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PROJECT NAME

ANSFORD, CASTLE CARY

REPORT

GEO-ENVIRONMENTAL ASSESSMENT & GEOTECHNICAL DESIGN REPORT (GIR)

CLIENT

ANDREW HOPKINS

REFERENCE NO

RP7003-GIR

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EXECUTIVE SUMMARY

Commission & Objectives	Red Rock Geoscience Ltd ('Red Rock') was commissioned by JRC Consulting, acting on behalf of Andrew Hopkins, to undertake an intrusive ground investigation for the proposed residential housing development site at Ansford, Castle Cary. The geo-environmental objectives of this assessment were to identify the site's historical land use, potential resulting contamination and associated risks, prior to more detailed intrusive investigations and determination of possible remediation requirements in order to enable the safe development of the site. The geotechnical objectives of this investigation were to determine the distribution, nature and engineering properties of the soils underlying the site to assist with the design of foundations to the proposed residential properties, road pavements and soakaway drainage. It should be noted that this investigation is focused towards the proposed developments at the site and may need to be re-assessed should the development proposals be revised.

Geotechnical Findings & Recommendations	
Ground Conditions Encountered	Near surface ground conditions generally comprise Topsoil, localised Made Ground, cohesive Head Deposits, cohesive Residual Soil and Langport Member, Blue Lias Formation and Charmouth Mudstone Formation (Undifferentiated).
Foundation Design	In general, the cohesive soils encountered below the Made Ground and soft Topsoil will be suitable for the construction of traditional strip or shallow trench fill foundations for the proposed development. To have a consistent design, such foundations should be designed on the basis of a net safe bearing capacity of 100kN/m2 to cater for the variability in the shear strength of the underlying soils.
Floor Design	As a result of the near-surface cohesive soils with a medium to high volume change potential, it is recommended that a fully suspended floor construction be used. The minimum sub-floor void dimension should be 150mm (suspended cast insitu concrete ground floor) or 300mm (pre-cast concrete floor, including 150mm ventilation allowance) in accordance with tables 9 and 10 of NHBC Chapter 4.2.
Buried Concrete Design Sulphate Class	Laboratory sulphate analyses undertaken on soil samples indicate that buried concrete can be design in accordance with design sulphate class DS-3 ACEC class of AC-2s of BRE Special Digest 1 (2005).
Soakaway Drainage Potential	The insitu soakaway tests were abandoned due to very slow rates of infiltration. This relatively slow rate of percolation, together with the typical high groundwater table, indicates that soakaways are unlikely to form an effective method for surface water drainage for this site.

Geo-Environmental Findings & Recommendations	
Assessment of geo-environmental test Results	A total of 8 no. samples were tested for standard metals and metalloids. No results recorded values above the generic guideline values. A total of 8 no. samples were tested for speciated polycyclic aromatic hydrocarbons (PAHs). No results recorded values above the generic guideline values. A total of 2 no. samples were tested for total petroleum hydrocarbons (TPHs). No results recorded values above the generic guideline values.

Geo-Environmental Findings & Recommendations	
Human Health Risk Assessment	Significant levels of contamination are unlikely on this site. No visual signs of vegetation distress or any indication that soils may be toxic to Fauna or Flora. Any impact to vegetation would be localised in nature. Presence of contamination in concentrations likely to pose a risk to water resources not expected. Contaminant percolation, leaching, and migration unlikely to be extensive in view of the underlying geology. Contamination unlikely to be extensive or in concentrations likely to pose a risk to future concrete structures or pipework. No Radon Protection or ground gas assessment required on site.
Unidentified Contamination	Regular inspections should be carried out by ground workers during any excavation work, and advice should be sought in the event that unexpected ground conditions are encountered. Should any visual or olfactory signs of contamination be found during construction works, soils should be tested and assessed. Should further testing and assessment identify areas of unacceptable risk, appropriate remedial measures would need to be implemented. A detailed remediation strategy should be prepared, any remedial works and associated clean-up levels would need to be discussed with and approved by the Regulatory Authorities. Additionally, a Validation Statement would need to be prepared upon completion of any remedial works, detailing the works undertaken and the results of the associated validation testing.

Recommended Further Work
Once layout plans and building levels have been finalized, assessment of the foundation requirements and depths will need to be considered on a plot by plot basis, and further ground investigations are recommended.

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

1 INTRODUCTION

1.1 Commission

Red Rock Geoscience Ltd ('Red Rock') was commissioned by JRC Consulting, acting on behalf of Andrew Hopkins, to undertake an intrusive ground investigation for the proposed residential housing development site at Ansford, Castle Cary.

A factual and interpretative report was required on the investigation.

1.2 Development Proposals

The development proposals comprise residential properties with associated gardens, public open space, garages and access roads.

An outline of the proposals are shown on the Exploratory Hole Location Plan, enclosed in Appendix A.

1.3 Objectives

The geo-environmental objectives of this assessment were to identify the site's historical land use, potential resulting contamination and associated risks, prior to more detailed intrusive investigations and determination of possible remediation requirements in order to enable the safe development of the site.

