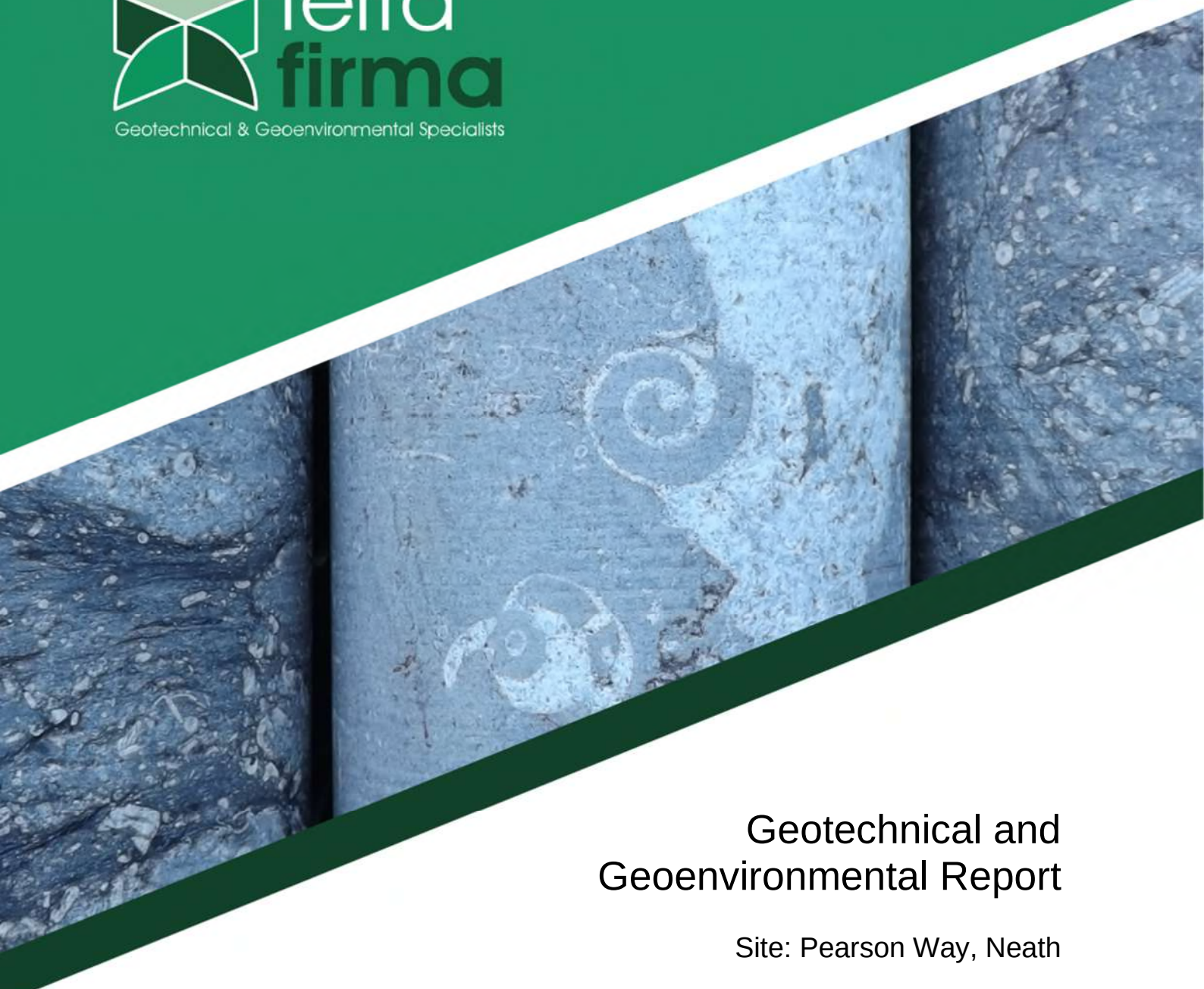




Geotechnical and Geoenvironmental Report

Site: Pearson Way, Neath

Prepared For: Wellspring Property and Investments Ltd

Issue Date: April 2022

Job No: 16819

REPORT TITLE : **Geotechnical and Geoenvironmental Report:
Proposed Development, Pearson Way, Neath**

