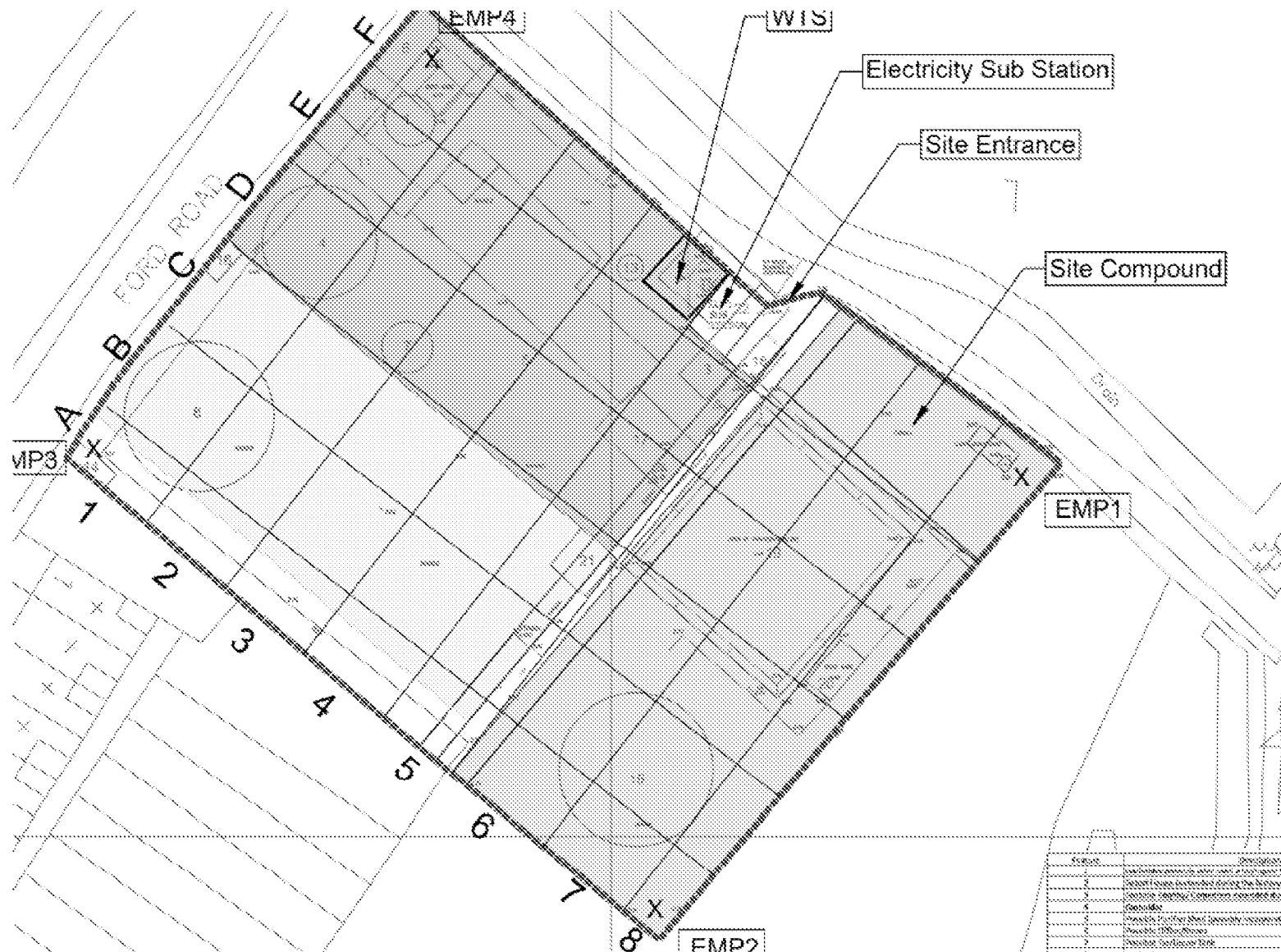


## FIGURE 3 HISTORICAL LAYOUT





## **FIGURE 4 REMEDIATION ZONES**



**Remediation Zones**  
(reproduced from Celtic  
remediation report)

**Client:** Oakford Homes

**Figure No:** 4

**Site:** Arundel Gas Works

**Job No:** 29780

**Scale:** N.T.S

**Source:** N/A



## FIGURE 5 VERIFICATION GRID



Verification Grid (reproduced  
from Celtic remediation report)

