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Warren Hall, Broughton

Phase 1 Geo-Environmental Assessment
Desk Top Study

Report Reference: A093950-15

Llywodraeth Cymru
Welsh Government

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Prepared on behalf of WYG Environment Planning Transport Limited

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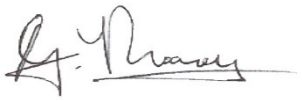
Prepared by:  Alex Lamb Consultant	Checked by:  Graham Rooney Senior Consultant	Approved By:  Chris Pugh Technical Director
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CONTENTS

LIST OF TABLES

FIGURES

APPENDICES

EXECUTIVE SUMMARY

The Site	The site covers an area of approximately 75ha comprising agricultural fields used for grazing sheep in the north and cattle in the south. The A5104 and Warren Hall is to the north and Lesters Lane to the east. Kinnerton Lane and residential properties bound the site to the south and west.
Site History	Earliest BGS mapping shows the site as agricultural fields and farmland with Gravel Hole Wood in the north adjacent to a central pond and Warren Dingle stream crossing the site from the west to the south-east. A boat house was present in the centre of the site between 1890 to sometime prior to 1969. A tank and sewage bed were recorded from 1969 with the tank being removed by 1983. Earthworks were undertaken in the north east of the site prior to 2010 which resulted in a gravel filled area with adjacent mounding of materials.
Geology	The BGS record the site as being free from significant Made Ground, however, Made Ground associated with previous earthworks in the north-east of the site is anticipated. The superficial deposits are generally Glacial Till with areas of Glaciofluvial deposits in the east and west. A pocket of head deposits are recorded in the south-west. Bedrock comprises Bowland Shale Formation – Mudstone deposits with bands of Gwespyr Sandstone. Previous investigations have confirmed that the ground profile comprises Topsoil, Made Ground & infilled hollows, Glacial Till and bedrock of mudstone, siltones and sandstone. The Glacial Till soils were found to be high variable in composition with little consistency between exploratory holes.
Hydrogeology and Hydrology	The Gwespyr Sandstone bedrock and Glaciofluvial superficial deposits are designated as Secondary A Aquifers whilst the Bowland Shale Formation Mudstone and Glacial Till/Head are classified as Secondary Undifferentiated Aquifers. The nearest watercourse is Warren Dingle which is located onsite. Previous investigations at the site have encountered a variable and shallow groundwater regime.
Radon	The site is located in a Low to High Probability Radon area where <1% to 10% - 30% of homes are above the action level.
Unexploded Ordnance	Freely available unexploded ordnance (UXO) mapping data shows the site to be located within a Low Risk Area.
Environmental Database Search	There is one Historical Landfill and one Registered Landfill located in the north-east of the site. Both are associated with McAlpine and were operational between 1982 and 1984. The historic landfill received inert waste whilst the registered landfill did not have any known restrictions on waste received. There is also a licenced waste management facility 151m north. The site is located within a nitrate vulnerable zone and there are several areas of ancient woodland onsite.

Preliminary Geotechnical Assessment	Shallow groundwater is present on site that will require groundwater control during earthworks and construction excavations. A hydrogeological assessment should be undertaken to inform the design of groundwater control measures. The near surface soils have been identified as being variable and susceptible to moisture content variation. Significant earthworks are required in order to create development plateaus; however, the combination of variable, moisture content sensitive soils and a high groundwater table represent a high risk for undertaking earthworks. This has been demonstrated by a previous failed attempt to undertake earthworks in 2010. A methodology for maximising the re-use of site won soils will need to be prepared and is likely to include the addition of lime and/or cement to stabilise the soils and will need to include field trials. Earthworks will need to be tightly controlled. Works should only be undertaken during drier periods. An onsite laboratory for rapid testing and full-time supervision by an experienced geotechnical resident engineer should be considered essential. Ground conditions are generally suitable for the adoption of spread foundations bearing on firm natural clay and/or bedrock at shallow depth. Where conditions are laterally variable, or clay of sufficient strength is not present at shallow depth, trench fill foundations may be adopted. Deep foundations e.g. piles or ground improvement columns may be required in select areas where Made Ground deposits are of significant thickness (e.g. the north-east / east), or where building footprints span areas of cut and engineered fill. Consultation with specialist contractors should be made following any further investigation works and development of detailed proposed site layouts and preliminary construction drawings.
Preliminary Ground Contamination Assessment	The assessment has identified the potential for Made Ground from historical usage of part of the site as a landfill in the north-east of the site associated with historical construction of the A55, a groundworks contract undertaken in 2010, isolated gravel pits to the north-west and from agricultural usage. Areas of significant Made Ground deposits are likely to be limited to the north-east / east of site. The preliminary risk assessment identified a Low risk to Human Health (for commercial end use and maintenance workers. There is a Moderate/Low risk to Human Health (for residential end use, Surface Waters, and the Secondary A Aquifer.
Conclusions and Recommendations	Further ground investigation works will be required in relation to Radon risk, ground gas risk, contamination risk, groundwater control and geotechnical assessment of the site. A methodology for maximising the re-use of site won soils will need to be prepared and future earthworks will need to be tightly controlled. Outline recommendations for the scope of these works are provided in Section 9.2.

1.0 INTRODUCTION

1.1 Instruction

WYG Environment Planning Transport Ltd (WYG) was commissioned by the Welsh Government to undertake a Geo-Environmental Desk Top Study on land known as Warren Hall in Broughton (referred to hereafter as "the site"). The site boundaries are delineated on Welsh Government Drawing No. 1109 and also on Figure 1.

1.2 Brief

The brief was to provide a Phase 1 Geo-environmental Assessment Desk Study report including a review of third-party historical ground investigation data and to make recommendations on further investigation works necessary in support of a development viability assessment and to support production of the Development Framework documentation.

1.3 Proposed Development

The Warren Hall development site consists of circa 75 Hectares situated on the western fringes of Broughton, Flintshire. The site is allocated in the Flintshire UDP for Strategic mixed use development and has been identified within Flintshire LDP Preferred Strategy as a Key Strategic Mixed Use site incorporating a total of 76,394 square metre business park (Class BI), hotel and associated leisure facilities and a housing allocation of approximately 300 units. An illustrative masterplan of the proposed development has been produced by WYG Planning and is presented on Drawing No. A093950-15-33. Hotel / leisure units are proposed for the north-east corner, employment units are proposed for the north-eastern, central and eastern areas and residential properties are proposed for southern and northern areas.

The majority of residential development is to be constructed from the existing levels, but the commercial development will require creation of new development platforms with associated battered slopes. Existing ground investigation information indicates that shallow ground conditions comprise variable, moisture susceptible glacial materials with groundwater present at shallow depth. An initial groundworks contract undertaken in 2010 in the North East of the site during the winter months was suspended owing to the moisture content of excavated

material and high groundwater levels.

1.4 Report Scope

This report includes the following key elements:

- A record of the visual inspection undertaken during a site walkover visit;
- A discussion of the current site status and key associated environmental influences observable by general visual inspection around the site;
- A historical review of the site and surrounding area, primarily referring to past editions of Ordnance Survey (OS) maps;
- A discussion of the general expected ground and groundwater conditions within the site area referring to the British Geological Society (BGS) geological and hydrogeological map library;
- Details of an Environmental database search (Envirocheck™ report) of key relevant agencies including Local and Statutory Authorities e.g. Natural Resources Wales;
- A review of third-party historical ground investigation reports;
- A geotechnical and ground contamination assessment discussing the results of the research above not only concerning potential on-site conditions, constraints and contamination but also an overview of the potential for contamination migration onto or off-site with respect to neighbouring land;
- A baseline UXO risk assessment using the Zetica online mapping tool to classify the level of UXO risk on-site;
- Qualitative ground contamination risk assessment (compliant with CIRIA 552 (CIRIA,

2001) methodology);

- Development of a preliminary conceptual model (PCM) for the site;
- Development of a preliminary geotechnical risk register;
- Recommendations for further ground investigation works (if necessary); and,
- An executive summary of the report to allow a rapid layman's overview.

1.5 Limitations

The recommendations and opinions expressed in this report are based on information obtained as part of the desk study or provided by others. Information provided from other sources is taken in good faith and WYG cannot guarantee its accuracy.

This report is subject to the report conditions presented in Appendix A.

The information contained in this report is intended for the use of the Welsh Government and WYG can take no responsibility for the use of this information by any third party or for uses other than that described in this report or detailed within the terms of our engagement.

2.0 SITE INFORMATION

2.1 Location

The site is located to the west of Broughton near Chester and is accessed from the A5104 Mold Road. The site is approximately 75ha in area and is centred on National Grid Reference (NGR) 332420, 362520.

The site address is Warren Hall, Mold Road, Broughton, Chester, North Wales CH4 0EW

A site location plan is presented on Figure 1.

2.2 General Area Context

Table 1 - Surrounding land uses

	Description
North	A5104 Mold Road and Warren Hall Court residential properties
East	Lesters Lane with farmland and associated buildings beyond
South	Kinnerton Lane with farmland beyond and residential properties to the south-east
West	Kinnerton Lane with farmland and associated buildings on Barracks Lane beyond

2.3 Site Description

A site walkover inspection was undertaken by WYG's Engineer on 30th April 2019. A series of photographs are presented in Appendix B and are cross referenced in the following section. The general site layout and photograph locations are shown on Figure 2.

2.3.1 Current Site Usage

The site is split into two, north and south by the Warren Dingle stream. The entire site is used as grazing land for livestock with sheep and lambs to the north of Warren Dingle and cattle to the south. Discussion between WYG's Engineer and the current tenants in the north and south confirmed that no pesticides are currently used on-site and that to their knowledge no burial pits are present. A large gravel covered area is present in the north east of the site with mounds of up to 4m high present to the south. This is associated with an initial groundworks contract begun in February 2010 and subsequently terminated. Anecdotal evidence from one of the tenants suggested that soil was excavated from the north-east to an approximate depth of 2m and the pit infilled with gravel. The excavated material was then stockpiled in mounds to the south.

2.3.2 Topography

The topography varies considerably across the site with many undulations. The general fall in gradient is from approx. 91metres (m) above ordnance datum (AOD) in the west to approx. 37m AOD to the east.

2.3.3 Ground Cover and Vegetation

The majority of the site comprises soft landscaped grazing land with concrete access tracks around a pond in the centre. Numerous mature trees are present along the site perimeter and within the field enclosures and a dense wooded area known as Gravehole Wood is present in the central / western part of site. Warren Dingle passes through the south of site on an east-west alignment, with the western two thirds of the stream being bound by dense woodland.

2.3.4 Drainage

Given the sites historical and current agricultural usage, land drains are likely to be present below the site.

2.3.5 Services

Overhead telecoms lines cross the site from north west to south east. Service plans have not been obtained for the site at this stage, however, several manhole covers were noted within the site boundary during the walkover survey.