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Executive Summary

Site Location and Proposed Development	<i>The development site is rectangular in shape and locates at Pearson Way, Neath, SA11 2EJ. The site centres on an approximate National Grid Reference of 274640 195700, occupying a plan area of approximately 0.25 Hectares. The proposed development is residential in nature.</i>
Site History	<i>The site has remained as undeveloped land, however it has been the subject of cut and fill exercises.</i>
Geology	<i>The site is underlain by the Hughes Member of the Upper Coal Measures strata of Carboniferous Age. The conjectural outcrop of the Mountain Coal seam is shown close to the west of the site. Due to the topography of the area this seam will underlie the site at shallow depth. No superficial deposits are shown to overlie the solid geology, however residual soils are likely to be present.</i> <i>Significant made ground/reworked materials are likely to overlie the in-situ deposits.</i>
Radon	<i>No radon protective measures are required for new developments on the investigation site.</i>
Coal Mining Risk Assessment	<i>The site situates within the South Wales coal fields. The Coal Authority CONM29M Coal Mining Report states that the property is not within a surface area that could be affected by any past recorded underground coal mining.</i> <i>However, the property is in an area where the Coal Authority believes there is coal at or close to the surface. This coal may have been worked at some time in the past.</i> <i>The seam referred to is the Mountain seam which is estimated to lie between 25m and 45m beneath the site. This seam is thin and intermittent with no historical evidence of it being worked beneath the site. The risk is therefore concluded to be low. This low risk can be negated by the use of appropriate foundations.</i>
Ground Conditions	<i>Ground conditions encountered during investigation beneath the site shows re-worked till deposits of a generally firm and stiff consistency down to a maximum 3.7m depth.</i>
Contamination of Concern	<i>There were no contaminants of concern encountered during the ground investigations.</i>
Ground Gas Risk Assessment	<i>Gas monitoring has placed the site in Gas Characteristic Situation 2 (GCS 2), requiring gas protective measures. Protection measures should be designed and validated.</i>
Foundation Solution	<i>A reinforced concrete raft on 1.0m of recompacted ground is recommended. Depending upon the finished floor slab levels it may be economic to construct a reinforced box construction incorporating an integral reinforced concrete retaining wall and floor slab.</i> <i>In order to negate the low mining risk, the raft should be designed to span a crown hole of 3m with a cantilever effect on corners of 1.5m.</i>

TABLE OF CONTENTS

SECTION 1 Introduction and Proposed Development	1
1.1 Introduction	1
1.2 Limitations and Exceptions of Investigation	1
1.3 Quality Assurance	2
SECTION 2 Review of Existing Data	3
2.1 Physical Setting and Current Site Use	3
2.2 Site History	4
2.3 Geological Setting	5
2.3.1 Geology	5
2.3.2 Radon	5
2.3.3 Mining	5
2.3.4 Natural Hazards	5
2.4 Environmental Setting	6
2.4.1 Hydrogeology	6
2.4.2 Hydrology	6
2.4.3 Flooding	6
2.4.4 Waste	6
2.4.5 Pollution	6
2.4.6 Sensitive Land Use	6
2.4.7 Measured Urban Soil Chemistry	7
2.4.8 Industrial Land Use	7
2.4.9 Infilled Land	7
SECTION 3 Coal Mining Risk Assessment	8
3.1 Geotechnical Risk	8
3.1.1 Underground Mining	8
3.1.2 Shafts & Adits	9
3.1.3 Conclusion	9
3.2 Geoenvironmental Risk	9
3.2.1 Mine Gas Risk Assessment	9
SECTION 4 Preliminary Human Health and Environmental Risk Assessment	10
4.1 General	10
4.2 Potential Sources of Contamination	10
4.3 Potential Pollution Pathways	10
4.4 Potential Receptors	11
4.5 Preliminary Conceptual Site Model	11
SECTION 5 Field Investigation	13
5.1 Site Works	13
5.2 Ground Conditions	13
5.3 Groundwater	14
5.4 Stability and Obstructions	14
5.5 Installation Well Construction	14
5.6 Laboratory Chemical Testing	14
5.6.1 Sampling Strategy	14
5.6.2 Soil Laboratory Analysis	15
5.7 Soil Property Testing	15
5.7.1 In-situ Permeability Testing	15