The geotechnical objectives of this investigation were to determine the distribution, nature and engineering properties of the soils underlying the site to assist with the design of foundations to the proposed residential properties, road pavements and soakaway drainage.

It should be noted that this investigation is focused towards the proposed developments at the site and may need to be re-assessed should the development proposals be revised.

Reference should be made to the 'General Notes and Limitations' included in Appendix I at the end of this report, which provide information on the procedures followed in the investigation and data assessment, and explains the context within which this report should be read.

The current report was developed on the basis of the various current publications by UK policy makers, in particular the NHBC Standards[1] and model procedures by DEFRA[2].

The geo-environmental sections of this report only address potential ground contamination issues and do not include issues pertaining to ecology, habitat, or wider environmental concerns. Appropriate professionals with expertise in these areas should be consulted.

1.4 Site Location and Description

The site is located in Ansford, Castle Cary, and is centred on National Grid Reference 363476, 133308. The site is formed of two irregularly shaped fields of different sizes, and is approximately 9.63 Ha in total. The site dips gently from east to west.

The site area is mostly bounded by hedgerows and mature trees, as well as infrastructure including Ansford Hill Road (southern border), Station Road (western border) and Castle Cary Train Station (northern border).

[1] NHBC, 2019, Standards.

[2] Department of Environment, Food and Rural Affairs (DEFRA) & Environment Agency, 2004, Contaminated Land Report 11 Model Procedures for the Management of Contamination.

The site is bordered by residential housing and gardens to the west and south-east, to the south by housing developments and agricultural land and to the north and east by additional agricultural grassy fields.

1.5 Published Geological Information

Published geological information from the British Geological Survey (1:50,000 scale Solid Geological Map) indicates that the solid geology beneath the site comprises the Lias Group, the Dyrham Formation and Marlstone Rock Formation (undifferentiated) of Jurassic and Triassic geological age. The Dyrham Formation and Marlstone Rock Formation typically comprise siltstone. The Lias Group typically comprises interbedded limestone and mudstone.

Although not shown on the geological maps, this solid geology would typically be overlain by a mantle of Residual Soil derived from the insitu weathering of the underlying bedrock.

Superficial deposits of River Terrace Deposits (undifferentiated) are shown to be in close proximity to the site associated with the River Brue.

1.6 Summary of the Findings of the Geo-environmental Desk Study

The review of the historic maps indicates that the site comprises undeveloped open fields from at least the 1890s. The layouts of the hedges have changed over the years and farm buildings (Hillcrest Farm) have developed on the southern boundary during the 1930s.

The land surrounding the site was originally open fields and the town of Ansford from at least the 1880s. Throughout the 1900s, Ansford and Castle Cary underwent gradual expansion, with residential areas eventually surrounding the site to the south-east. Infrastructure was also advanced to support the expansion, including the development of many roads, bridges and railway lines. The surrounding area has also encompassed churches, schools and residential housing located within 500m from the site boundary. There are no active or historical trade entries likely to have impacted the site.

Based on an assessment of the Desk Study Data significant contamination on the site is unlikely to be present however localized contamination resulting from the sites historic agricultural may be possible. Localised hydrocarbon contamination may be present due to the historical and current use of farm vehicles on the site area. Asbestos containing materials (ACMs) may be present within the buildings present on site and a survey may be prudent prior to demolition.

The varied bedrock underlying the site is classified as ‘Secondary A Aquifer’ and ‘Secondary B Aquifer’ in accordance with the new Environment Agency designations for aquifer classification. Secondary A Aquifers are comprised of 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. These are generally aquifers formerly classified as Minor Aquifers. Secondary B Aquifers are comprised of predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering. These are generally the water-bearing parts of the former non-aquifers.

No Radon Protection or ground gas assessment required on site.

2 FIELDWORK

2.1 Methodology

The investigation comprised:

- 15 no. trial pits used to identify the underlying strata to aid foundation design (TP01 – TP13)
- 4 no. trial pits used for soakaway testing in accordance with BRE 365[3] (SA01 – SA04)
- 10 no. DCP (Dynamic Cone Penetration) Tests (DCP01 – DCP10)

The ground investigation fieldwork was undertaken in general accordance with BS 5930 (2015)[4]. Samples collected were typically classed a Category 'C' in accordance with BSI (2007)[5], and assessment of strength and consistency were undertaken using traditional field techniques as described in BSI (2002)[6]. Soils have been logged, generally in accordance with BSI (2004)[7]. Where relevant, the bedrock was logged in accordance with BSI (2003)[8].

The locations of the exploratory holes are shown on the Exploratory Hole Location Plan, enclosed as Appendix A.

The fieldwork was undertaken on the 11th and 12th of February 2019 and was supervised full-time by an engineering geologist.

2.2 Trial Pits

13 trial pits were excavated using a JCB 3CX hydraulic excavator to depths of between 2.2 and 3.2m below existing ground level to provide information on both the geotechnical and geo-environmental conditions. The trial pits were positioned by Red Rock in relation to development layouts.

The profiles of strata, or other features, were recorded as excavation proceeded and measurements taken from ground level. Trial pits were entered where safe to do so to allow logging, in-situ testing and sampling. Subsoil samples were taken where appropriate for subsequent laboratory examination and analyses.