2.3.6 On-Site Structures and Fuel Tanks

The majority of the site is undeveloped. An arched brick structure lies adjacent to the east of the central pond. A sewage bed (still active and used by off-site properties on the Warren Hall

Court private estate to the north of the pond) is located in the east.

2.3.7 Electrical Substations

No electrical substations were observed on or adjacent to site.

2.3.8 Asbestos Containing Materials

No asbestos containing materials (ACMs) were observed on-site.

2.3.9 Signs of Contamination

There were no obvious signs of contamination noted during the walkover survey.

3.0 GEOLOGY, HYDROGEOLOGY, HYDROLOGY AND RADON

3.1 Geology

Details of the geology underlying the site have been obtained from the following sources:

- British Geological Survey (BGS) Sheet No. 108 (Flint) Solid and Drift Edition, 1:50,000;
- BGS website (British Geological Survey , 2018);
- Environmental database (Envirocheck™) presented in Appendix B;
- BR211 Indicative Radon Mapping (Scivyer, 2015); and,
- Coal Authority Interactive Mapper (The Coal Authority, 2018).

3.1.1 Made Ground

The BGS record much of the site as free from significant Made Ground except an area in the north-west of the site which appears to be associated with the construction of the A55. The Atkins report states that Made Ground was encountered in many investigation locations however, this can be divided into three areas, namely the northern end of the site comprising road construction materials, an infilled hollow in the centre of the site and isolated patches in the south west which were noted as potentially infilled ponds/kettle holes.

3.1.2 Superficial Geology

The site is shown to be largely overlain by Glacial Till (clay) with an area in the western corner where drift deposits are not recorded. Glaciofluvial deposits (sand and gravel) are noted in several across the site, these are recorded to the west of Warren Hall, a thin strip in the east and a two of areas in the west. Head deposits, generally comprising *'clay silt sand and gravel'* are recorded to the south-west of Warren Hall. The Atkins report indicates that superficial deposits are highly variable across the site comprising sand, silt and clay with varying gravel and cobble content with no consistency between adjacent exploratory holes.

3.1.3 Solid Geology

The site is underlain by the Bowland Shale Formation – Mudstone deposits with bands of Gwespyr Sandstone. Several faults are shown to cross the site generally in a north to south direction. The fault in the east of the site (east of Warren Farm pond) downthrows to the east with Bowland Shale deposits on either side with bands of Gwespyr Sandstone. Four faults are

present close to the western corner in close succession down-throwing in a westerly direction. The Ian Farmer Associates investigation shows the depth to bedrock varied considerably across the site with BH5 adjacent to the pond in the centre of the site encountering a grey brown Sandstone bedrock at 0.50m bgl and BH11 in the north east corner encountering a grey black Mudstone at 14.20m bgl.

3.1.4 Historical Borehole Logs

The British Geological Survey (BGS) online borehole records were consulted to find records of ground conditions on site and the surrounding area that were not included within the aforementioned third-party historical ground investigation reports. A summary of ground conditions recorded by the BGS is presented in the table below, with copies of the corresponding borehole logs presented in Appendix C.

Table 2 – Summary of BGS Borehole Logs

Reference Number	Hole Type and Depth	Distance and Direction from Site	Details (m bgl)
SJ36SW8	Cable Percussive (36.58m) Water 16.46	On Site (in the south-west)	0.00m – 10.36m – Hard marl 10.36m – 20.72m – Soft shale 20.72m – 26.82m – Slate rock 26.82m – 36.58m – Hard rock & grit
SJ36SW9	Cable Percussive (37.80m) Water 3.96m	5m (south-east)	0.00m – 7.31m – 'Well' 7.31m – 24.38m – Sale with bands of ironstone 24.38m – 28.04m – Soft black shale 28.04m – 29.87m – Hard rock 29.87m – 37.80m – Marl or shale
SJ36SW154	Rotary (60.00m) Water 12.00m	17m (north-east)	0.00m – 0.50m – Soil 0.50m – 3.00m – Clay 3.00m – 6.00m – Fractured sandstone 6.00m – 60.00m – Mudstone with layers of sandstone
SJ36SW20	Cable Percussive (9.80m) Water 7.00m	34m (south-east)	0.00m – 0.30m – Soil. 0.00m – 9.20m – Stiff red brown sandy CLAY. 9.20m – 9.80m – Siltstone with mudstone
SJ36SW5	Cable Percussive (52.88) Water – NR	40m (south)	0.00m – 0.30m – Soil 0.30m – 2.81m – Brick soil 2.81m – 9.75m – Light blue metal 9.75m – 9.86m – Ironstone 9.86m – 17.68m – Light-blue metal 17.68m – 17.73m – Ironstone 17.73m – 19.56m – Black metal

Reference Number	Hole Type and Depth	Distance and Direction from Site	Details (m bgl)
			19.56m – 19.63m – Ironstone 19.63m – 22.38 – Black shale with ironstone 22.38m – 24.61m – Light warrant 24.61m – 26.37m – Blue metal 26.37m – 29.26m – Grey rock 29.26m – 47.85m – Blue metal with rock bands. 47.85m – 51.51m – Black shale 51.51m – 52.88m – Brown warrant
SJ36SW16	Cable Percussive (10.10m) Water 3.60m	84m (south-east)	0.00m – 0.01m – Sandy topsoil 0.10m – 0.80m – Firm brown sandy clay with brick and stones. Backfill 0.80m – 1.30m – Firm brown sandy grey silty mottled Clay 1.30m – 3.40m – Stiff brown silty sandy Clay 3.40m – 4.30m – Very stiff brown sandy Clay 4.30m – 4.80m – Compact very silty sand with lenses of clay 4.80m – 6.70m – Firm brown silty Clay with sand lenses 6.70m – 8.00m – Very stiff brown sandy Clay with bands of sand and stone 8.00m – 10.10m – Compact silty Sand with bands of firm brown silty clay

3.2 Hydrogeology

3.2.1 Aquifer Classification

The Gwespyr Sandstone bedrock and Glaciofluvial superficial deposits are designated as Secondary A Aquifers. These are 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.

The Bowland Shale Formation Mudstone bedrock and Glacial Till/Head superficial deposits are classified as a Secondary Undifferentiated Aquifers. This has been assigned in cases where it has not been possible to attribute either a Secondary A or B aquifer to the soil type due to the variable characteristics. In most cases, this means that the layer in question has previously

been designated as both minor and non-aquifer in different locations due to the variable characteristics of the rock type.

3.2.2 Groundwater Vulnerability

Guidance released by the EA (Envionment Agency , March 2017) states that activities that have the potential to affect the quality or quantity of groundwater must prevent groundwater pollution. All groundwater is vulnerable to pollution, and some geological formations are more vulnerable than others. The risks of groundwater pollution from any given activity depend in part on:

- The physical, chemical and biological properties of the underlying soil and rocks;
- Depth and quality of soil;
- The presence of glacial sediment and other materials – known as 'drift' deposits; and,
- Depth of the unsaturated zone.

All of the above affect how groundwater is more or less vulnerable to pollution, with type of vulnerability generally one of the following:

- Intrinsic vulnerability – this relates to the physical characteristics, it includes soil type, presence of superficial soils, or rock type; and,
- Specific vulnerability – this relates to the effect of the proposed activity including any contaminant and consequent risk to groundwater.

A review of the Groundwater Vulnerability Maps for England has revealed that the bedrock and superficial deposits below the site are categorised as 'Medium Vulnerability – Secondary Aquifer'. Medium vulnerability aquifers are defined as being *"areas that offer some groundwater protection. Intermediate between high and low vulnerability"*. EA guidance document[1] goes on to state that Activities in these areas should as a minimum follow good practice to ensure they do not cause groundwater pollution*".*

3.2.3 Groundwater Source Protection Zones

The EA defines groundwater Source Protection Zones (SPZs) around identified abstractions to aid the assessment of risk to groundwater or abstraction sources from development. SPZs have three subdivisions and bespoke SPZs are defined for all major abstraction sources intended for human consumption or food use, e.g. boreholes and springs. These sub-divisions are defined

as follows:

- SPZ1 – Inner protection zone - defined as the 50-day travel time from any point below the water table to the abstraction source. This zone has a minimum radius of 50 metres;
- SPZ2 – Outer protection zone - defined by a 400-day travel time from a point below the water table. This zone has a minimum radius of 250 or 500 metres around the abstraction source, depending on the size of the abstraction;
- SPZ3 – Source catchment protection zone - defined as the area around an abstraction source within which all groundwater recharge is presumed to be discharged at the abstraction source.

The site is not shown to be situated within an EA defined groundwater SPZ.

3.2.4 Depth to Groundwater and Anticipated Groundwater Flow Direction

The Atkins report indicated groundwater lies between 1.0m bgl to 6.25m bgl.

3.2.5 Groundwater Abstractions and Water Wells

The following groundwater abstractions are recorded within 250m of the site as recorded within the Environmental Database (Envirocheck™).

Table 3 – Summary of Groundwater Abstractions within 250m

Location	Details
30m – South East No address supplied.	Operator: Mr E Moore. Licence Number: 24/67/9/0095. For general farming and domestic.
137m – North No address supplied.	Operator: Mr D H Maxwell. Licence Number: 24/67/9/0049. For general industrial usage.

Table 4 – Summary of Nearby Water Wells

Location	Details
Onsite (south-west) – Warren Dale	Reference SJ36/37. Sunk in 1938.
Adjacent to south-west Kinnerton Lodge	Reference SJ36/38A. Sunk in 1899.
Adjacent to south-east Crabmill Farm Higher Kinnerton	Reference SJ36/126. Sunk in 2017.
10m south-east Crab Mill	SJ36/36. Sunk in 1937.

3.3 Hydrology

Details of the hydrology of the area have been obtained from the following sources:

- MAGIC interactive mapping website (DEFRA, 2018); and,
- Environmental database (Envirocheck™).

3.3.1 Watercourses

A surface watercourse, Warren Dingle, crosses the south of site from east to west. A pond is located in the north of the site, south of Warren Hall. Several other ponds are located off-site, near the site's eastern and western boundaries.

3.3.2 Surface Water Abstractions

There are no Surface Water Abstractions recorded within 250m of the site.

3.3.3 Discharge Consents

The table below outlines the surface water discharge consents recorded within 250m of the site.

Table 5 – Summary of Surface Water Discharge Consents within 250m of the site.

Location	Details
57m (north)	Five noted within 250m of the site all operated by Warren Hall Court Management for sewage discharges into a tributary of Brad Brook (1 active, 4 revoked).

3.3.4 Pollution Incidents and Prosecutions

There are no recorded Pollution Incidents or Prosecutions within 250m of the site.