SECTION 6 Evaluation of Geoenvironmental Analytical Results	16
6.1 Assessment Methodology	16
6.2 Soil Test Results	16
6.2.1 Inorganics & Miscellaneous	16
6.2.2 Organics	17
6.2.3 Asbestos Testing	18
SECTION 7 Ground Gas Risk Assessment	19
7.1 Gas Risk Characterisation	19
7.1.1 Gas Source	19
7.1.2 Gas Migration Pathways	19
7.1.3 Potential Receptors	19
7.2 Gas Screening Value	19
7.3 Conclusion	20
SECTION 8 Quantitative Risk Assessment	21
8.1 Contaminants of Concern	21
8.2 Mitigation and Remedial Measures	21
8.2.1 Human Health	21
8.2.2 Ground Gas	22
8.2.3 Aquatic Environment	22
SECTION 9 Engineering Recommendations	23
9.1 Preparation of Site	23
9.2 Foundation and Floor Slab Solution	23
9.3 Excavations and Formations	24
9.4 Protection of Buried Concrete	24
9.5 Access Roads and Car Parking Areas	25
9.6 Storm Water Drainage	25
9.7 Retaining Walls	25
Tables	
Table 2.1 Historical Development from Map Information	4
Table 2.2 Detailed Stratigraphical Information	5
Table 2.3 BGS Recorded Mineral Sites	5
Table 2.4 Relevant Contemporary Trade Summary	7
Table 2.5 Potentially Infilled Land	7
Table 3.1 Stratigraphical Sequence	8
Table 4.1 Contamination Sources	10
Table 4.2 Preliminary Conceptual Site Model	12
Table 5.1 Summary of Typical Ground Conditions	13
Table 5.2 Groundwater Summary	14
Table 5.3 Installation Well Summary	14
Table 5.4 Sample Locations, Depths and Targets	14
Table 5.5 Soil Laboratory Analysis	15
Table 5.6 Summary of Soakaway Results	15
Table 6.1 Summary of Soil Chemical Test Results – Inorganics & Miscellaneous	16
Table 6.2 Summary of Soil Chemical Test Results – Speciated Polycyclic Aromatic Hydrocarbons and Phenol	17
Table 6.3 Summary of Soil Chemical Test Results – Petroleum Hydrocarbons	18
Table 7.1 Measured Gas Concentration Summary	19
Table 9.1 Effective Shear Stress Parameters	25

Figures

Figure 2.1 Site Location	3
Figure 3.2 Sheet SS 79 NW Geological Map	8
Figure 3.3 Site levels detail	8

Annexes

Annex A Envirocheck Report
Annex B Coal Authority Mining Report
Annex C Risk Assessment Definitions
Annex D Windowless Sampling Borehole and Trial Pit Logs
Annex E Soil Laboratory Chemical Test Results
Annex F Gas Monitoring Results

Drawings

Drawing 01 Proposed Site Layout

SECTION 1 Introduction and Proposed Development

1.1 Introduction

Wellspring Property and Investment Limited (the Client) is proposing the development of residential housing at Pearson Way, Neath.

PHG Consulting is the Consulting Civil and Structural Engineer for the development.

Terra Firma (Wales) Limited has been commissioned by PHG Consultant Engineers Ltd on behalf of the Client to undertake a geoenvironmental assessment and geotechnical investigation of the site.

The main objectives of the geoenvironmental assessment programme are:

- Investigate the potential human health and environmental liabilities at the site associated with any contamination
- Provide a summary of the human health and environmental conditions at the site, together with any necessary further intrusive works and / or remediation works to render the site fit for its intended use

The main objectives of the geotechnical site investigation are:

- Investigated the type, strength and bearing characteristics of the shallow superficial and underlying solid geology
- Investigate the risk, if any, from historical shallow underground mining features
- Provide engineering foundation and floor slab recommendations for the proposed development
- Provide infiltration rates and stormwater drainage viability.
- Provide recommendations regarding any other geotechnical aspects pertaining to the development

In order to achieve the above objectives, Terra Firma (Wales) Limited carried out an assessment programme including a review of existing data, followed by a field investigation to collect geotechnical and geoenvironmental data from selected locations.

1.2 Limitations and Exceptions of Investigation

The Client has requested that a Geoenvironmental Site Assessment (GSA) and Geotechnical Investigation (GI) be performed to enable the outlined main objectives.

The GSA and GI were conducted, and this report has been prepared for the sole internal reliance of the Client and their design and construction team. This report shall not be relied upon or transferred to any other parties without the express written authorisation of Terra Firma (Wales) Limited. If an unauthorised third party comes into possession of this report, they rely on it at their peril and the authors owe them no duty of care and skill. The report represents the findings and opinions of experienced geoenvironmental and geotechnical consultants. Terra Firma (Wales) Limited does not provide legal advice and the advice of lawyers may be required.

The subsurface geological profiles, any contamination and other plots are generalised by necessity and have been based on the information found at the locations of the exploratory holes and depths sampled and tested.

Excavation in the far west of the site was not possible on account of buried services

1.3 Quality Assurance

The quality and environmental aspects of the assessment comply with Terra Firma Wales Ltd business management system which is UKAS Accredited to ISO 9001:2015 and ISO 14001:2015 standards.

SECTION 2 Review of Existing Data

2.1 Physical Setting and Current Site Use

The development site is rectangular in shape and locates at Pearson Way, Neath, SA11 2EJ. The site centres on an approximate National Grid Reference of 274640 195700, occupying a plan area of approximately 0.25 Hectares.