Trial Pit Records are enclosed in Appendix B, and in addition to detailed strata descriptions give information on any groundwater, stability and samples recovered.

On completion, the trial pits were backfilled with arisings.

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3 Building Research Establishment. (2007). *Digest 365: Soakaway design*. London: Building Research Establishment.
4 British Standards Institute. (2015). BS 5930 with Addendum 2: Code of practice for site investigations. London: BSI.
5 British Standards Institute. (2007). BS EN 1997-2: Eurocode 7 – Geotechnical design. Part 2 Ground investigation and testing. London: BSI.
6 British Standards Institute. (2002). BS EN ISO 14688-1:2002. Geotechnical investigation and testing – Identification and classification of soil – Part 1: Identification and description: London BSI
7 British Standards Institute (2004). BS EN ISO14688-2:2004. Geotechnical investigation and testing – Identification and classification of soil – Part 2: Principles for a classification. London: BSI
8 British Standards Institute. (2003). BS EN ISO 14689-1: Geotechnical investigation and testing – Identification and classification of rock – Part 1: Identification and description. London: BSI

2.3 Insitu DCP (Dynamic Cone Penetration) Testing

10 insitu dynamic cone penetration (DCP) tests were undertaken using the TRL apparatus to provide a continuous insitu measurement of the estimated strength of the soils beneath areas of proposed road pavement. This apparatus conforms to that described in TRL Project Report PR/INT/277/04 and the values obtained can be equated to equivalent estimated CBR value using the approach described in Advice Note 73/06 Revision 1 (2009) 'Design Guidance for Road Pavement Foundations (Draft HD25)'. The results of the DCP tests are presented in both tabular and graphical form in Appendix D.

2.4 Insitu Soakaway Testing

4 insitu soakaway percolation tests were undertaken in trial pits SA01 to SA04 in general accordance with the procedures detailed in BRE 365. The positions of the soakaway trial pits were located by Red Rock in relation to development layouts.

During the fieldwork, the soakaway tests (SA01 – SA04) were abandoned due to extremely slow infiltration rates. Water levels in these test pits did not reduced and stayed at the water level they commenced at across a period of between 170 - 220 minutes.

The results of the soakaway tests are enclosed in Appendix C.

3 LABORATORY TESTING

3.1 Geotechnical Laboratory Testing

The following geotechnical laboratory tests were undertaken on selected samples obtained during the site investigation:

Table 3.1: Geotechnical Laboratory Testing	
Test	**Number of Samples**
Moisture Content	5
Liquid and Plastic (Atterberg) Limits	5
pH, total sulphate, soluble sulphate and total sulphur (BRE SD1 Suite) - Soils	5

Laboratory testing was undertaken, where appropriate, in accordance with BS1377 (BSI, 1990) and test results are enclosed as Appendix E. All testing was undertaken in UKAS accredited laboratories.

3.2 Contamination Laboratory Testing

On the basis of the past site usage and observations during the intrusive investigations, the following chemical testing was undertaken on selected near surface soil samples.

Table 3.2: Geo-environmental Laboratory Testing - Soils	
Test	**Number of Samples**
Metal & metalloid suite: arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium and zinc and pH	8
Speciated Polycyclic Aromatic Hydrocarbons	8
Total Petroleum Hydrocarbons (3-Band Speciation)	2
Organic Matter	8

The geo-environmental Laboratory test results are enclosed as Appendix F.

4 GROUND CONDITIONS ENCOUNTERED

4.1 Strata Encountered

The strata sequence encountered in the exploratory holes were in general agreement with that expected based on the published information, and are summarised in the table below:

Table 4.1: Summary Table of Strata Encountered

Stratum	SA01	SA02	SA03	SA04	TP01
Topsoil	0.0 – 0.3	0.0 – 0.3	0.0 – 0.3	0.0 – 0.3	0.0 – 0.3
Head Deposits	0.3 – 1.6	0.3 – 1.2	0.3 – 1.0	0.3 – 1.1	0.3 – 1.2
Residual Soil	1.6 – 2.6	1.2 – 2.8	1.0 – 2.3	1.1 – 2.6	1.2 – 2.4
Langport Member, Blue Lias Formation and Charmouth Mudstone Formation (Undifferentiated)	–	–	2.3 – 2.7	–	2.4 – 2.5
Stratum	**TP02**	**TP03**	**TP04**	**TP05**	**TP06**
Topsoil	0.0 – 0.3	0.0 – 0.2	0.0 – 0.3	0.0 – 0.3	0.0 – 0.3
Head Deposits	0.3 – 1.2	0.2 – 0.9	0.3 – 1.1	0.3 – 1.5	0.3 – 1.8
Residual Soil	1.2 – 2.3	0.9 – 2.2	1.1 – 2.3	1.5 – 2.9	1.8 – 3.0
Langport Member, Blue Lias Formation and Charmouth Mudstone Formation (Undifferentiated)	2.3 – 2.6	2.2 – 2.8	2.3 – 2.6	–	–
Stratum	**TP07**	**TP08**	**TP09**	**TP10**	**TP11**
Topsoil	0.0 – 0.3	0.0 – 0.3	0.0 – 0.3	0.0 – 0.3	0.0 – 0.3
Head Deposits	0.3 – 1.5	0.3 – 0.7	0.3 – 1.7	0.3 – 1.6	0.3 – 1.2
Residual Soil	1.5 – 2.0	0.7 – 2.4	1.7 – 2.6	1.6 – 2.9	1.2 – 2.3
Langport Member, Blue Lias Formation and Charmouth Mudstone Formation (Undifferentiated)	2.0 – 2.4	2.4 – 2.5	–	2.9 – 3.2	2.3 – 2.6
Stratum	**TP12**	**TP13**	**TP14**	**TP15**	
Topsoil	0.0 – 0.3	0.0 – 0.1	0.0 – 0.3	0.0 – 0.3	
Made Ground	–	0.1 – 0.4	–	–	
Head Deposits	0.3 – 1.2	0.4 – 1.9	0.3 – 1.4	0.3 – 1.1	
Residual Soil	1.2 – 2.6	1.9 – 2.6	1.4 – 3.0	1.1 – 2.2	