Client: Oakford Homes

Figure No: 5

Site: Arundel Gas Works

Job No: 29780

Scale: N.T.S

Source: N/A



## FIGURE 6 SPT 'N60' VERSUS DEPTH PLOT



## SPT 'N60' Values vs Depth

Site:

Former Arundel Gas Works

Client:

Oakford Homes

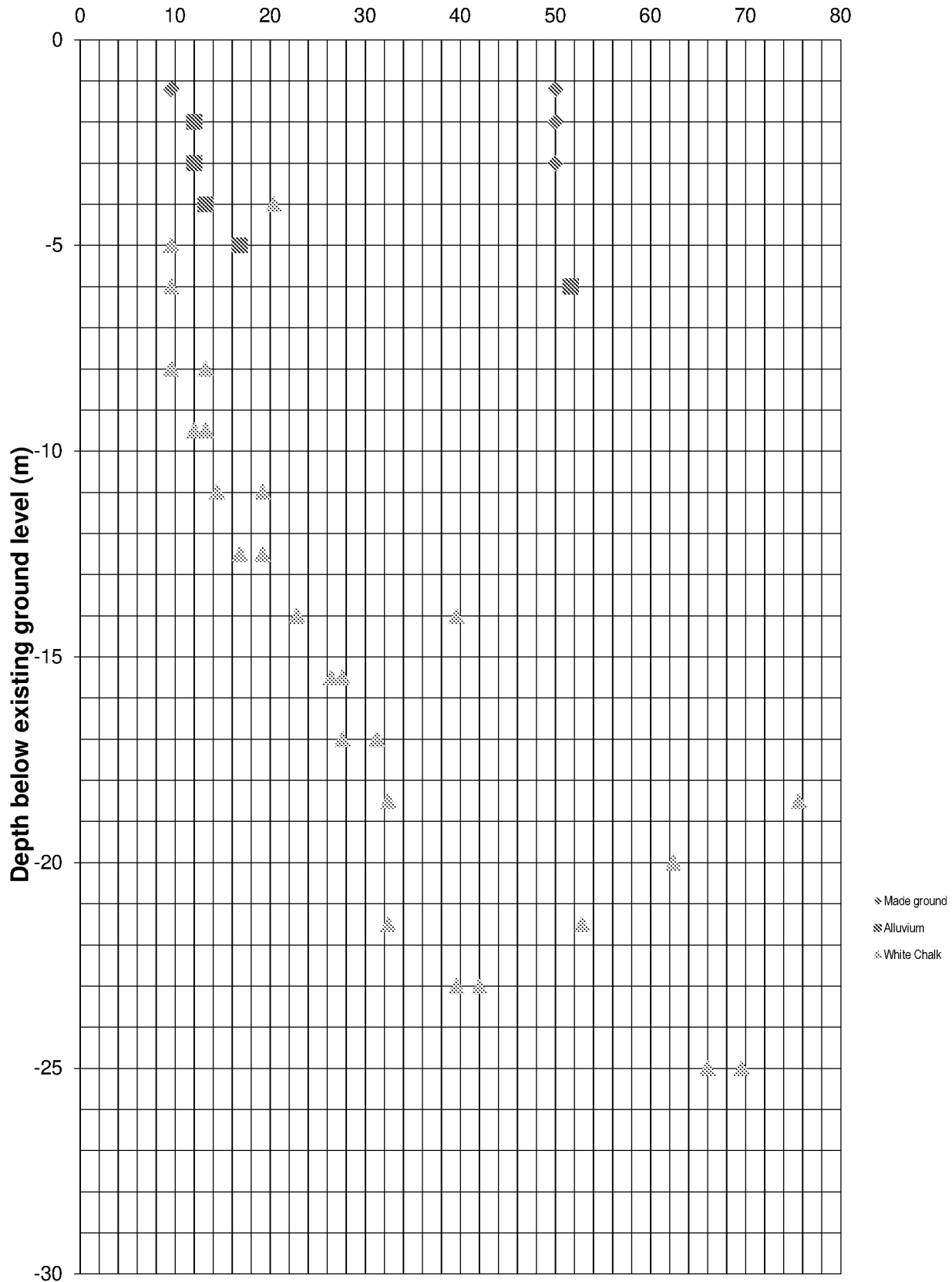
Job Number:

29780

Figure:

6

### SPT 'N60' Value (for 300mm penetration)



# APPENDICES

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## **APPENDIX A**

### **SERVICE CONSTRAINTS**

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1. This report and the site investigation carried out in connection with the report (together the "Services") were compiled and carried out by RSK Environment Limited (RSK) for Oakford Homes Limited (the "Client") in accordance with the terms of a contract between RSK and the Oakford Homes and Soilfix. The Services were performed by RSK with the reasonable skill and care ordinarily exercised by an environmental consultant at the time the Services were performed. Further, and in particular, the Services were performed by RSK taking into account the limits of the scope of works required by the client, the time scale involved and the resources, including financial and manpower resources, agreed between RSK and the Client.
2. Other than that, expressly contained in paragraph 1 above, RSK provides no other representation or warranty whether express or implied, in relation to the Services.
3. Unless otherwise agreed in writing, the Services were performed by RSK exclusively for the purposes of the Client. RSK is not aware of any interest of or reliance by any party other than the Client in or on the Services. Unless expressly provided in writing, RSK does not authorise, consent or condone any party other than the client relying upon the Services. Should this report or any part of this report, or otherwise details of the Services or any part of the Services be made known to any such party, and such party relies thereon that party does so wholly at its own and sole risk and RSK disclaims any liability to such parties. **Any such party would be well advised to seek independent advice from a competent environmental consultant and/or lawyer.**
4. It is RSK's understanding that this report is to be used for the purpose described in the introduction to the report. That purpose was a significant factor in determining the scope and level of the Services. Should the purpose for which the report is used, or the proposed use of the site change, this report may no longer be valid and any further use of or reliance upon the report in those circumstances by the client without RSK's review and advice shall be at the client's sole and own risk. Should RSK be requested to review the report after the date of this report, RSK shall be entitled to additional payment at the then existing rates or such other terms as agreed between RSK and the client.
5. The passage of time may result in changes in site conditions, regulatory or other legal provisions, technology or economic conditions which could render the report inaccurate or unreliable. The information and conclusions contained in this report should not be relied upon in the future without the written advice of RSK. In the absence of such written advice of RSK, reliance on the report in the future shall be at the Client's own and sole risk. Should RSK be requested to review the report in the future, RSK shall be entitled to additional payment at the then existing rate or such other terms as may be agreed between RSK and the client.
6. The observations and conclusions described in this report are based solely upon the Services which were provided pursuant to the agreement between the Client and RSK. RSK has not performed any observations, investigations, studies or testing not specifically set out or required by the contract between the client and RSK. RSK is not liable for the existence of any condition, the discovery of which would require performance of services not otherwise contained in the Services. For the avoidance of doubt, unless otherwise expressly referred to in the introduction to this report, RSK did not seek to evaluate the presence on or off site of asbestos, invasive plants, electromagnetic fields, lead paint, heavy metals, radon gas, persistent, bioaccumulative or toxic chemicals (including PFAS/ PFOS) or other radioactive or hazardous materials, unless specifically identified in the Services.
7. The Services are based upon RSK's observations of existing physical conditions at the Site gained from a visual inspection of the site together with RSK's interpretation of information, including documentation, obtained from third parties and from the Client on the history and usage of the site, unless specifically identified in the Services or accreditation system (such as UKAS ISO 17020:2012 clause 7.1.6):
  - a. The Services were based on information and/or analysis provided by independent testing and information services or laboratories upon which RSK was reasonably entitled to rely.