3.4 Radon

The BRE document 211 (Scivyer, 2015) mapping coverage for the site area was consulted and indicates that the site is located within an area where full radon protective measures are necessary for new developments. This statement is supported by the Envirocheck Report (Appendix B) which confirms that the site is in a low to high probability radon area where the amount of homes above the action level ranges from <1% to 10 – 30%.

3.5 Historical Mining

According to the Coal Authority Interactive Viewer (The Coal Authority, 2018) the site is not

located within a Coal Mining Reporting Area.

3.6 BGS Recorded Mineral Sites

With reference to the Environmental Database (Envirocheck™) and the BGS Geoindex database the following BGS recorded mineral sites are recorded within 1km of the site.

Table 6 – Summary of BGS Recorded Mineral Sites within 1km of the site.

Site Name	Reference and Status	Type	Geology	Commodity	Distance and Direction from Site
Warren Mountain	Ref: 105033 Ceased	Opencast	Bowland Shale Formation	Sandstone	40m (west)
Bryn-Teg Quarry	Ref: 6199 Ceased	Opencast	Cefn-y-Fedw Sandstone Formation	Sandstone	151m (west)
Warren Mountain Sand Pit	Ref: 105195	Opencast	Glaciofluvial Deposits	Sand	389m (north)

4.0 UNEXPLODED ORDNANCE

Based on freely available mapping data from the Zetica UXO website (Zetica UXO, 2008), the site is located within a Low Risk Area with regards to Unexploded Ordnance (UXO). A 'Low Risk' area is defined by Zetica as:

'Low risk regions are those with a bomb density of up to 10 bombs per 1000 acres. These areas are considered to have a significant but low UXB risk. In general, further action to mitigate the risk is considered prudent, although not essential. Care is required when assessing the risk for specific sites where the risk may be higher because of local wartime activity'.

A copy of the Zetica UXO Risk Map for the subject site and surrounding area is provided in Appendix D.

5.0 SITE HISTORY

5.1 Introduction

The historical development of the site and surrounding area has been assessed using information available from historical Ordnance Survey (OS) maps within the Envirocheck Report for the site which is presented in E of this report.

In the context of the summary of historical development of the surrounding area, the descriptions are limited to within approximately 500m of the site boundary, unless specified in the following section.

5.2 Site History

5.2.1 Detailed Analysis of Site History

The table below provides a detailed account of the review of available OS mapping coverage and historical aerial imagery for the site and general area dating back to 1871.

Table 7 – Summary of Historical Data

Map Date & Scale	Within Site Boundary	Surrounding Area
1871 (1:10,560)	The site primarily comprises agricultural fields/farmland. Gravel Hole Wood is located in the north adjacent to a central pond and water well. Warren Dingle (stream) crosses the site from the west to south-east with the western half of the stream bounded by woodland.	Much of the surrounding land use is agricultural with 'The Warren' located adjacent to the site centrally disjointing the northern boundary with a small pond present on the boundary. Warren Bank farmstead is located 20m to the north with associated water well. Crab Mill farm is adjacent to the south west corner.
1881 (1:10,560)	No significant change.	No significant change.
1890 (1:10,560)	A boat house and fishpond are located in the centre of the site.	Two old quarries are located 20m off the sites north-western boundary. 'The Warren' is now recorded as Warren Farm and Warren Hall with additional buildings present. A reservoir is recorded 90m to the north beyond Warren Farm. A cottage has been developed to the west.
1914 (1:10,560)	No significant change.	No significant change.
1954 (1:10,000)	No significant change.	Residential construction has begun 220m to the north-east.
1966 (1:10,000)	No significant change.	No significant change.
1969 (1:10,000)	The fishpond and boat house are no longer recorded. A tank and sewerage bed are now recorded in the north east.	The old quarries to the north-west corner are no longer recorded.
1983 (1:10,000)	The north-eastern tank is no longer recorded.	A farmstead has been developed off the sites north-eastern boundary.
1991 (1,10,000)	No significant change.	A further cottage has been developed to the west.
1999 (1:10,000)	No significant change.	No significant change.
2019 (1:10,000)	No significant change.	No significant change.

5.2.2 Summary of Site History

The site appears to be largely agricultural with streams and pond present. From 1969 to 1983 a tank was recorded in the north-west with adjacent sewerage bed present from 1969 to sometime prior to 2019.

6.0 ENVIRONMENTAL DATABASE SEARCH

6.1 Introduction

Regulatory authority information relevant to the site and its surroundings has been obtained from the undertaking of an environmental database search (Envirocheck$^{TM)}$. The information is summarised below, and the environmental database records are enclosed in E. Distances stated are approximate and are taken from the boundary of the site to the database recorded entries.

The following summary is generally limited to locations within 250m of the site boundaries unless it is considered that installations or activities beyond that range could potentially have an impact on the site or be affected by the redevelopment of the site.

6.2 Pollution Controls

There are no Integrated Pollution Controls, Integrated Pollution Prevention and Controls or Local Authority Pollution Prevention and Controls within 250m of the site.

6.3 Waste

A summary of records pertaining to waste disposal, management and transfer facilities are presented in the table below.

Table 8- Summary of Waste Facilities within 250m of the Site

Facility Type	Location	Details
Historical Landfill	Onsite (north-east)	Licence Holder: McAlpine and Son Northern Limited. Operational between 31/12/1982 and 31/12/1984 and accepted inert waste. Reference: 6835/0047.
Registered Landfill	Onsite (north-east)	Licence Holder: Alfred McAlpine. Operational from 1982 with no end date supplied. Licence has lapsed. Ref 113/82 & 114/82.
Licensed Waste Management Facility	151m (north)	Located at Broughton Cottage Farm, Mold Road. Licence number FB3734RP. Issued 05/06/13.

6.4 Hazardous Substances

There are no Control of Major Hazards Sites (COMAH), Explosive Sites or Notification of

Installations Handling Hazardous Substances (NIHHS) within 250m of the site boundary.

6.5 Environmentally Sensitive Areas

Table 9 – Summary of Environmentally Sensitive Areas

Designation	Location and Name	Details
Nitrate Vulnerable Zone (Surface Waters)	Onsite	There are two designated Nitrate Vulnerable Zones in the south-east of the site.
Ancient Woodland	Onsite	There are eight entries of Ancient Woodland on the site.
	11m – 224m (north, west and south)	Seven entries of Ancient Woodland surrounding the site.

6.6 Flooding

The absence or presence of flooding potential at the site is summarised in the table below.

Table 10 - Summary of Flooding Potential

Designation	On Site	Detail
Flooding at Surface (from Groundwater)	Yes	Potential for flooding to occur at surface.
Flooding below Ground Level (from Groundwater)	Yes	Potential for flooding of property below ground level.
Flooding from Surface Waters	No	-

6.7 Industrial Land Use

There are no Contemporary Trade Entry records within 250m of the site.

6.8 Summary of Environmental Setting

There is one Historical Landfill and one Registered Landfill located in the north-east of the site. Both are associated with McAlpine and operational between 1982 and 1984. The historic landfill received inert waste whilst the registered landfill did not have any known restrictions on waste received. There is also a licenced waste management facility 151m north. The site is also located within a nitrate vulnerable zone and there are several areas of ancient woodland onsite.

7.0 PREVIOUS INVESTIGATIONS

The following table summarises the third-party historical ground investigation reports made available to WYG:

Table 11 – Summary of Previous Reports

Author	Date	Title	Client	Comments
Ian Farmer Associates (IFA)	February 2008	Warren Hall Broughton, Factual Investigation Report (Ref. No. W08/40274)	Welsh Assembly Government	Investigation was focused on the north-east/east and centre of site (referred to as Plateaus A & B).
Ian Farmer Associates	March 2008	Warren Hall Broughton, Interpretative Report on Ground Investigation and Development Plateaus (Ref. No. W08/40274-3)	Welsh Assembly Government	Interpretation of data provided in the IFA February 2008 Factual Report.
Atkins	September 2010	Warren Hall, Geotechnical Overview Report (Ref. No. 5078488.106/32905)	Welsh Assembly Government	Overview of the geotechnical conditions at the site based on review of previous reports following termination of a groundworks contract. Includes review of the 2008 IFA G.I. reports and numerous historical G.I. reports not made available to WYG

Information contained within the reports above has been taken in good faith and WYG do not accept any responsibility for inaccuracies in the reported data. WYG understand that The Welsh Government have full reliance on the information enclosed within said reports.

7.1.1 Ian Farmer Associates Factual G.I. Report (February 2008)

Ian Farmer Associates were instructed by Opus International Consultants (UK) Ltd on behalf of the Welsh Assembly Government to carry out a ground investigation to determine ground and groundwater conditions at the site and provide a factual report.

The investigation area was limited to the north-east / east and centre of the site which at the time was split into two development phases known as Plateau A & Plateau B. The position of Plateaus A & B in relation to the current development masterplan is delineated on Drawing No.

A093950-15-MAN-01 (Figure 3 in this report).

Scope of Investigation

The scope of the investigation comprised:

- 17 No. cable percussive boreholes (BH01 – BH17);
- 10 No. rotary follow-on boreholes (BH04 – BH10 & BH15 – BH17);
- 11 No. ground gas / groundwater monitoring well installations;
- 17 No. dynamic sample boreholes (WS01 – WS17);
- 18 No. dynamic probe tests (DP01 – DP18); and,
- 15 No. trial pits (TP01 – TP15).

Exploratory hole logs and in-situ test results were provided in the Appendices of the report. The exploratory hole positions are presented on the Atkins Drawing No. 20082593/SM/32992.

Laboratory Testing

Geotechnical classification testing was undertaken in accordance with BS1377: Part 1 (1990) and comprised:

- 18 No. Moisture Content;
- 18 No. Plasticity Indices;
- 1 No. Bulk Density;
- 14 No. Particle Size Distribution (PSD) by Wet Sieve;
- 11 No. PSD by Sedimentation;
- 21 No. pH Level;
- 14 No. Water Soluble Sulphate;
- 2 No. Groundwater Sulphate;
- 3 No. Dry Density / Moisture Content Relationship;
- 7 No. California Bearing Ratio;
- 8 No Undrained Triaxial; and,
- 7 No. One Dimensional Consolidation.

In addition, the following chemical analyses was undertaken:

- 56 No. soil samples –
    - Metals suite
    - VOC & BTEX suite
    - Organic suite
    - Inorganic suite
- 7 No. leachate samples –
    - WAC suite
- 6 No. water samples –

- Metals suite
- Organic suite
- Inorganics suite

Geotechnical and chemical laboratory test results were provided in the Appendices of the report.

7.1.2 Ian Farmer Associates Interpretative G.I. Report (March 2008)

Ian Farmer Associates (IFA) were instructed by Opus International Consultants (UK) Ltd on behalf of the Welsh Assembly Government to prepare an interpretative report based on the site work previously factually reported in February 2008 and the following historic third-party data:

- Stats Ltd 'Proposed Development at Warren Hall Report on Ground Investigation Ref. No. M 1459' (July 1989)
- Exploration Associates 'Warren Hall: Highway Infrastructure Factual Report on Ground Investigation Ref. No. 125001' (April 1995)

The historic ground investigation data was not provided within the Appendices of the report.