Topsoil

Material interpreted as Topsoil was encountered in all of the trial pit locations, to depths of between 0.1 and 0.3m. These materials typically comprised soft dark brown slightly sandy clay with occasional roots and rootlets.

Made Ground

Material interpreted as Made Ground was encountered in TP13, to depths of 0.4m. These materials typically comprised soft light yellowish brown to dark brown silty clay and slightly sandy clay, which included wore fragments of rubber and a neoprene rubber gasket.

Head Deposits

Material interpreted as Head Deposits was encountered in all of the trial pit locations, to depths of between 0.3 and 1.9m. These materials typically comprised firm to stiff light brownish grey silty clay, with extremely close fissures and occasional medium sized gravel fragments of subangular mudstone. The material also contained occasional shear surfaces/ slickensides.

Slickenside/shear surfaces are smooth surfaces caused by frictional movement along two planes. The presences of these surfaces are an indication of previous land slipped material. These surfaces were noted to depths of between 0.5m and 1.6m in trial pits TP07, TP09 and TP12. The observed shear surfaces were not continuous and therefore were not considered to be one unique shear surface controlling the stability of the site.

The material interpreted as Head Deposits also occasionally consisted of stiff light orangish brown slightly gravelly sandy clay; where the gravel is fine to medium grained subangular mudstone.

Insitu shear vane tests recorded undrained shear strength values between 53 and 100 kPa (Average 69.75 kPa) indicating the stratum to having medium undrained shear strength.

The index property test results obtained on samples of this sub-stratum gave natural moisture content (NMC) values of between 29% and 30%, and Plasticity Index values of between 40% and 44%. These results classify the soils as high to very high plasticity clay on the Casagrande classification system. In each case, the NMC is similar than the respective Plastic Limit, indicative of material with a plastic consistency. After correcting the Plasticity Index values for the 'stone' content (material >0.425mm), the samples tested have modified plasticity index values of between 40% and 44% indicating them to have a high volume change potential in accordance with the criterion NHBC Chapter 4.2[9].

Residual Soil

Material interpreted as Residual Soil was encountered in all of the trial pit locations, to depths of between 0.7 and 3.0m. These materials typically comprised firm to stiff light blueish grey silty clay, with extremely close fissures and light brown silt infill. The material also contained occasional fine to coarse grain sized gypsum crystals.

This material also occasionally consisted of dense dark bluish grey clayey sandy gravel; where the gravel is fine to medium grained subangular mudstone. This material was found in layers within TP10 and in small cobble sized pockets throughout the Residual Soil within the western side of the site area.

Insitu shear vane tests recorded undrained shear strength values between 60 and 90 kPa (Average 82.5 kPa) indicating the stratum to having high undrained shear strength.

The index property test results obtained on samples of this sub-stratum gave natural moisture content (NMC) values of between 24% and 26%, and Plasticity Index values of between 20% and 26%. These results classify the soils as intermediate to high plasticity clay on the Casagrande classification system. In each case, the NMC is similar than the respective Plastic Limit, indicative of material with a plastic consistency. After correcting

[9] NHBC. (2019). Standards. Amersham: NHBC

the Plasticity Index values for the 'stone' content (material >0.425mm), the samples tested have modified plasticity index values of between 20% and 26% indicating them to have a medium volume change potential in accordance with the criterion NHBC Chapter 4.2[10].

Langport Member, Blue Lias Formation and Charmouth Mudstone Formation (Undifferentiated)

Material interpreted as Langport Member, Blue Lias Formation and Charmouth Mudstone Formation (Undifferentiated) was encountered in the majority of trial pit locations, to depths of between 2.2 and 3.2m. This stratum typically comprised extremely weak light blueish grey mudstone. The mudstone is thinly bedded and extremely closely fractured. Occasional iron staining and silt infill present on the fracture surfaces.

4.2 Signs of Contamination

Although Made Ground was encountered in TP13, there was no visual or olfactory evidence of contamination noted.