The site is currently empty brownfield space. Vegetation covers the whole of the site. The site is a steep slope inclining towards the west.

The northern and southern boundaries of the site are defined by residential housing and their gardens. The eastern boundary of the site is defined by Pearson Way Road. A public footpath is located adjacent to the east of the site.

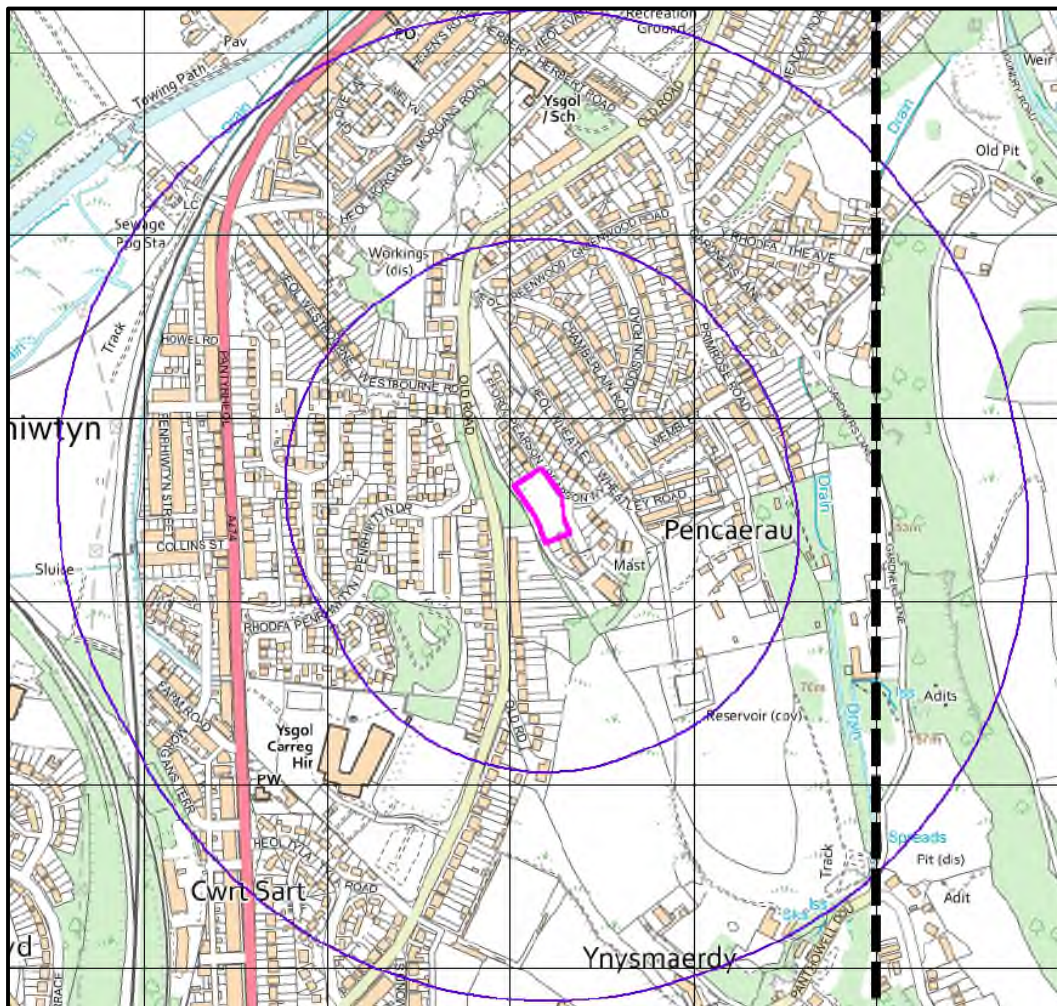
The wider surrounding area is predominantly residential housing with empty greenfield space.

The site elevation is approximately 55 to 45m AOD steeply sloping down to the west. A steep drop off is situated in the northwest of the site.

The site location can be seen on

Figure 2.1 along with the proposed site layout on **Drawing 01**.