The report notes that site proposals at the time of writing comprised large-scale cut and fill works to facilitate development of Plateaus A & B for commercial end use.

Ground Conditions

The exploratory hole logs available at the time of writing were reviewed by IFA and the ground conditions summarised as a surface layer of topsoil overlying natural clay with subordinate sand and gravel deposits underlain by a sequence of interbedded mudstone, siltstone and sandstone bedrock. The boundary between the soil and rock was noted to generally fall towards the east, mirroring the overall topography of the investigation site. It was speculated that an area of deeper granular soils towards the north-east corner of the site may indicate a buried channel-type feature.

Groundwater

During drilling works, groundwater was encountered as seepages within drift deposits (typically sand or silt strata) between 0.5m bgl and 2.5m bgl. Groundwater was also encountered at the boundary of drift deposits and bedrock between 2.5m bgl and 6.5m bgl, with a slight pressure head of up to around 1m. During subsequent monitoring visits, groundwater level was found to

vary between 0.4m bgl and 2.7m bgl.

As such, groundwater flows are expected during earthworks from cut faces where the boundary between soil and rock is encountered and as seepages within soils.

Soil / Bedrock Properties

Results of the aforementioned geotechnical classification laboratory testing reported in IFA's factual report were summarised in the report as follows:

- Plasticity Indices indicated that the in-situ clay stratum is predominantly of low plasticity and locally intermediate plasticity, the in-situ silt is of high plasticity;
- Bulk Density of the in-situ clay stratum ranged from 2.1 – 2.4Mg/m^3 with Dry Density ranging from 1.8 – 2.1Mg/m^3;
- Undrained Shear Strength (Cu) ranged from 45 kN/m^2 (firm) – 287kN/m^2 (very stiff) with a mean value of 126kN/m^2 (stiff) calculated. It was concluded that Cu values did not indicate any systematic variation between strength and depth;
- Uniaxial Compressive Strength (UCS) testing on bedrock core samples found results ranging from 0.8MPa – 67MPa, with a mean of 30MPa calculated (although it was noted that due to only the most competent core recovery being suitable for UCS testing, the results likely represent an upper bound value for the material); and,
- Point Load testing on bedrock core samples derived UCS results ranging from 1.2MPa – 57.6MPa, similar to the direct UCS measurement tests.

Radon

It is stated that a Radon classification was provided within Phase 1 Desk Study report by IFA (not made available to WYG) and that the classification data was contradictory, meaning a single level of Radon risk could not be determined for the site.

Earthworks

It was concluded that excavated materials would be suitable for use as Type 1 / 2 general fill or Type 6 / 7 structural fill. It was recommended that embankment areas be prepared by the removal of topsoil and the placement of a granular drainage layer on the exposed formation. Embankments up to 6m in height were anticipated. The estimated total and differential settlements below embankments were not considered likely to be of sufficient magnitude to

affect the development programme or require post construction monitoring.

Geotechnical Assessment

After assessing the observed ground conditions and in-situ and laboratory test results, IFA advised that shallow spread foundations would be suitable for adoption with anticipated bearing capacities of about 100kN/m2 in clay and "properly engineered" embankment fill. It was advised that significantly higher bearing capacities would be available in the observed bedrock. It was recommended that foundations may require extending to bedrock by trench fill at locations where strata types vary laterally due to the risk of differential settlement.

IFA stated that piles may be considered in areas where high column loads are anticipated from proposed buildings and the underlying strata (presumably at shallow depth) is clay or embankment fill. It was advised that specialist piling contractors be contacted for comment on the suitability and carrying capacity of their respective pile types in the observed ground conditions.

It was recommended that where proposed buildings are located close to the top of embankment crests, detailed slope stability analysis should be carried out to determine the effect of building loads on slope stability.

Pavement Design

In-situ California Bearing Ratio (CBR) tests recorded values ranging from 7.4% – 19% for the clay formation and ranging from 8.7% – 30%. Laboratory CBR tests recorded values ranging from 2.0% – 5.2% for clay. After reference to Highways Agency 12.13 guidance, it was recommended that preliminary design of roads be based on a CBR of 5% in natural strata and 2% in embankment fill.

Buried Concrete

Results of laboratory chemical analyses for pH level and Sulphate concentrations in soil and groundwater were assessed against the guidance of BRE Special Digest 1 [SD1] (2005), resulting in an Aggressive Chemical Environment for Concrete (ACEC) classification of AC-3z when considering on-site groundwater as mobile. IFA then concluded that a Design Sulphate Class of DS-1 may be used in design. However, when referring back to the BRE SD1 guidance, WYG found this appears to be incorrect. See Section 2.4.4 of this report for details.

Human Health Risk Assessment

Quantitative risk assessment of soil chemical test data was undertaken by assessing contaminant

concentrations against threshold values (CLEA SGV's and LQM & CIEH GAC's) for a commercial / industrial end use and found that no contaminant exceeded its respective threshold value. Therefore, it was considered by IFA that no significant risk to human health would be posed by the development.

Controlled Waters Risk Assessment

Quantitative risk assessment of groundwater and soil leachate chemical test data was undertaken by assessing concentrations against published threshold values (EQS Freshwater). The assessment found that all contaminants were below their respective threshold values with the exception of very slightly elevated Total Petroleum Hydrocarbons (TPH) in the range C15 – C40 in boreholes BH4 and BH9. IFA concluded that the TPH exceedances were not consistent with the wider data set and that it may have been caused by a minor localised oil or diesel spillage from agricultural or ground investigation plant. As such, it was stated that further assessment of the risk to controlled waters was not likely to be required.

Ground Gas Risk

Across the majority of the site, monitored gas concentrations and flow rates were not considered high enough to warrant incorporation of protection measures in commercial buildings. However, at BH11 in the north-east corner of the site, a Methane concentration of 16% with a flow rate of 1.8litres/hour (l/hr) was recorded before a subsequent visit recorded a 2.3% Methane with a negligible flow rate. The initial result at BH11 would require gas protection measures to be incorporated into the construction of new buildings. Additional investigation was recommended to clarify the gas regime and the requirement for any protection measures.

7.1.3 Atkins Geotechnical Overview Report (September 2010)

Atkins, under instruction from the Welsh Assembly, prepared a Geotechnical Overview Report including an earthworks assessment. The report covered the whole development site but largely focused on the Plateau A / Plateau B / Phase 1 development areas to the north-east / east and centre of site as delineated on Atkins Drawing No. 20082593/SM/32992.

The following historical ground investigation reports were reviewed by Atkins:

- Exploration Associates 'G.I. Report for Hawarden Bypass' (1975)
- Stats Ltd 'Proposed Development at Warren Hall Report on Ground Investigation Ref. No. M 1459' (July 1989)
- Exploration Associates 'Warren Hall: Highway Infrastructure Factual Report on Ground

Investigation Ref. No. 125001' (April 1995)

- Ian Farmer Associates 'Warren Hall, Broughton Desk Study Ref. No. W08/40274-1' (February 2008)
- Ian Farmer Associates 'Warren Hall, Broughton Factual Report on Ground Investigation Ref. No. W08/40274' (February 2008)
- Ian Farmer Associates 'Warren Hall, Broughton Interpretative Report on Ground Investigation: Development Plateaus Ref. No. W08/40274-3' (March 2008)
- Opus International Consultants (UK) Ltd 'Geo-Environmental Ground Investigation for the Warren Hall Development, Boughton, Flintshire, North Wales Ref. No. RC4677/39/WJG/AC/LP'

Copies of the IFA factual and interpretative ground investigation reports were provided to WYG and have been summarised in the previous Sections 2.4.1 and 2.4.2. The other historic reports referred to by Atkins were not made available to WYG.

Additional Investigation Works

Additional intrusive ground investigation works were undertaken due to limitations identified by Atkins in the historic geotechnical laboratory test data set that precluded completion of an earthwork's assessment:

- 3 No. trial pits by Atkins (2009); and,
- 9 No. trial pits by Jacobs Engineering (2010).

The additional works were confined to the former Phase 1 development area in the north-east of the site.

Laboratory Testing

Geotechnical classification testing was undertaken in accordance with BS1377: Part 1 (1990)

and comprised:

- 9 No. MCV tests (5 point with 2.5kg rammer);
- 13 No. MCV tests (1 point);
- 13 No. Moisture Content;
- 13 No. Plasticity Indices;
- 13 No. PSD (pipette sedimentation method); and,
- 13 No. Shearbox tests.

Ground Conditions

Following completion of the 2010 trial pits, Atkins provided an updated, detailed summary of ground conditions across the site. The Made Ground encountered was considered by Atkins to be broadly divided into 3 types / areas:

- A55 trunk road construction material to the north of the investigation area (north-east corner of current development site boundaries) which comprised reworked glacial materials with organic matter, occasional pieces of wood, brick and coal. The Stats Ltd boreholes were logged as natural ground, but it was considered by Atkins that the soft mixed strata in TP1 and organic inclusions in BH1 may be indicative of made ground. This made ground was encountered to depths of between 1.0m and 2.6m bgl on-site and up to 4.55m bgl in the Exploration Associates boreholes immediately off-site to the north-east. Atrkins state that the Exploration Associates report speculated these materials were associated with the construction of the A55 Trunk Road (1976 - 1984). The location of this material was also stated by Atkins to be consistent with the area of landfill identified by an unspecified desk study.
- Infilled hollow in the centre of the investigation area up to its eastern boundary (east of current development site boundaries) comprised reworked glacial materials with occasional brick, coal and ash fragments. Made ground was encountered to depths of between 1.0m and in excess of 6.0m bgl It is stated that Stats Ltd boreholes within this area were logged as natural ground, but Atkins considered that organics, vegetation and timber remnants in TP2 & BH3 may be indicative of Made Ground. The IFA report noted that this area appeared to be coincident with a valley-type feature in the bedrock

contours, which may imply the historic backfilling of excavations or a drainage feature.

- Possible infilled ponds / kettle holes in isolated locations to the south-west / west of the investigation area (centre of current development site boundaries) comprised glacial deposits with organic matter, peat and brown-black mottling which may be made ground or natural and could either be infilled hollows / kettle holes / ponds or natural glacial features.

The natural glacial till deposits were encountered directly below the topsoil or made ground. The glacial materials encountered were considered to be highly variable and intermixed across the site including brown, red-brown and orange sands, silts and clays with varying proportions of gravel and cobbles. Materials were described as varying from very soft to very stiff and loose to dense. Although it should be noted that clay was the major constituent in the majority of glacial deposits. It was considered by Atkins that plotting of a coherent cross section for the investigation site was not possible due to the variable conditions. It was speculated that the mixed soil types may be a result of the glacial depositional environment or due to periglacial processes such as solifluction (as periglacial features such as kettle holes had historically been reported in the area).