4.3 Groundwater

Groundwater was encountered in the exploratory holes as summarized in the following table:

Table 4.3: Summary of Groundwater Strikes in Exploratory Holes

Exploratory Hole	Depth Water Encountered (mbgl)	Comment(s)
SA01	1.60	Seepage
TP10	1.80	Seepage
TP03	1.40	Seepage
TP06	2.70	Seepage

10 NHBC. (2019). Standards. Amersham: NHBC

5 GEOTECHNICAL ASSESSMENT

5.1 Ground Conditions Summary

Near surface ground conditions generally comprise Topsoil, localised Made Ground, cohesive Head Deposits, cohesive Residual Soil and Langport Member, Blue Lias Formation and Charmouth Mudstone Formation (Undifferentiated).

5.2 Foundation Design

In general, the cohesive soils encountered below the Made Ground and soft Topsoil will be suitable for the construction of traditional strip or shallow trench fill foundations for the proposed development. To have a consistent design, such foundations should be designed on the basis of a net safe bearing capacity of 100kN/m^2 to cater for the variability in the shear strength of the underlying soils.

Plasticity Index testing has shown that the clay soils have an medium to high volume change potential in accordance with NHBC Chapter 4.2. Therefore, outside the zone of influence of existing, proposed or recently removed trees, foundations should be placed a depth of at least 1.0m to prevent problems associated with shrinkage and swelling (allowing for geographical climate zone correction).

Evidence of ancient land-slipping in the form of residual shear surfaces was noted in some of the trial pits. The maximum observed depths of these shear surfaces in the trial pits was 1.7m (TP09). Although shear surfaces were noted in these pits, similar features must be expected elsewhere where the same geological stratum (Head Deposits) exists. The shear surfaces, where seen, were not continuous and there is not considered to be one unique shear surface controlling the stability of the site. However, there is theoretically potential for re-activation of ancient land slipping along these pre-existing shear surfaces if foundation loads are imposed above the level of the basal surfaces, and if there is continuity down slope of such surfaces. Although, as discussed, the latter is not considered likely, the potential consequences of these shear surfaces must not be discounted. Consequently, all foundations should be taken through any pre-existing shear surfaces in the Head Deposits and into the underlying Residual Soil stratum.

Foundations should be placed at a depth of at least 250mm below any Made Ground or 150mm below relic shear zone (whichever is the greater depth). Based on these criteria, the following foundation depths are indicated by the exploratory hole data.

Table 5.1: Minimum Foundation Depths Indicated by Exploratory Holes

Exploratory Hole	Foundation Depth (mbgl)	Factor Governing Foundation Depth
SA01 – TP03	≥1.00m	Minimum depth for shrinkable clay soils
TP04 – TP06	≥1.00m	Minimum depth for shrinkable clay soils
TP07	≥1.00m	Minimum depth for shrinkable clay soils and 150mm below relic shear zone
TP08	≥1.00m	Minimum depth for shrinkable clay soils
TP09	≥1.75m	150mm below relic shear zone.
TP10 – TP11	≥1.00m	Minimum depth for shrinkable clay soils
TP12	≥1.25m	150mm below relic shear zone.
TP13 – TP15	≥1.00m	Minimum depth for shrinkable clay soils

Foundations within the zone of influence of such trees should be locally deepened in accordance with the requirements of NHBC Chapter 4.2, or until granular (non-shrinkable) soil is encountered.

Any foundations for external walls that are sufficiently close to existing trees (that are to remain or be removed) such that the foundation depth indicated by NHBC Chapter 4.2 is greater than 1.5m, should incorporate precautions against potential heave in accordance with Sitework Clause 4.2-S4 of the NHBC guidance.

To allow for the variability in the nature and/or stiffness of the soils at and directly below proposed strip foundation level, it is recommended that they be appropriately reinforced to accommodate potential differential settlement.

5.3 Floor Design

As a result of the near-surface cohesive soils with a medium to high volume change potential, it is recommended that a fully suspended floor construction be used. The minimum sub-floor void dimension should be 150mm (suspended cast insitu concrete ground floor) or 300mm (pre-cast concrete floor, including 150mm ventilation allowance) in accordance with tables 9 and 10 of NHBC Chapter 4.2.

5.4 Retaining Wall Design

Due to the sloping nature of the site, the development proposals may need to include the construction of retaining walls.

As discussed above, evidence of ancient land-slipping in the form of residual shear surfaces was noted in the Head Deposits stratum in some of the trial pits, with shear surfaces observed to depths of 1.6m. Although shear surfaces were noted in these pits, similar features must be expected elsewhere where the same geological stratum (Head Deposits) exists. Although the observed shear surfaces were not continuous and there is not considered to be one unique shear surface controlling the stability of the site, their localised presence could have a critically significant effect on the stability of any retaining structure. Consequently, unless the strata to be retained by a particular structure is proven to not contain any pre-existing shear surfaces, it is recommended that residual shear strength parameters be used for the Head Deposits stratum in the design.

When the location and retained height of any retaining structures within the development layout has been finalised, additional trial pitting investigations could be undertaken at the location of each structure to confirm the depth (or absence) of any shear surfaces, which would identify any retaining structures that can be designed on the basis of peak rather than residual shear strength parameters.