Figure 2.1 Site Location



2.2 Site History

Historical maps of the site have been obtained in an Envirocheck Report, provided by Landmark Information Group. The history plans are supplied in **Annex A** of this report, and the most relevant editions are summarised in **Table 2.1**. Distances where quoted are approximate, and any changes in-between map editions may not be recorded

Table 2.1 Historical Development from Map Information

Map Edition & Scale	Key Features on Site	Key Features off Site
1878 -1882 1:2500	The site is part of an empty greenfield space. A track runs along the site's western boundary.	The site is surrounded by empty greenfield space. Houses of Mansell Terrace lie nearby to the southeast. An old Quarry is shown 170m north of the site.
1899 1:2500 1900 1:10,000	No significant changes.	More quarrying has taken place to the north. The gardens of Mansell Terrace are becoming more established. In the wider area to the north and west residential and commercial development has occurred.
1918 -1919 1:2500	The formation of a level plateau by a cut and fill exercise has taken place in the south of the site	An old coal level heading in a north easterly direction is shown to be present 150m south of the site. 'New Graded' Infirmary has been constructed to the west.
1935 – 1941 1:2500	No Significant changes are evident.	Significant residential development has occurred in the surrounding area. New Grade Infirmary is now known as Penrhiwtyn Infirmary.
1951 1:1250	The earth to the south of the site has been levelled. A slope is shown in the southern corner of the site and along the western boundary of the site.	Residential houses 50m northeast at Wheatley Road are now present. Further residential and commercial development has occurred in the surrounding area. Penrhiwtyn Infirmary has increased significantly size and is now known as Neath General Hospital.
1958 – 1967 1:1250	Earthworks are shown in the northeast corner of the site. Mapping indicates a level plateau has been constructed but a cut and fill exercise.	No significant changes.
1964:1970 1:2500	No significant changes.	No significant changes.
1979-1989	No significant changes.	Development has occurred at Neath General Hospital to the west of the site.
1993 1:2500 1992 – 1996 1:10,000	No significant changes.	No significant changes.
2006 1:10,000	No significant changes since previous map additions.	The whole of Neath General Hospital has been demolished and this is now an empty space.
2021 1:10,000	The site is shown to be flat and level.	Residential development has occurred in the immediate sounding area. Including adjacent houses north, south and west of Pearsons Way.
Historical Google Earth Satellite Imagery.		
2002 -	The site is empty greenfield space. Evidence of mounds of material is evident at the site and wider field.	
2006	A track runs through the site. The houses west of the site are in development and a cut exercise has taken place into the hill side.	
2013	The houses north of the site are now in development. Earth has been moved and mounded onto the site itself.	
2016	Construction of 3No Houses at the northern end of Pearson Way is nearing completion. Cut earthworks exercises for the garden areas are evident. The site is now a sloping grass field.	

2.3 Geological Setting

2.3.1 Geology

The 1:10,000 scale British Geological Map of the area (SS 79 NW) was consulted for geology underlying the site. The site is shown to be underlain by sandstone rock. Detailed stratigraphical information is provided in **Table 2.2**.

Table 2.2 Detailed Stratigraphical Information

Period	Group	Formation
Carboniferous		Hughes Member – Described as “Green-grey, lithic arenites (“Pennant sandstones”), with thin mudstone/siltstone and seatearth interbeds, and mainly thin coals.”
		The conjectured outcrop of the Mountain Coal Seam is shown to the west of the site. Due to the topography of the area this seam will underlie the site at relatively shallow depth.

Superficial deposits are not recorded at the site.

Made ground is anticipated at the site to an unknown depth in relation to historical earthworks.

2.3.2 Radon

The Envirocheck Report (**Annex A**) details that **NO** radon protective measures are required for new developments on the investigation site.

2.3.3 Mining

The site situates within the South Wales coal fields. The Coal Authority CONM29M Coal Mining Report states that the property is not within a surface area that could be affected by any past recorded underground coal mining.

However, the property is in an area where the Coal Authority believes there is coal at or close to the surface. This coal may have been worked at some time in the past.

There are no recorded coal mine entries known to the Coal Authority within, or within 20m, of the boundary of the property.

The Coal Authority has no record of a mine gas emission requiring action.

Relevant BGS mineral sites as recorded in the Envirocheck Report datasheets (**Annex A**) are summaries in **Table 2.3**.

Table 2.3 BGS Recorded Mineral Sites

Site Name	Distance/ Direction from site	Type	Commodity
Garth-Mor	146m South	Underground	Coal -Deep
Pen-Rhiw-Tyn	172m North	Opencast	Sandstone

The Coal Authority Consultants Coal Mining Report is appended in **Annex C**.

2.3.4 Natural Hazards

All natural hazards within the Envirocheck report are described as a very low hazard or no hazard.

2.4 Environmental Setting

The following sections have been compiled using the Landmark Information Group Envirocheck datasheet and maps which can be found in **Annex A**.

2.4.1 Hydrogeology

The bedrock deposits beneath the site have an aquifer designation of secondary aquifer – A.

Deep groundwater flow within the underlying bedrock will be controlled by the strata dip and any fractures or bedding planes within the rock units.