- b. The Services were limited by the accuracy of the information, including documentation, reviewed by RSK and the observations possible at the time of the visual inspection.
- c. The Services did not attempt to independently verify the accuracy or completeness of information, documentation or materials received from the client or third parties, including laboratories and information services, during the performance of the Services.

RSK is not liable for any inaccurate information or conclusions, the discovery of which inaccuracies required the doing of any act including the gathering of any information which was not reasonably available to RSK and including the doing of any independent investigation of the information provided to RSK save as otherwise provided in the terms of the contract between the Client and RSK.

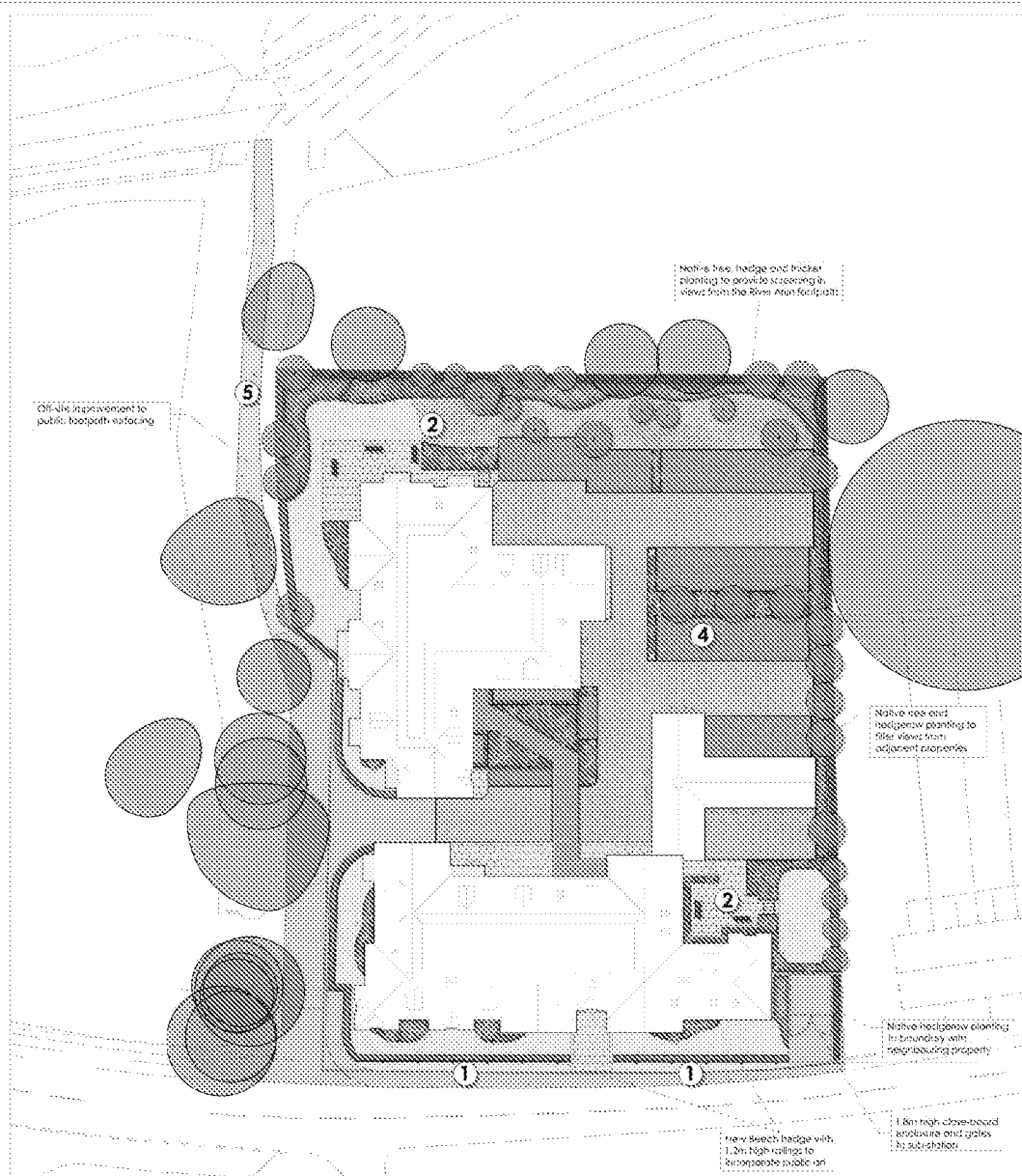
- 8. The intrusive environmental site investigation aspects of the Services are a limited sampling of the site at pre-determined locations based on the known historic / operational configuration of the site. The conclusions given in this report are based on information gathered at the specific test locations and can only be extrapolated to an undefined limited area around those locations. The extent of the limited area depends on the properties of the materials adjacent and local conditions, together with the position of any current structures and underground utilities and facilities, and natural and other activities on site. In addition, chemical analysis was carried out for a limited number of parameters (as stipulated in the scope between the client and RSK, based on an understanding of the available operational and historical information) and it should not be inferred that other chemical species are not present.
- 9. Any site drawing(s) provided in this report is (are) not meant to be an accurate base plan but is (are) used to present the general relative locations of features on, and surrounding, the site. Features (intrusive and sample locations etc) annotated on site plans are not drawn to scale but are centred over the approximate location. Such features should not be used for setting out and should be considered indicative only.
- 10. The comments given in this report and the opinions expressed are based on the ground conditions encountered during the site work and on the results of tests made in the field and in the laboratory. However, there may be conditions pertaining to the site that have not been disclosed by the investigation and therefore could not be taken into account. In particular, it should be noted that there may be areas of made ground not detected due to the limited nature of the investigation or the thickness and quality of made ground across the site may be variable. In addition, groundwater levels and ground gas concentrations and flows, may vary from those reported due to seasonal, or other, effects and the limitations stated in the data should be recognised.
- 11. Asbestos is often observed to be present in soils in discrete areas. Whilst asbestos-containing materials may have been locally encountered during the fieldworks or supporting laboratory analysis, the history of brownfield and demolition sites indicates that asbestos fibres may be present more widely in soils and aggregates, which could be encountered during more extensive ground works.
- 12. Unless stated otherwise, only preliminary geotechnical recommendations are presented in this report and these should be verified in a Geotechnical Design Report, once proposed construction and structural design proposals are confirmed.