The ground investigation indicates that groundwater is likely to be encountered at relatively shallow depth across the site between 1.4m and 2.7m below existing ground levels. Therefore, appropriate drainage may need to be incorporated into the slope, or the wall will need to be designed to accommodate an appropriate groundwater level behind.

If a gravity wall is to be founded on shrinkable clays and located within the zone of influence of existing, proposed or recently removed trees, the foundations will need to be locally deepened in accordance with the requirements of NHBC Chapter 4.2.

5.5 Foundation Excavation Considerations

Groundwater was encountered at relatively shallow depth across the site in the exploratory holes, at depths of between 1.4m and 2.7m. Based on these observations, groundwater is likely to be encountered in excavations below a typical depth of 1.8m and will require dewatering. Based on the nature of the materials present, it is anticipated that simple sump pumping will be sufficient to deal with any ground water ingress into trenches and other small excavations to around 1.8m depth. However, the depth to groundwater can vary both spatially across the site and in response to seasonal fluctuations, and it is recommended that groundwater control be undertaken in accordance with the guidance given in CIRIA Report C515 (2000)[11].

The trial pits indicate that foundation excavations are likely to be generally stable. However, all excavations should be monitored and, if necessary, supported in accordance with appropriate guidance such as CIRIA Report 97 (1992).

5.6 Buried Concrete Design Sulphate Class

Laboratory sulphate analyses undertaken on soil samples indicate that buried concrete can be design in accordance with design sulphate class DS-3 ACEC class of AC-2s of BRE Special Digest 1 (2005).

5.7 Road Pavement Design

The development proposal includes the construction of estate roads and car-parking areas.

The likely Subgrade soils will comprise firm to stiff light brownish grey to light blueish grey silty clay. Atterberg Limit tests on these soils indicate them to have a Plasticity Index of between 20% and 44%.

On the basis of these criteria, Highways Agency Interim Advice Note (IAN 73/06) (Draft HD 25, 2009) recommends a long-term (equilibrium moisture content) design CBR value of 2.5% on the presumption that the Subgrade is protected by adequate site drainage (including during construction) and is promptly covered with a capping layer or sub-base.

The insitu DCP tests undertaken on areas of proposed highway pavement produced lower bound CBR values of between 2.0% and 4.0%. Consideration of these test values suggests a construction phase design CBR value of 2.0% is applicable.

On the basis of the above design values, the road pavement design is governed by the construction phase/Permanent Works condition and an overall design CBR value of 2.0% is therefore recommended.

The likely Subgrade soils will be susceptible to appreciable deterioration (softening) if allowed to become saturated (particularly if trafficked), with a consequential reduction in both construction phase and Permanent Works CBR value. Therefore, the formation should be prevented from being exposed to heavy rainfall and be adequately drained through all construction phases.

Because the Subgrade soils comprise a clay/silt material, it is recommended that an appropriate separation geotextile be placed on the formation to prevent potential subsequent deterioration of the basal capping / sub-base layers via impregnation of 'fines' during initial pavement construction layers and/or fluctuations in groundwater level.

The Subgrade soils are likely to be frost susceptible. Consequently, based on TRL Research Report 45 (1986)[12],in this geographical area the total pavement construction thickness should comprise at least 450mm of non-frost susceptible materials to prevent problems of frost heave. However, based on the CBR design value the construction thickness required for structural reasons is likely to provide sufficient cover.

If any roads are to be adopted by the Local Authority, it is recommended the pavement design criteria be agreed with them prior to the commencement of construction. To this end, the adopting authority may insist

11 Preene, M., Roberts, T.O.L., Powrie, W. and Dyer, M.R., (2000). Groundwater Control: Design and Practice. C515. London: CIRIA.

12 Sherwood, P.T. and Roe, P.G., (1986). Winter air temperatures in relation to frost damage to roads. TRRL Research Report 45. Berkshire: Department of Transport.

that they conduct their own supplementary investigation to satisfy themselves of the engineering characteristics of the subgrade soils.

For any road pavement construction, the Formation should be carefully inspected and (if necessary) tested to identify any localized weaker areas with a CBR value lower than the design value. Any such areas should be excavated out and replaced with capping material or Class C10 concrete.

5.8 Soakaway Drainage Potential

The insitu soakaway tests were abandoned due to very slow rates of infiltration. This relatively slow rate of percolation, together with the typical high groundwater table, indicates that soakaways are unlikely to form an effective method for surface water drainage for this site.

It should be noted that the infiltration characteristics of soils can be variable both spatially across the site and with depth below ground level. Similarly, the depth to groundwater (and presence of perched groundwater) can also vary both spatially across the site and in response to seasonal fluctuations. Provided the locations of the tests undertaken coincide with the anticipated locations and levels of proposed soakaways, and worst case seasonal groundwater levels do not vary significantly from those encountered in this investigation, these infiltration parameters are applicable for detailed soakaway design.