The hydraulic gradient will be at its steepest during periods of heavy rainfall and aquifer recharge.

The site does not locate within a groundwater source protection zone.

The nearest groundwater abstraction point is located 1989m away and will not be affected by the site.

2.4.2 Hydrology

The nearest surface water feature locates off site, 269m to the east and comprises a drain.

The topography of the site slopes down towards to the west. Surface water is likely to drain in this direction.

2.4.3 Flooding

The site is not at risk from extreme flooding from rivers or sea.

2.4.4 Waste

No Historical or Recorded landfill sites are shown to be situated within 250m of the site

One licensed waste management facility is situated 109m west, situated at Pant Yr Heol, Neath, NPT SA11 and operated by Glan Y Mor NHS Trust. This facility is likely concerning an operation at the old Neath hospital now demolished. The license is surrendered, this should not affect the site.

Two waste Transfer sites are recorded 221m southwest, these are again relating to Neath General Hospital, and will no longer affect the site.

No discharge consents are shown to be situated within 250m of the site.

2.4.5 Pollution

No pollution incidents are recorded to have occurred within 250m radius of the site.

2.4.6 Sensitive Land Use

The site is not located within a sensitive land use area.

2.4.7 Measured Urban Soil Chemistry

The BGS have published measured urban soil chemistry concentrations locally to the site for a number of common contaminants, i.e. arsenic, cadmium, chromium, lead and nickel.

The site is shown to lie within an area where high Arsenic levels are typically encountered. 35-45mg/kg with a Threshold value of 37mg/kg. Arsenic contamination may be present at the site.

All other given determinants have anticipated concentrations that are below the recognised trigger levels for a residential with plant uptake scenario.

2.4.8 Industrial Land Use

Relevant contemporary trade directory entries recorded within proximity of the site are summarised in **Table 2..**

Table 2.4 Relevant Contemporary Trade Summary

Company	Distance/Direction from site	Classification	Status
Neath general Hospital	163	Hospitals	Inactive

2.4.9 Infilled Land

Potentially infilled land features within 250m of the site are summarised in **Table 2..**

Table 2.5 Potentially Infilled Land

Feature	Distance/Direction from site
Infilled Land (Non-Water) Unknown Filled Ground (Pit, quarry etc)	162m South
Infilled Land (Non-Water) Unknown Filled Ground (Pit, quarry etc) – Shown to be relating to the historical sandstone quarry	163m Northwest

However, historical mapping for the site show that infill has taken place historically at the site. Additionally, fill is shown to have been placed on site from recent nearby residential development.

SECTION 3 Coal Mining Risk Assessment

3.1 Geotechnical Risk

3.1.1 Underground Mining

Based upon geological map data, the stratigraphical sequence within 50m of the ground surface of the site is illustrated in

Figure 3.2 Sheet SS 79 NW Geological Map

Figure 3.3 Site levels detail

Table 3.1 Stratigraphical Sequence

Holocene	Residual Soils & Fill	2-6m
South Wales Lower Coal Measures	Coal Bearing Sandstone with occasional Mudstone/Siltstone bands	25-45m
	COAL - "Mountain" primarily two "thin" coal seams.	25-45m

Figure 3.2 Sheet SS 79 NW Geological Map



Figure 3.3 Site levels detail



As previously stated, the Coal Authority Report reports that the property is not within a surface area that could be affected by any past recorded underground coal mining. However, the property is in an area where the Coal Authority believes there is coal at or close to the surface. This coal may have been worked at some time in the past.

Geological map evidence indicates that the Mountain coal seam lies approximately 30m to the west. Generally, geology within the area is dipping 15° to the northeast.

Map contours show the mountain coal seam to lie at approximately 125m AOD. Topographically the site drops steeply towards the west and the level of the site is shown to be 150-160m AOD. The coal seam is therefore anticipated to lie 25-to 45m depth below the site.

The mountain coal seam is shown as primarily two thin coal seams.

3.1.2 Shafts & Adits

The Coal Authority Report (presented in **Annex B**) states there are no known mine entries within 20m of the site.

Geological mapping shows that the presence of an 'old coal level' first recorded on the 1918/19 1:2500 OS map, 146m to the south. This level was not recorded on the previous 1899 edition so had a short operating life, an indication of either poor geological conditions or poor quality coal. The recorded rock strata is Hughes Sandstone, a strong and competent rock. It is therefore likely that the old coal level was a trial abandoned due to inferior coal. The geological maps Generalised vertical section shows the Mountain seam to be thin in two leaves and intermittent in nature. The historical maps also show no mining features such as adits or shafts that could have affected the site.