The depth to rockhead varies considerably across the site. Bedrock was encountered at between 0.5m bgl (IFA BH5) and 14.2m bgl (IFA BH11) and was not encountered in all exploratory hole positions. In terms of ordnance datum, the shallowest proven rockhead was 63.12m above Ordnance Datum (AOD) (Stats Ltd TP09) and the deepest proven was 27.68m AOD (IFA BH11). Generally, rockhead is deepest in the north-east corner of the investigation area (north-east of current development site) and shallowest at the south-eastern and western boundaries of the investigation area (south-east and centre of current development site).

The bedrock is variable, comprising alternating sequences of sandstone, mudstone and siltstone, with breccia and 0.4m thickness of coal noted at a single borehole (IFA BH16). Lateral as well as vertical (stratigraphic) variation in bedrock type was stated to be likely.

2010 Earthworks

In February 2010, the Welsh Assembly Government appointed Alun Griffiths Ltd as earthworks contractor for Phase 1 of the Warren Hall development (within the north-east of current development site as illustrated on Drawing No. A093950-15-MAN-N-01). The initial cut and fill activities undertaken are illustrated on Atkins Drawing No. 5078488/PL/007. Due to difficulties moving plant across areas of cut and stripped topsoil in Fill Area 1, Alun Griffiths Ltd installed a "rock starter layer" (presumably engineered granular fill). The thickness of the fill layer needed

to support plant movements is understood to have been determined by in-situ trials.

The earthworks were eventually abandoned before completion due to problems with standing water levels encountered above the final cut levels. Land drains were also encountered which fed water into excavations, initially as a fast flow before reducing over time. Weather during the works was noted to be particularly cold with snow and prolonged periods of freezing conditions. During we weather, increases in groundwater flow were observed.

Future Enabling Works

In view of the difficulties with the high groundwater and ground conditions at the site it was considered by Atkins that enabling works should be undertaken in advance of subsequent earthworks to trial and implement suitable measures.

Re-Use of Soils

To maximise re-use of site-won materials, it was advised that the high groundwater table would need to be controlled by dewatering operations. Following dewatering, it was speculated that the soils may have higher than acceptable moisture contents and additional measures would be required to maximise their suitability for re-use which may include:

- Undertaking earthworks during summer months (when natural moisture contents of soils are lower and rainfall contributing to increased groundwater flow is limited);
- Spreading (to allow quicker drying of soils);
- Stockpiling (to include a capillary break layer beneath the stockpile and possibly supplemented by additional layers of granular fill to aid drainage);
- Lime modification by mixing imported lime with wet soils before compaction (feasibility would require determination by grading tests on in-situ soils).

Re-Use of Rock

Atkins stated that the bedrock encountered in Phase 1 (to the north-east of site) would be suitable for re-use if the filling took place in dry conditions. If filling is to be undertaken in wet weather, it was advised that the mudstone and siltstone lithologies may break down during placement. It was stated that any coal encountered would not be suitable for re-use.

Conclusions & Recommendations

The existing ground investigation information indicates that conditions across the site are highly

variable and moisture susceptible and that groundwater lies close to the surface. During the 2010 earthworks contract it was demonstrated that undertaking cut and fill operations during wet weather was not feasible.

Atkins made the following recommendations with regard to future cut and fill operations on the site:

- It is recommended that a temporary and permanent dewatering strategy is developed.
- Measures to maximise the suitability of site won fill materials should be considered and an earthworks strategy should be developed.
- Prior to any significant earthworks at the site enabling works should be carried out. The enabling works should comprise:
    - Trials and installation of a temporary drainage system to allow the future earthworks to be undertaken
    - Trials to confirm the feasibility of the earthworks strategy which may involve working in summer weather conditions, groundwater control, spreading, stockpiling, lime modification etc

It was suggested that enabling works are undertaken initially within the former Phase 1 development area with the intention that once a suitable strategy is developed it could subsequently be implemented in other areas of the site.

7.1.4 Issues Identified by WYG

The following discrepancies were noted by WYG when reviewing the three foregoing reports:

- Copies of the Stats Ltd (1989) and Exploration Associates (1975 & 1995) exploratory hole logs were not provided in any of the reports;
- The borehole log for WS03 in Figure A2.2 of the IFA February 2008 factual report was incomplete;
- Appendix 5 of the IFA February 2008 factual report contained the results of only 2 No. ground gas / groundwater monitoring visits (1st February and 15th February 2008) but Section 11.0 of the subsequent IFA March 2008 interpretative report refers to data from 2 No. additional visits (25th February and unknown date) which is not provided in either

report;

- Section 8.8 of the IFA March 2008 interpretative report gives an ACEC classification of AC-3z based on groundwater being mobile on-site before concluding that a DS-1 classification may be used in design. However, Table D1 of the BRE SD1 guidance document states that ACEC class AC3-z translates to DC-3z for developments with an intended working life of either 50 or 100 years;
- Appendix 5 from the IFA March 2008 interpretative report which relates to pile design was missing from the copy provided to WYG; and,
- The position of BH01 was missing from Atkins exploratory hole location plan Drawing No. 20082593/SM/32992.

8.0 PRELIMINARY GEOTECHNICAL RISK REGISTER

8.1 Introduction

This risk register is based on the initial desk study research contained within this report and has been related to a general assumption of the latest master planning layout. However, the risk register should be reviewed as the project design progresses.

8.2 Preliminary Geotechnical Considerations

In order to create areas suitable for development, a series of cut and fill plateaus will need to be constructed in the western part of the site. A previous earthworks trial undertaken at the site in the north-west corner demonstrated the issues associate with a shallow and complex groundwater regime in association with the variable Glacial Till soils. Controlling groundwater and the moisture content of the cut soils will be essential to maximise the quantity of soil that can be re-used as engineered fill. Groundwater control measures for both temporary and permanent construction phases will need to be development, as previously proposed by Atkins for the Phase 1 area (Drawing Number 5078488/WA/C 140 and presented in Appendix C).

Foundations options can only be developed once formation levels are determined. In areas of cut the firm to stiff Glacial Till or weathered bedrock are likely to be suitable foundation strata for traditional pad or strip footings, critically depending on structural loadings. Special consideration will need to be given to buildings that span cut and fill areas, to minimise differential settlement. Deeper foundations such as piles or ground improvement techniques cannot be discounted at this stage based on the current, limited development information.

Consultation with specialist contractors should be made following any further investigation works and development of detailed proposed site layouts and preliminary construction drawings

8.3 Preliminary Geotechnical Risk Register

The preliminary Geotechnical Risk Register has been compiled to show the degree of risk attached to various ground related aspects of the proposed development. The purpose of the register is to provide an assessment of the risk to the project posed by common ground related problems, and to identify suitable mitigation measures that would correct the risk to an acceptable level. The risk register should be developed and refined as the geotechnical design

and assessment progresses such that the register will allow the management of the geotechnical risks.

The inclusion of a risk in the register does not constitute as confirmation that the problem actually exists at the Site. A probability of "very unlikely" is indicative of a condition which the available data suggests should not be present. The calculated risk is not the risk that the impact will occur. It is the risk that mitigation will be required to enable the project to progress. For the purposes of this risk register the magnitude of each impact of the resulting severity of risk is measured against that which would could "normally" be expected for each element. Before incorporation into the risk register, the impacts and risks for each element should be moderated by an assessment of the cost and time implication of the individual mitigation measures.

The Geotechnical Risk Register has been developed in general accordance with the guidance presented in ICE/DETR Document "Managing Geotechnical Risk" (2001) and the HA documents HD41//03 and HD22/08. The degree of risk (R) is determined by combining an assessment of the probability (P) of the hazard occurring with an assessment of the impact (i) of the hazard and associated mitigation will cause if it occurs (R = P x i). The scale against which the probability and impact are measured, and the resulting degree of risk determined is presented below.

Probability	(P)
Very Likely (VLk)	5
Likely (Lk)	4
Plausible (P)	3
Unlikely (U)	2
Very Unlikely (VU)	1

X

Impact	(I)
Very High (VH)	5
High (H)	4
Medium (M)	3
Low (Lw)	2
Very Low (VLw)	1

=

(R)	Risk
20 – 25	Severe (Sv)
15 – 19	Substantial (Sb)
10 – 14	Moderate (Md)
5 – 9	Minor (Mn)
1 – 4	None / Negligible (N)

Risk Rating Matrix

	PROBABILITY				
IMPACT	**5 Very likely**	**4 Likely**	**3 Plausible**	**2 Unlikely**	**1 Very unlikely**
5 Severe	25	20	15	10	5
4 Substantial	20	16	12	8	4
3 Moderate	15	12	9	6	3
2 Minor	10	8	6	4	2
1 None / Negligible	5	4	3	2	1

	Site/ Ground Conditions	Hazard	Potential Impact	Before Control			Comments and Proposed Mitigation
				Probability of Hazard	Magnitude of Impact	Risk	
Earthworks to construction development plateaus	High groundwater levels. Preferential groundwater flow paths emanating from cut slopes	Ingress from cut faces and above plateau levels	Collapse of cut slopes, de-stabilise excavations, deterioration of site conditions and impact quality of recovered soils for re-use	5	5	20	Construction must include provision to control groundwater both during earthworks (temporary) and post construction (permanent). A hydrogeological risk assessment with a particular focus on de-watering should be undertaken. Additional field data will need to be collected to inform detailed design
	Poor ground conditions. Predominantly comprise variable, moisture content susceptible, glacial deposits	Site won materials not suitable for re-use as engineered fill without processing. Soils difficult to handle.	Excessive unusable materials requiring offsite disposal. Importation of fill materials	5	5	20	Additional measures will be required to maximise the suitability of the soils for re-use. Options include naturally drying soils (such as by spreading) or by lime modification. Site trials should be undertaken.
	Poor control of earthworks	Poor construction incorporating unsuitable materials	Risk of earthwork failure	5	4	20	Specification required with strict acceptability and compliance testing regime. Full time independent supervision (Resident Engineer) as works progress by experienced Geotechnical Engineer.
	Cut materials unsuitable for re-use.	Poor construction incorporating unsuitable materials	Risk of earthwork failure	5	4	20	On site laboratory for rapid test results. Experienced site staff and clear change control protocols to be stipulated.
	Low strength and variable ground conditions.	Potential for high total and differential settlements.	Use of piled foundations may be required.	5	4	20	Likely foundation solutions to be considered during the design of earthworks.
	Cut/battered slopes	Failure and collapse	Programme, cost, H&S	4	4	16	Designs to be checked. Strict on site checking and compliance regime to be implemented and monitored.
	Warren Dingle Steam	Protect watercourse	Construction pollution impacting watercourse. Development easement.	3	3	9	Contractors to adhere to implement pollution control measures. Designers to consider requirement for easement

	Poor weather conditions with high rainfall	Softening and runnelling of slope faces. Site won materials becoming too wet.	Failure and collapse. Programme delays and additional cost	4	3	12	Work being undertaken over drier summer months. Works to be suspended during periods of heavy rainfall .