6 GEO-ENVIRONMENTAL ASSESSMENT

6.1 Assessment of Geo-environmental Results

Generic Assessment Criteria for Human Health

The Contaminated Land Exposure Assessment (CLEA) model enables the derivation of site-specific assessment criteria for contaminants present on a site. The most recent model (CLEA v1.07) was released in September 2009 together with guidance documents including toxicological reports for selected contaminants and standard land use scenarios. In addition, Land Quality Management (LQM) in association with Chartered Institute of Environmental Health (CIEH) published in 2009 Generic Assessment Criteria (GAC) values for a number of other contaminants not included in the EA publication. The 2009 generic assessment criteria values have been revised in 2015 and published as 'Suitable For Use Levels' (S4ULs) which have been utilised in this report for assessment of contaminant levels. In addition, guideline values for use in Part IIA determinations ('Category 4 screening Levels' – C4SLs) were also published in 2014 by DEFRA which included lead. In the absence of a lead S4UL, the C4SL for lead was utilised.

Development proposals comprise residential properties with gardens, open areas, garages and associated access roads. Therefore, the site is being considered under a scenario of Residential with Plant Uptake. The human health generic assessment criteria guideline values used in this assessment are enclosed in Appendix G.

Laboratory contamination results are included as Appendix F. The results are summarised, and where appropriate, discussed in further detail below.

Metals and Metalloids

A total of 8 (1no of samples of Made ground and 7no of samples of natural ground) were tested for standard metals and metalloids.

Table 6.1: Assessment of Results – Metals & Metalloids

Determinant	Human Health Criteria	Recorded Range	No. of Results Elevated above criteria Values
Arsenic	37.00	8.2 – 11	0
Cadmium	10.00	< 0.2	0
Chromium III	910.00	38 – 49	0
Chromium VI	6.00	< 0.4	0
Lead	210.00	24 – 33	0
Mercury (inorganic)	170.00	< 0.3	0
Nickel	130.00	20 – 43	0
Selenium	250.00	< 1.0	0
Copper	2,400.00	18 – 30	0
Zinc	3,700.00	79 – 140	0
Notes: All concentrations in mg/kg			

Hydrocarbons (PAHs and TPHs)

A total of 8 (1no of samples of Made ground and 7no of samples of natural ground) were tested for speciated polycyclic aromatic hydrocarbons (PAHs) and total petroleum hydrocarbons (TPHs). The results of the PAH and TPH testing are summarised in the table below and enclosed in Appendix F.

Table 6.2: Assessment of Results – PAHs			
Determinant	**Human Health Criteria**	**Recorded Range**	**Number of Samples above Criteria Values**
Naphthalene	2.30	< 0.05	0
Acenaphthylene	170.00	< 0.05	0
Acenaphthene	210.00	< 0.05	0
Fluorene	170.00	< 0.05	0
Phenanthrene	95.00	< 0.05	0
Anthracene	2,400.00	< 0.05	0
Fluoranthene	280.00	< 0.05 – 0.26	0
Pyrene	620.00	< 0.05 – 0.23	0
Benzo(a)anthracene	7.20	< 0.05 – 0.19	0
Chrysene	15.00	< 0.05 – 0.14	0
Benzo(b)fluoranthene	2.60	< 0.05 – 0.24	0
Benzo(k)fluoranthene	77.00	< 0.05 – 0.12	0
Benzo(a)pyrene	2.20	< 0.05 – 0.23	0
Dibenzo(ah)anthracene	0.24	< 0.05	0
Indeno(123-cd)pyrene	27.00	< 0.05	0
Benzo(ghi)perylene	320.00	< 0.05	0
Notes: All concentrations in mg/kg Human health criteria assumes 1% soil organic matter as per laboratory results			

Table 6.3: Assessment of Results – TPHs			
Determinant	**Human Health Criteria**	**Recorded Range**	**Number of Samples above Criteria Values**
TPH Aliphatic EC5-6	42.00	< 0.001	0
TPH Aliphatic EC6-8	100.00	< 0.001	0
TPH Aliphatic EC8-10	27.00	< 0.001	0
TPH Aliphatic EC10-12	48.00	< 1.0	0
TPH Aliphatic EC12-16	24.00	< 2.0	0
TPH Aliphatic EC16-35	65,000.00	<8.0 -8.6	0
TPH Aromatic EC5-7	70.00		0
TPH Aromatic EC7-8	130.00	< 0.001	0

Table 6.3: Assessment of Results – TPHs			
Determinant	**Human Health Criteria**	**Recorded Range**	**Number of Samples above Criteria Values**
TPH Aromatic EC8-10	34.00	< 0.001	0
TPH Aromatic EC10-12	74.00	< 0.001	0
TPH Aromatic EC12-16	140.00	< 1.0	0
TPH Aromatic EC16-21	260.00	< 2.0	0
TPH Aromatic EC21-35	1,100.00	< 10	0
Notes: All concentrations in mg/kg Human health criteria assumes 1% soil organic matter as per laboratory results			

6.2 Assessment of Pollutant Linkages

A number of exposure pathways link the contamination to the receptor and potential risks are dependent on active pathways. The qualitative assessment of potential pollutant linkages based on the Desk Study information involves the matching of the identified sources of contamination to the receptors through the possible migration pathways. These links must be completed for there to be any risk associated with the site and its development.