3.1.3 Conclusion

The overall risk to the surface stability of the site from possible unrecorded workings is considered low. This low risk can be negated by the use of an appropriate foundation/floor slab solution as recommended in **Section 9.2**.

3.2 Geoenvironmental Risk

3.2.1 Mine Gas Risk Assessment

Gas monitoring is taking place at the site due to the deep made ground of unknown nature expected at the site. This monitoring will also detect any mine related gases.

SECTION 4 Preliminary Human Health and Environmental Risk Assessment

4.1 General

The preliminary human health and environmental risk assessment is a qualitative evaluation of unacceptable risks to human health or the environment from potential 'contaminated land', based on reviewed information in preceding sections of this report.

For 'contaminated land' to exist as defined in Part 2A of the Environmental Protection Act (EPA) 1990, a Pollutant Linkage needs to be identified. Pollutant linkages are defined by having a valid 'source – pathway – receptor' as established in the preliminary conceptual site model.

For our definitions of pollution linkage and how we define risk please refer to **Annex B** which includes our classifications of consequence and probability, and risk assessment matrix.

4.2 Potential Sources of Contamination

Potential or known sources of contamination associated the sites current and historical land use are summarised in **Table 4.1**.

Table 4.1 Contamination Sources

ID	Source	Contaminant
S1	Made Ground	Potentially metals, hydrocarbons, PAH, asbestos, sulphates
S2	Contaminated Groundwater	
S3	Made ground/infilled land	Carbon dioxide and methane
S4	Possible mine workings beneath the site	Carbon dioxide and methane
S5	Aggressive Ground Conditions	Soil pH and sulphate levels may affect construction concrete

No other significant potential on-site or off-site sources of contamination have been identified during the desk study.

4.3 Potential Pollution Pathways

Potential contaminant pathways associated with a residential with home grown produce land use are as follows.

- P1 – Direct soil ingestion
- P2 – Dermal contact with soil
- P3 – Inhalation and ingestion of soil dust
- P4 – Consumption of home grown produce
- P5 – Dermal contact with groundwater
- P6 – Inhalation of asbestos fibres
- P7 – Horizontal and vertical migration and inhalation of ground gas
- P8 – Horizontal and vertical migration and inhalation of mine gas
- P9 – Absorption of contaminants into potable water pipes
- P10 – Vertical migration of leachates (unsaturated zone)
- P11 – Surface run-off
- P12– Horizontal and vertical migration of contaminants (saturated zone)
- P13 – Direct contact with construction materials

4.4 Potential Receptors

There are human and hydrological receptors to any contamination that may be present on site. Potential receptors include.

- R1 – Construction and maintenance workers
- R2 – Future site users (residents)
- R3 – Passers-by or neighbouring site users
- R4 – Groundwater (aquifer)
- R5 – Surface waters (river/lake)
- R6 – Construction materials (concrete/potable water pipes)

4.5 Preliminary Conceptual Site Model

The preliminary conceptual site model establishes potential pollutant linkages between contaminants (source), pathways and receptors, realised during the preparation of the desk study report. Where a potential pollutant linkage is identified an assessment of risk is subsequently undertaken. The preliminary conceptual site model is tabulated in **Table 4.2**.

Outcomes of the preliminary conceptual site model are used as a basis for the design and implementation of the site investigation, whereby areas of potential contamination can be targeted as well as investigating the wider site.

Findings of the site investigation can in turn be used to develop and refine the conceptual site model.

Table 4.2 Preliminary Conceptual Site Model

Source	Pathway	Receptor	Preliminary Risk Assessment		
			Consequence	Probability	Risk
Human Health					
Made Ground S1	Direct soil and dust ingestion P1 Dermal contact with soil P2 Inhalation and ingestion of dust P3 Dermal contact with groundwater P5 Inhalation of asbestos fibres P6	Construction and maintenance workers R1	Medium	Likely	Medium Risk - COSHH assessment and good level of PPE/ hygiene by site workers/ staff; dust suppression measures if required. Suitably designed site investigation recommended
Made Ground S1	Inhalation and ingestion of dust P3	Passers-by or neighbouring site users R3	Medium	Unlikely	Low Risk - Dust suppression measures if required.
Made Ground S1	Inhalation of asbestos fibres P6	Passers-by or neighbouring site users R3	Medium	Unlikely	Low Risk - Dust suppression measures if required.
Made Ground S1	Direct soil and dust ingestion P1 Dermal contact with soil P2 Inhalation and ingestion of dust P3 Consumption of home grown produce P4	Future site users (residents) R2	Medium	Likely	Medium Risk - Suitably designed site investigation recommended
Made Ground S1	Inhalation of asbestos fibres P6	Future site users (residents) R2	Medium	Likely	Medium Risk - Suitably designed site investigation recommended
Made ground/Infilled Land S3	Migration and inhalation of ground gas P7	Future site users (residents) R2	Severe	Likely	Medium Risk –High volumes of made ground on site evident.- assessed through gas monitoring
Mine Workings S4	Migration and inhalation of mine gas P8	Future site users (residents) R2	Severe	Unlikely	Low Risk – Underground mining unlikely beneath the site. Assessed through gas monitoring
Contaminated Groundwater S2	Dermal contact with groundwater P5	Future site users (residents) R2	Medium	Unlikely	Low Risk
Aggressive ground conditions S5	Direct contract with construction materials	Construction materials (concrete) R7	Mild	Low Likelihood	Low Risk
Aquatic Environment					
Contaminated Soils S1	Vertical migration of leachates (unsaturated zone) P10	Groundwater R4 Surface waters R5	Mild	Low Likelihood	Low Risk
Contaminated Groundwater S2	Surface run-off P11	Surface waters R5			
	Horizontal and vertical migration of contaminants (saturated zone) P12				