## **APPENDIX B**

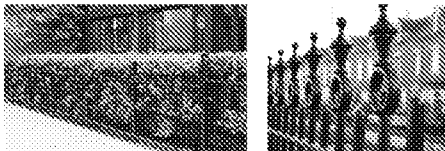
### **DEVELOPMENT DRAWINGS**

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### 1 Ford Road Boundary Treatment and Public Art

The boundary treating Ford Road will comprise black metal railings and a new native beech hedge row, to match the adjacent cemetery boundary. The railings will be 1.2m in height, with the potential to incorporate public art at the detailed design stage. The building will be set back from Ford Road in line with the pattern of adjacent properties.



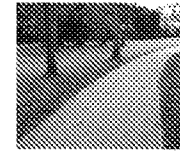
### 4 Car Parking

The parking area will be broken up with areas of ornamental shrub planting and a row of trees, softening the space. Low level board lighting to aid navigation towards the building entrances. High quality black paving will be used throughout the parking area.



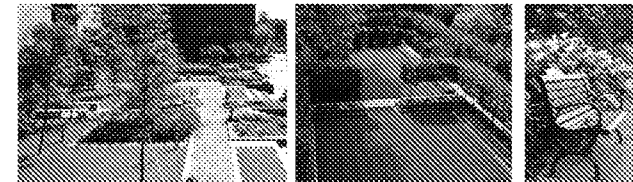
### 5 Public Footpath Improvement

The public footpath connecting Ford Road to the River Arun footpath will be upgraded as part of the application, with a new flagging surface and timber edging providing durable year round access to the river.



### 2 Communal Courtyards

Each of the apartment blocks will be served by a high quality communal courtyard. Both courtyards will make use of their south facing aspect and provide an attractive rest area for the new residents. Seating areas, set within attractive planted surroundings will be lit with low level lighting to provide year enjoyment. A combination of colourful herbaceous and structural shrub planting will also surround private amenity lawn areas.