This assessment is presented in terms of the Source (S), Pathway (P) and Receptor (R) concept and applying a qualitative value judgement to this appraisal. The assessment assigns a level of risk to each SPR link based on the probability and potential consequence of the risk being realised. A final level of risk is assessed assuming control measures are in place during the development or recommendations are followed.

A detailed conceptual model and the assessment of pathways and pollutant linkage tables are enclosed in Appendix H together with associated risk phrases and matrices. A summary is presented in the following table.

Table 6.4: Risk Assessment Summary			
Source	**Pathway**	**Receptor**	**Risk Assessment**
Metals & Metalloids **Hydrocarbons (TPHs and PAHs)**	Indoor / outdoor ingestion of and dermal contact with soils and dust Indoor / outdoor inhalation of fugitive dust	Future Site Users / Residents Site Construction Workers	Negligible Risk Low contaminant concentrations recorded. Adequate precautions and appropriate personal hygiene and safety protocols should be employed by all construction workers on site at all times.
Metals & Metalloids **Hydrocarbons (TPHs and PAHs)**	Ingestion of tainted mains water	Future Site Users / Residents Site Construction Workers	Guidance on the selection of materials for water supply pipes can be sought from the UK Water Industry Research (UKWIR) publication "PE Pipes for Contaminated Land", 2010.

Table 6.4: Risk Assessment Summary			
SOURCE	**PATHWAY**	**RECEPTOR**	**RISK ASSESSMENT**
Ground Gas (Landfill gas)	Indoor / outdoor inhalation of vapour or gas	Future Site Users / Residents Site Construction Workers	Low Risk Adequate precautions and appropriate personal hygiene and safety protocols should be employed by all construction workers on site at all times.
Radon	Indoor / outdoor inhalation of vapour or gas	Future Site Users / Residents	Negligible Risk The site is located within an area where less than 1% of homes are above the action level, and No Radon protective measures are required.
Asbestos Containing Materials (ACMs) in the soil	Indoor / outdoor inhalation of airborne asbestos fibres	Future Site Users / Residents Site Construction Workers	Low Risk No asbestos was identified in the soil.
Metals & Metalloids **Hydrocarbons (TPHs and PAHs)**	General contaminant uptake on site General contaminant uptake on adjacent land Exposure due to contaminated surface water runoff and/or contaminated surface water bodies	Flora and Fauna	Negligible Risk Low contaminant concentrations recorded.
Metals & Metalloids **Hydrocarbons (TPHs and PAHs)**	Surface Water Mobilisation	Rivers, Streams and Other Surface Water Bodies	Low contaminant concentrations recorded.
Metals & Metalloids **Hydrocarbons (TPHs and PAHs)**	Groundwater Mobilisation	Groundwater and Water Abstractions	Negligible Risk Low contaminant concentrations recorded. There are no groundwater abstraction points at locations likely to be impacted by activities on the subject site.

Table 6.4: Risk Assessment Summary			
SOURCE	**PATHWAY**	**RECEPTOR**	**RISK ASSESSMENT**
Naturally elevated Sulphates **Hydrocarbons (TPHs and PAHs)** **Ground Gas (Landfill gas)**	Adverse Effects to Future Built Environment by Direct attack, mobilisation, and Permeation of Aggressive Contaminants	Pipe-work, Ducts and Concrete Structures	Low Risk Guidance on the selection of materials for water supply pipes can be sought from the UK Water Industry Research (UKWIR) publication "PE Pipes for Contaminated Land", 2010.

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 General

Environmental testing recorded generally low contaminant concentrations in the soils and no remedial measures are required with respect to soils and groundwater.

The site is located within an area where less than 1% of homes are above the action level. Radon protective measures are not required.

The following are general recommendations:

- Adequate precautions and appropriate personal hygiene and safety protocols should be employed by all construction workers on site at all times.
- Guidance on the selection of materials for water supply pipes can be sought from the UK Water Industry Research (UKWIR) publication “PE Pipes for Contaminated Land”, 2010.
- Regular inspections should be carried out by ground workers during any excavation work, and advice should be sought in the event that unexpected ground conditions are encountered. Should any visual or olfactory signs of contamination be found during construction works, soils should be tested and assessed.
- Should further testing and assessment identify areas of unacceptable risk, appropriate remedial measures would need to be implemented. A detailed remediation strategy should be prepared, any remedial works and associated clean-up levels would need to be discussed with and approved by the Regulatory Authorities. Additionally, a Validation Statement would need to be prepared upon completion of any remedial works, detailing the works undertaken and the results of the associated validation testing. It is emphasised that such works are unlikely to be necessary on the basis of the assessments undertaken.

Appendix A. EXPLORATORY HOLE LOCATION PLAN

Appendix B. TRIAL PIT RECORDS

Appendix C. Soakaway Test Results

Appendix D. In-situ DCP Test Results

Appendix E. GEOTECHNICAL LABORATORY TEST RESULTS

Appendix F. GEO-ENVIRONMENTAL LABORATORY TEST RESULTS

Appendix G. Generic Assessment Criteria Values

Appendix H. RISK ASSESSMENT OF POLLUTANT LINKAGES

Appendix I. General Notes and Limitations