9.0 SITE CONCEPTUAL MODEL AND PRELIMINARY GROUND CONTAMINATION RISK ASSESSMENT

9.1 Overview

The information presented in the previous sections of this report have been collated and evaluated to establish an initial qualitative risk assessment for the site. A conceptual model of the site has been generated based on information derived from this Phase 1 Geo-environmental Assessment, supplemented by information attained during the WYG site walkover.

The site has been considered with regard to current UK legislation and guidance, namely Part 2A of the Environmental Protection Act 1990 and the Contaminated Land (England) Regulations 2006, as amended, and in accordance with current UK good practice guidelines (for example BS10175: 2011).

In general, ground contamination can occur through several causes, particularly from historical operations and activities. Contamination can result from either on-site sources or from on-site migration from off-site sources, leading to long term liabilities under recent legislation for any site owner.

For a risk of pollution or environmental harm to occur as a result of ground contamination, all of the following elements must be present:

- Source, i.e. a substance that is capable of causing pollution or harm;
- Pathway, i.e. a route by which the contaminant can reach a target; and
- Receptor (target), i.e. something which could be adversely affected by the contaminant.

If one of these elements is absent there can be no significant risk. If all are present then the magnitude of the risk is a function of the magnitude and mobility of the source, the sensitivity of the receptor and the nature of the migration pathway.

9.2 Current Site Usage and Proposed Development

It is understood that the proposed development will involve a mixed commercial and residential

usage.

9.3 Conceptual Site Model

The key source, pathways and receptor model is outlined below within the context of potential development of the site.

As the proposed development is for a mixed commercial and residential purpose, the following risk assessment is undertaken in the context of a residential without plant uptake end use scenario to provide a conservative approach.

9.3.1 Potential Sources of Contamination

The main potential sources of contamination on the site are associated with existing features as well as historical land uses on the site as summarised below.

On-Site Sources

- Made Ground (specifically in the north-east) from historical usage, including registered landfill, mounds and gravelled area in the north-east, potentially infilled pond and demolition of former buildings;
- Use as a farm which may have given rise to in-ground contamination and / or impacted groundwater (potential storage of herbicides, pesticides, fuel, biohazards, (slurry and associated animal wastes) and asbestos containing materials; and,
- Ground gases from on-site landfill and potentially infilled ponds.

Off-Site Sources

Based on historical uses identified surrounding the site, it is considered that there are no additional potential off-site contamination sources other than those already designated as potential on-site sources. Therefore, off-site sources of the same contaminants have been discounted from further consideration.

9.3.2 Potential Contaminant Pathways

The following contaminant pathways are considered to potentially be active based on the current

site use and proposed development:

Human Exposure Pathways

- Direct dermal contact or ingestion of soils, or inhalation of dust and / or vapours (i.e. human interaction with surface and sub-surface materials).

Environmental Pathways

- Leaching and horizontal or vertical migration through the unsaturated ground, either through permeable sub-surface materials and / or preferential pathways;
- Lateral and vertical migration of groundwater through permeable sub-surface materials and / or preferential pathways;
- Leaching to surface water run-off / drainage;
- The migration and accumulation of gases or vapours through permeable sub-surface materials and / or preferential pathways.

9.3.3 Potential Receptors at Risk

The following potential receptors have been identified:

Human Health –

- Future site users (commercial and residential);
- Site workers during the redevelopment of the site; and,
- Adjacent site users (commercial and residential).

Wider Environment –

- Secondary A Aquifer within Glaciofluvial superficial and Gwespyr Sandstone deposits;
- Secondary Undifferentiated Aquifer within Glacial Till/Head superficial deposits and Bowland Shale Formation Mudstone;
- Surface waters (Warren Dingle); and,
- Building infrastructure and water supply pipes.

9.4 Ground Conditions Risk Assessment

The source, pathway, receptor linkages identified in the previous section are outlined and a

qualitative risk assessment shown in the following tables.

The risk assessment considers the site within an area context and assesses potential risks to identified receptors in relation to the existing site setting and the proposed development. CIRIA C552 has been used to define the risk rating presented in the Qualitative Risk Assessment matrix, the methodology for which is presented in Appendix E.

Table 12- CIRIA C552 Qualitative Risk Assessment

This matrix is based on CIRIA C552 risk evaluation methodology, definitions for risk ratings is presented in Appendix D						
Source	**Pathway**	**Receptor**	**Consequence of risk being realised**	**Probability of risk being realised**	**Risk Classification**	**Potential risk management requirements**
Onsite: Made Ground from historical usage.	Dermal contact, ingestion and/or inhalation of vapours or dusts.	Human Health Future Site Users (Residential)	Chronic risk to human health (Medium)	Low Likelihood	**Moderate/Low**	Surface will be covered by hardstanding or (where required) clean imported cover in residential gardens/soft landscaped areas post-development, which is likely to reduce the risk to Low. Ground investigation required to confirm ground conditions in residential development areas.
		Human Health Future Site Users (Commercial)		Unlikely	**Low**	It is likely that the commercial areas will be located within areas of mainly hardstanding with some managed landscaping. The probability of exposure is therefore limited.
		Human Health Construction/ Maintenance Workers		Unlikely	**Low**	The risk rating can be reduced/mitigated through use of Personal Protection Equipment (PPE) and appropriate working procedures.
	Leaching Lateral/Vertical migration of contaminants.	Surface Waters (Warren Dingle and Pond)	Pollution to sensitive controlled waters and ecosystems (Medium)	Low Likelihood	**Moderate/Low**	Limited mobile contaminants anticipated however, Glaciofluvial deposits onsite provide potential pathway for any that are present. This should be confirmed by an intrusive ground investigation.
		Groundwater (Secondary A Aquifer)		Low Likelihood	**Moderate/Low**	

On-Site: Current and historical agricultural usage.	Dermal contact, ingestion and/or inhalation of vapours or dusts.	Human Health Future Site Users (Residential)	Chronic risk to human health (Medium)	Low Likelihood	**Moderate/Low**	There is potential for contamination to be present in near surface soils. The surface should be covered by hardstanding or clean cover in gardens/soft landscape areas post development, where required, reducing the risk to Low. Ground investigation required to confirm ground conditions in residential development areas
		Human Health Future Site Users (Commercial)		Unlikely	**Low**	It is likely that the commercial areas will be located within areas of mainly hardstanding with some managed landscaping. The probability of exposure is therefore limited.
		Human Health Construction/ Maintenance Workers		Unlikely	**Low**	The risk rating can be reduced/mitigated through the use of Personal Protection Equipment (PPE) and appropriate working procedures.
	Leaching Lateral/Vertical migration of contaminants.	Surface Waters (Warren Dingle)	Pollution to sensitive controlled waters and ecosystems (Medium)	Low Likelihood	**Moderate/Low**	Limited mobile contaminants anticipated however, Glaciofluvial deposits onsite provide potential pathway for any that are present. This should be confirmed by an intrusive ground investigation.
		Groundwater (Secondary A Aquifer)		Low Likelihood	**Moderate/Low**	
On-Site: Radon Gas	Inhalation of vapours.	Human Health Future Site Users (Residential)	Chronic risk to human health (Severe)	Low Likelihood	**Moderate**	Further assessment of Radon risk by procuring site-specific BGS Radon Report to assist in breaking down existing Low to High risk rating for the whole site into zones for each rating. The risk can be reduced to Low through installation of basic radon protective measures within newly constructed dwellings as
		Human Health Future Site Users (Commercial)		Low Likelihood	**Moderate/Low**	

		Human Health Construction/ Maintenance Workers		Unlikely	**Moderate**	appropriate to their location in respective risk rating zones.
Ground Gas generated from On-Site & Off-Site Sources: Historical/Registered Landfill in the north east, former quarries & gravel pits to the north-west and potentially infilled pond.	Generation, migration and accumulation of ground gases.	Human Health Future Site Users (Residential)	Asphyxiation & Explosion (Severe)	Low Likelihood	**Moderate**	Landfill recorded onsite. The accumulation of ground gas presents a risk where enclosed buildings are constructed onsite. Ground gas monitoring is recommended with a CIRIA 662 compliant risk assessment to determine the requirement for ground gas protection measures within new dwellings.
		Human Health Future Site Users (Commercial)		Low Likelihood	**Moderate**	
		Buildings and Services	Explosion (Severe)	Low Likelihood	**Moderate**	

10.0 CONCLUSIONS AND RECOMMENDATIONS

10.1 Conclusions

10.1.1 Ground Contamination

The assessment has identified the potential for Made Ground from historical usage of part of the site as a landfill, mounding and gravel platform in the north-east of the site, isolated gravel pits to the north-west and from agricultural usage. Areas of significant Made Ground deposits are likely to be limited to the north-east / east of site. Potential contaminants include asbestos, PAH and metals.

The preliminary risk assessment identified a Low risk to Human Health (for commercial end use and maintenance workers. There is a Moderate/Low risk to Human Health (for residential end use, Surface Waters, and the Secondary A Aquifer.

A Moderate risk is considered to be posed by ground gas to residential and commercial users, buildings and services.

10.1.2 Geotechnical

The assessment has identified a likelihood of shallow groundwater being present on site that will require groundwater control during earthworks and construction excavations.

Ground conditions are generally suitable for the adoption of spread foundations bearing on firm natural clay and/or bedrock at shallow depth. Where conditions are laterally variable, or clay of sufficient strength is not present at shallow depth, trench fill foundations may be adopted. Deep foundations e.g. piles or ground improvement columns may be required in select areas where Made Ground deposits are of significant thickness (e.g. the north-east / east). Consultation with specialist contractors should be made following any further investigation works and development of detailed proposed site layouts and preliminary construction drawings.

The historic third-party ground investigation reports provided did not robustly assess all areas within the current development site boundaries, with the south and west only being sparingly investigated by Stats Ltd in 1989. Additional investigation is therefore required to enable sufficiently comprehensive assessment of development viability / options at the site. The required design specification for buried concrete also needs to be clarified due to discrepancies in historic third-party reporting.

Site won materials are considered unlikely to be suitable for re-use as engineered fill without processing. Site trials will be required to assess the options for dewatering and to assess the additional measures required to maximise the suitability of the soils for re-use.