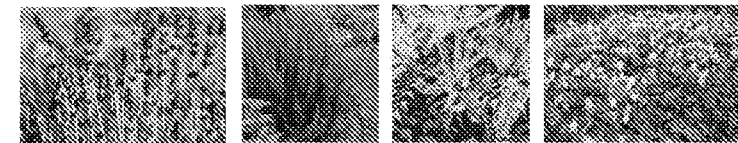


### 3 Soft Landscaping: Indicative Planting Schedule

A variety of planting across the Site will achieve a high quality landscape design and help to integrate the new development into the existing landscape framework. The proposed planting will reflect the character of the area and provide an attractive place to live. Formal, ornamental planting will be used within the communal open space, with more native species introduced within the car parking area and on the entrance to the Site. New trees, shrub planting and landscaping along the boundaries will help filter potential views of the new housing from the surrounding area. These areas will provide ecological benefits as well as creating an attractive landscape. Proposed planting will be easy to maintain and complement the setting of the new residential development.

Below is a suggested planting list for the soft landscaping:

| Latin Name                                 | Common Name                      |
|--------------------------------------------|----------------------------------|
| <b>Tree Planting</b>                       |                                  |
| <i>Betula pendula</i>                      | Silver Birch                     |
| <i>Prunus avium</i> 'Plend'                | Double Cherry                    |
| <b>Hedge Planting</b>                      |                                  |
| <i>Fagus sylvatica</i>                     | Common Beech                     |
| <b>Native Hedgerow Mix</b>                 |                                  |
| <i>Acer campestre</i>                      | Hedge Maple                      |
| <i>Corylus avellana</i>                    | Hazelnut                         |
| <i>Crataegus monogyna</i>                  | Quetsch                          |
| <i>Crataegus latifolia</i>                 | Hornbeam                         |
| <i>Eucalyptus europaeus</i>                | Common Spindle                   |
| <i>Ilex aquifolium</i>                     | Holly                            |
| <i>Malus sylvestris</i>                    | Crab Apple                       |
| <i>Prunus spinosa</i>                      | Blackthorn                       |
| <i>Rhamnus cathartica</i>                  | Blackthorn                       |
| <i>Viburnum lentum</i>                     | Wayfaring                        |
| <i>Viburnum opulus</i>                     | Guelder Rose                     |
| <b>Shrubs</b>                              |                                  |
| <i>Chamaecyparis 'Sunkist'</i>             | Medican Orange                   |
| <i>Hebe 'Midsummer Beauty'</i>             | Shrubby Veronica                 |
| <i>Lavandula angustifolia</i> 'Hidcote'    | English Lavender 'Hidcote'       |
| <i>Mahonia media</i> 'Winter Sun'          | Oregon Grape 'Winter Sun'        |
| <i>Rosa rugosa</i> 'Miss Jessop's upright' | Rosemary 'Miss Jessop's upright' |
| <b>Herbaceous</b>                          |                                  |
| <i>Geranium macranthum</i> 'White Ness'    | Geranium 'White Ness'            |
| <i>Red valerian</i> 'Goldcrest'            | Red valerian 'Goldcrest'         |
| <i>Veronica perfoliata</i>                 | Veronica 'Veronica'              |
| <i>Stachys byzantina</i>                   | Lamb's Ear                       |
| <b>Specimen Shrubs/Groves</b>              |                                  |
| <i>Prunella laevis</i>                     | New Zealand Box                  |
| <i>Box coccinea</i> 'Dark Green'           | Box-leaved Holly                 |
| <i>Calluna vulgaris</i> 'Overdam'          | Feather Bedded-grass 'Overdam'   |



#### LEGEND

APPLICATION BOUNDARY

EXISTING FERRY ROAD

Softscape

FORMAL TREE PLANTING

FORMAL HEDGE PLANTING

NATIVE HEDGE PLANTING

ORNAMENTAL HEDGE PLANTING

FORMAL MIX

FORMAL SHRUB PLANTING

FORMAL MIX

FORMAL MIX

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