10.2 Recommendations

It is recommended that the following further works be undertaken:

- Procurement of a site-specific Radon Report from the BGS to further refine Radon risk since it may be possible to designate different risk ratings (and therefore remedial requirements) to different areas of the site;
- Intrusive ground investigation within the proposed commercial development areas to the north-east, east and centre of site to supplement the historic data set (2008 investigation by IFA and 2009 investigation by Atkins) in relation to future detailed development layouts and groundwork requirements to establish development platforms;
- Intrusive ground investigation within the three proposed residential development areas to the north and south where historic data is both very limited (1989 investigation by Stats Ltd) and has not been made available to WYG;
- Installation of ground gas monitoring wells targeting the identified potential gas sources (former landfill to north-east, high Methane concentration recorded in 2008 by IFA at BH11 to north-east, former on-site gravel pits and off-site quarries to west and infilled pond) to further refine the existing ground gas risk assessment and assess the requirement for gas protection measures in new developments;
- A hydrogeological risk assessment with a particular focus on de-watering should be undertaken. Additional field data will need to be collected to inform detailed design and future groundwater control operations;
- Additional laboratory testing for pH levels & Sulphate concentrations across the development site to clarify the buried concrete design specification in accordance with BRE SD1 (2005) guidance;
- Re-assessment of historic pH & Sulphate data from the IFA 2008 ground investigation given the inaccuracy of Design Sulphate Class assessment in IFA's March 2018 G.I. report;
- Laboratory testing across the development site for the potential contaminants identified in the PCM to allow the undertaking of human health risk assessments for residential end use (in proposed housing areas to the north and south) and for commercial end use (in proposed hotel / leisure area to the north-east and proposed employment areas to the north-east, east and centre);

- Re-assessment of historic soil and groundwater chemical data using current published guidance to form part of the human health risk assessment; and,
- Site trials to assess the measures that will be required to maximise the suitability of the soils for re-use. Options to be assessed include naturally drying soils (such as by spreading) or by lime or cement modification.
- Development of an earthworks specification to be informed by hydrogeological assessment, further ground investigation and on site trials. This is likely to require a strict acceptability and compliance testing regime together with full time independent supervision (Resident Engineer) as works progress by experienced Geotechnical Engineer.

11.0 GLOSSARY

AOD	above Ordnance Datum
bgl	below ground level
BGS	British Geological Survey
BTEX	Benzene, Toluene, Ethylbenzene and Xylenes
C4SL	Category 4 Screening Levels
CIEH	Chartered Institute of Environmental Health
CLEA	Contaminated Land Exposure Assessment
CoC	Constituent of Concern
CSM	Conceptual Site Model
DEFRA	Department of Environment, food and Rural Affairs
DQRA	Detailed Quantitative Risk Assessment
DTS	Desktop Study
DRO	Diesel Range Organics
DWS	Drinking Water Standard
EA	Environment Agency (England)
EPH	Extractable Petroleum Hydrocarbons
EQS	Environmental Quality Standards
FOC	Fraction Organic Carbon
GPR	Ground Penetrating Radar
LOD	Limit of detection
LQM	Land Quality Management
NRW	Natural Resources Wales
OS	Ordnance Survey
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyl
PPE	Personal Protection Equipment
ppm	parts per million
PRO	Petroleum Range Organics
SGV	Soil Guideline Values
SOM	Soil Organic Matter
SVOC	Semi-volatile organic compounds
TPH	Total Petroleum Hydrocarbon
TSV	Tier 1 Screening Values
VOC	Volatile Organic Carbon
VPH	Volatile Petroleum Hydrocarbons

12.0 REFERENCES

British Geological Survey . (2018). *GeoIndex* . Retrieved from http://www.bgs.ac.uk/GeoIndex/

CIRIA. (2001). *Contaminated land risk assessment A guide to good practice.*

DEFRA. (2018). *MAGIC*. Retrieved from Magic Map: http://magic.defra.gov.uk/MagicMap.aspx

Envionment Agency . (March 2017). *New Groundwater Vulnerability Mapping Methodology in England and Wales. Reference SC040016/R.* Environment Agency .

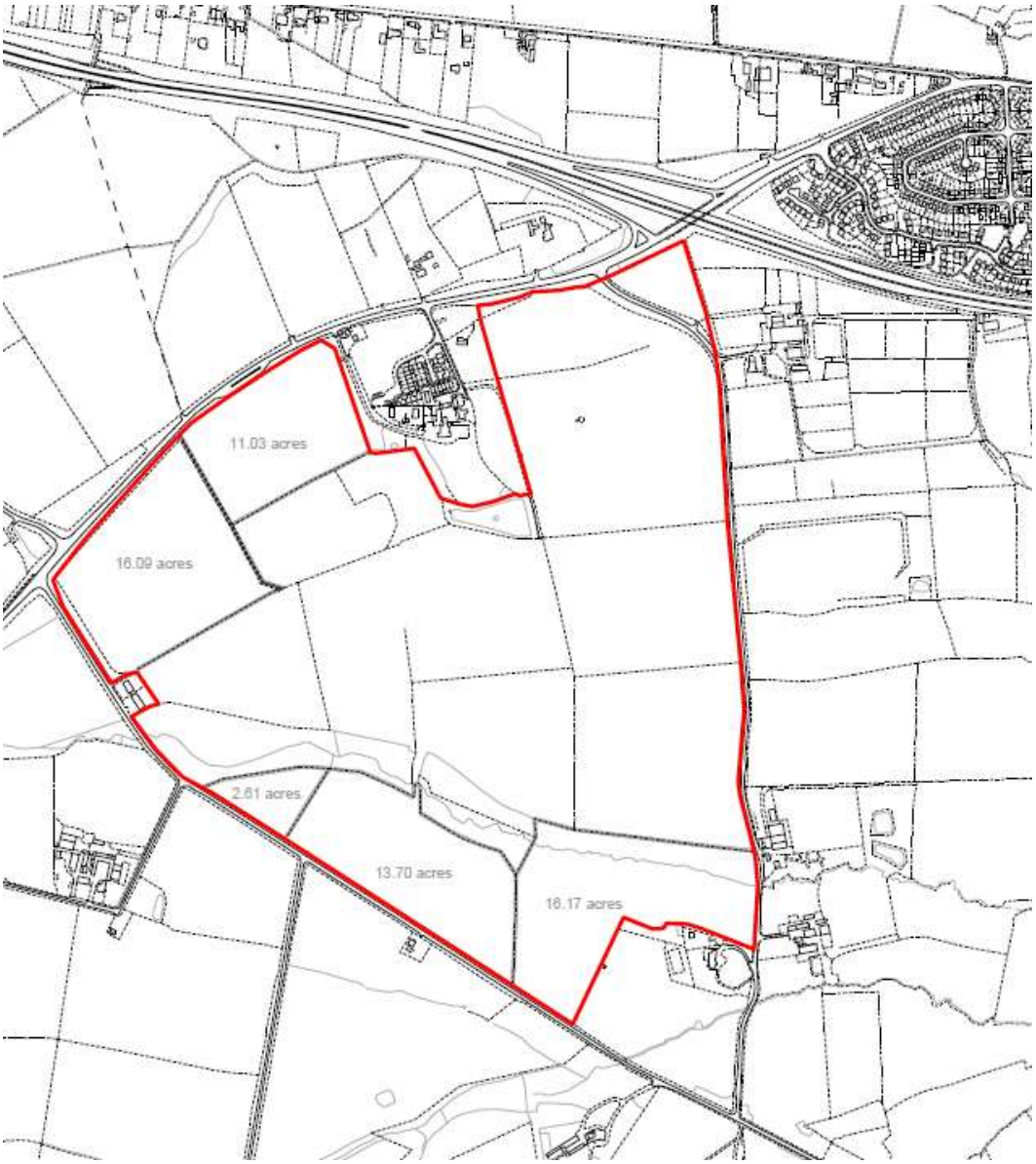
Environment Agency. (2008). *R&D Publication 66. Guidance for the Safe Development of Housing on Land Affected by Contamination.*

Scivyer, C. (2015). *BRE 211. Radon: Guidance on protective measures for new buildings (including supplementary advice for extensions, conversions and refurbisment projects). Fifth Edition. .* BRE.

The Coal Authority. (2018). *Coal Athority Interactive Viewer*. Retrieved from http://mapapps2.bgs.ac.uk/coalauthority/home.html

Zetica UXO. (2008). *Zetica UXO Risk Maps*. Retrieved from https://zeticauxo.com/downloads-and-resources/risk-maps/

FIGURES



Area of Proposed Extension

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Tel: 0161 872 3223
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Environmental Consultancy
Ground Technologies & Investigation

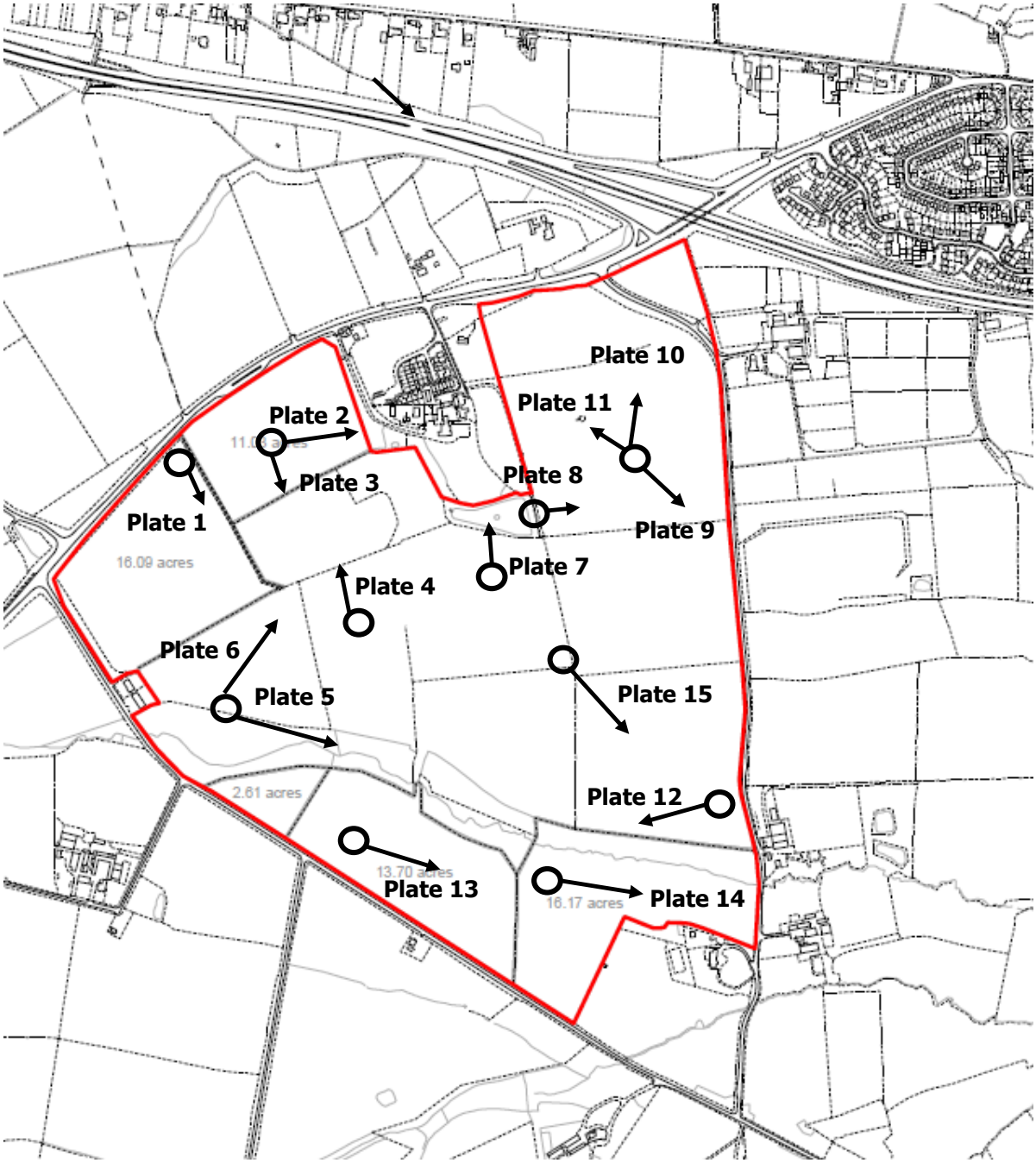
Project: Warren Hall, Broughton

Client: The Welsh Government

Figure 01 – Site Location Plan

Project No: A093950-15

Date: May 2019



Site Boundary

WYG ENVIRONMENT
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Client: The Welsh Government

Figure 02 – Site Layout and Walkover Photo plan

Project No: A093950-15

Date: May 2019

N

DO NOT SCALE: CONTRACTOR TO CHECK ALL DIMENSIONS AND REPORT ANY OMISSIONS OR ERRORS

KEY

- CURRENT DEVELOPMENT BOUNDARY
- PHASE 1 AREA
- PLATEAU A
- PLATEAU B
- PROPOSED EMPLOYMENT END USE
- PROPOSED HOTEL / LEISURE END USE
- PROPOSED RESIDENTIAL END USE

0 25 50 75 100 125 m

SCALE 1:2500

REV	DESCRIPTION	BY	CHK	APP	DATE

Client:

WELSH GOVERNMENT

QUAY WEST at MediaCityUK
TRAFFORD WHARF ROAD
TARFFORD PARK
MANCHESTER
M17 1HH
TEL: +44 (0)161 872 3223
e-mail: manchester@wyg.com

Project: A093950-15

WARREN HALL

Drawing Title:

ILLUSTRATIVE 2019 MASTERPLAN WITH HISTORIC DEVELOPMENT AREAS

Scale @ A1	Drawn Date	Checked Date	Approved Date
1:2,500	CM 16.05.19		

Project No.	Office	Type	Drawing No.	Revision
A093950-15	MAN	N	Figure 3 01	

APPENDICES

APPENDIX A – REPORT CONDITIONS

APPENDIX A - REPORT CONDITIONS
GEO-ENVIRONMENTAL DESK TOP REVIEW

This report is produced solely for the benefit of The Welsh Government and no liability is accepted for any reliance placed on it by any other party unless specifically agreed in writing otherwise.

This report refers, within the limitations stated, to the condition of the site at the time of the inspections. No warranty is given as to the possibility of future changes in the condition of the site.

This report is based on a study of readily accessible referenced historical records. Some of the opinions are based on unconfirmed data and information and are presented in good faith without exhaustive clarification. Where ground conditions are discussed but no physical site test results are available to confirm this, the report must be regarded as initial advice only, and further assessment should be undertaken prior to detailed activities related to the site. Where test results undertaken by others have been made available these can only be regarded as a limited sample.

Whilst confident in the findings detailed within this report because there are no exact UK definitions of these matters, we are unable to give categorical assurances that they will be accepted by Authorities or Funds etc. without question, as such bodies may have unpublished, often more stringent objectives. This report is prepared for the proposed uses stated in the report and should not be used in a different context without reference to WYG. In time improved practices or amended guidance may necessitate a re-assessment. The opinions expressed cannot be absolute due to the limitations of time and resources within the context of the agreed brief and the possibility of unrecorded previous use and abuse of the site and adjacent sites. The report concentrates on the site as defined in the report and provides an opinion on surrounding sites.

APPENDIX B – SITE WALKOVER PHOTO PLATES

Photo Plate No. 01: View from north-west looking south towards wooded area.

Photo Plate No. 02: Undulating fields in north west.

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Appendix B – Site Walkover Photo Plates

Project No.: A093950-15

Date: May 2019

Photo Plate No. 03: Woodland along Warren Dingle (stream).

Photo Plate No. 04 : Gravelhole Wood.

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Photo Plate No. 05: View along Warren Dingle to south-east.

Photo Plate No. 06 : Agricultural machinery in centre.

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Appendix B – Site Walkover Photo Plates

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Photo Plate No. 07: Pond in center of the site.

Photo Plate No. 08 : Arched structure to south of pond.

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Appendix B – Site Walkover Photo Plates

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Photo Plate No. 09: Mounds associated with earthworks in east of site.

Photo Plate No. 10 : Gravel filled land in the north east.

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Appendix B – Site Walkover Photo Plates

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Photo Plate No. 11: Active sewage bed in center/east of the site.

Photo Plate No. 12 : Warren Dingle in the west.

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Appendix B – Site Walkover Photo Plates

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Photo Plate No. 13: Agricultural fields.

Photo Plate No. 14 : Warren Dingle.

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Appendix B – Site Walkover Photo Plates

Project No.: A093950-15

Date: May 2019

Photo Plate No. 15: Agricultural fields.

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Appendix B – Site Walkover Photo Plates

Project No.: A093950-15

Date: May 2019

APPENDIX C – HISTORICAL RECORDS

See separate document

APPENDIX D – SITE SPECIFIC UXO PRE-DESK STUDY ASSESSMENT

UNEXPLODED BOMB RISK MAP

SITE LOCATION

Location: CH4 0SD,
Map Centre: 332349,362899

LEGEND

High: Areas indicated as having a bombing density of 50 bombs per 1000acre or higher.

Moderate: Areas indicated as having a bombing density of 15 to 49 bombs per 1000acre.

Low: Areas indicated as having 15 bombs per 1000acre or less.

miltary **industry** **UXO find**

transport **dock** **Luftwaffe targets**

utilities **other**

How to use your Unexploded Bomb (UXB) risk map?

The map indicates the potential for Unexploded Bombs (UXB) to be present as a result of World War Two (WWII) bombing.

You can incorporate the map into your preliminary risk assessment* for potential Unexploded Ordnance (UXO) for a site. Using this map, you can make an informed decision as to whether more in-depth detailed risk assessment* is necessary.

What do I do if my site is in a moderate or high risk area?

Generally, we recommend that a detailed UXO desk study and risk assessment is undertaken for sites in a moderate or high UXB risk area.

More often than not, this further detailed research will conclude that the potential for a significant UXO hazard to be present on your site is actually low.

Never plan site work or undertake a risk assessment using these maps alone. More detail is required, particularly where there may be a source of UXO from other military operations which are not reflected on these maps.

If my site is in a low risk area, do I need to do anything?

If both the map and other research confirms that there is a low potential for UXO to be present on your site then, subject to your own comfort and risk tolerance, works can proceed with no special precautions.

A low risk really means that there is no greater probability of encountering UXO than anywhere else in the UK.

If you are unsure whether other sources of UXO may be present, you can ask for one of our **pre-desk study assessments (PDSA)**

If I have any questions, who do I contact?

tel: **+44 (0) 1993 886682**

email: **uxo@zetica.com**

web: **www.zeticauxo.com**

The information in this UXB risk map is derived from a number of sources and should be used in conjunction with the accompanying notes on our website: **(https://zeticauxo.com/downloads-and-resources/risk-maps/)**

It is important to note that this map is not a UXO risk assessment and should not be reported as such when reproduced.

*Preliminary and detailed UXO risk assessments are advocated as good practice by industry guidance such as CIRIA C681 'Unexploded Ordnance (UXO), a guide for the construction industry'.

APPENDIX E – ENVIROCHECK REPORT

See separate document

APPENDIX F – CIRIA C552 RISK METHODOLOGY

The following tables are derived from CIRIA C552 and have been used to define the risk rating presented in the Qualitative Risk Assessment matrix.

Classification of consequence

Classification	Definition
Severe	Short term (acute) risk to human health likely to result in 'significant harm' as defined by the Environment Protection Act 1990, Part IIA. Short term risk of pollution (note; Water Resources Act contains no scope for considering significant pollution) of sensitive water resource. Catastrophic damage to building/property. A short-term risk to a particular ecosystem, or organism forming part of such ecosystem. (Note the definitions of ecological systems within the Draft Circular on Contaminated Land DETR, 2000).
Medium	Chronic damage to human health ('significant harm', as defined In DETR, 2000). Pollution of sensitive water resources (note; Water Resources Act contains no scope for considering significant pollution). A significant change in a particular ecosystem, or an organism forming part of such an ecosystem. (Note the definitions of ecological systems within the Draft Circular on Contaminated Land DETR, 2000).
Mild	Pollution of non-sensitive water resources. Significant damage to crops, buildings, structures and services ('significant harm', as defined In DETR, 2000). Damage to sensitive buildings/structures/services or the environment.
Minor	Harm, although not necessarily significant harm, which may result in a financial loss, or expenditure to resolve. Non-permanent health effects to human health (easily prevented by means such as personal protective clothing etc). Easily repairable effects of damage to buildings, structures and services.

Classification of probability

Classification	Definition
High likelihood	There is a pollution linkage and an event that either appears very likely in the short term and almost inevitable over the long term or there is evidence at the receptor of harm or pollution.
Likely	There is a pollutant linkage and all the elements are present and in the right place, which means that it is probable that an event will occur. Circumstances are such that an event is not inevitable, but possible in the short term and likely over the long term.
Low likelihood	There is a pollution linkage and circumstances are possible under which an event could occur. However, it is by no means certain that even over a longer period that such an event would take place, and is even less likely in the shorter term.
Unlikely	There is a pollution linkage but circumstances are such that it is improbable that an event would occur even in the very long term.

Matrix of consequence against probability to gain a risk classification

		Consequence			
		Severe	**Medium**	**Mild**	**Minor**
Probability	**High Likelihood**	Very High Risk	High Risk	Moderate Risk	Moderate/Low Risk
	Likely	High Risk	Moderate Risk	Moderate/Low Risk	Low Risk
	Low likelihood	Moderate Risk	Moderate/Low Risk	Low Risk	Very Low Risk
	Unlikely	Moderate/Low Risk	Low Risk	Very Low Risk	Very Low Risk