SECTION 5 Field Investigation

5.1 Site Works

A geotechnical and geo-environmental site investigation comprising 3No Window Sampling Boreholes was undertaken on 28th of June 2021. Additionally, three trial pits were performed on 13th April 2022.

The fieldwork was supervised by Terra Firma (Wales) Limited, who logged the exploratory holes to the requirements of BS 5930:2015+A1:2020. The proposed locations of the exploratory holes were determined by Terra Firma (Wales) Ltd in general accordance with BS 10175:2011+A2:2017 in order to assess the findings of the preliminary conceptual site model.

The boreholes referenced WS01 to WS03, were formed using a Terrier 2000 rig. Dynamic sampling techniques were employed from surface to produce a continuous disturbed sample.

Standard penetration tests (SPT) were carried out at regular intervals in general accordance with BS1377: Part 9:1990:3.3. SPT results summarised as N values are presented on the borehole log.

Boreholes were monitored for groundwater ingress as drilling proceeded.

Trial Pits were performed using a 6 tonne tracked excavator

Representative disturbed samples were taken and retained in airtight containers for environmental and geotechnical testing.

The borehole logs and trial pit logs are presented in **Annex D**.

Exploratory hole locations are shown on **Drawing 01**.

5.2 Ground Conditions

The ground conditions encountered by the exploratory holes can in general be summarised as shown in **Table 5.1**.

Table 5.1 Summary of Typical Ground Conditions

Depth (m)			Thickness (m)	Stratum
0.00	-	0.1-0.8	0.1-0.8	Grass over soft brown very sandy locally gravelly, CLAY with fine rootlets.
0.1-0.8	-	1.7-2.2	1.1-1.4	Stiff to Very stiff occasionally firm brown, orange and blue mottled very Gravelly CLAY to medium dense clayey GRAVEL . (Made Ground Fill)
1.7-2.0	-	3.7-4.0	2.0-2.2	(Boreholes Only) Firm locally stiff brown very gravelly CLAY or Medium Dense very Clayey sandy GRAVEL . Very wet in places. (Made Ground) (Suspected Fill)
3.7	-	4.0	NA	(BH03 and TP02 and TP03 Only). Stiff to very stiff brown gravelly CLAY .
Gravels comprised typically angular sandstone with some weak angular mudstone.				

5.3 Groundwater

Groundwater information recorded during the site investigation is summarised in **Table 5.2**.

Table 5.2 Groundwater Summary

Location	Depth (m)	Details
WS02	2.0 - 2.3 3.8 - 4.0	Strata observed wet
WS03	1.7 - 3.7	Strata observed very wet
TP03	2.0	Minor groundwater ingress.

5.4 Stability and Obstructions

All Boreholes refused at 4m depth. An obstruction was encountered in the south of TP02 at 0.8m depth.

5.5 Installation Well Construction

Gas well locations were selected on a non-targeted basis to characterise the gas contamination status for the whole length of site.

Groundwater/Gas installation well construction details are summarised in **Table 5.3**.

Table 5.3 Installation Well Summary

Location	Response Zone		Stratum
	From (m)	To (m)	
WS01	4	3	Made Ground / Infill
WS02	4	3	Made Ground / Infill
WS03	3.7	2.7	Made Ground / Infill

5.6 Laboratory Chemical Testing

5.6.1 Sampling Strategy

Soil sampling locations were selected on a non-targeted basis to characterise the contamination status of the site area.

Sample locations, depths and suspected/known contamination source targets are summarised in **Table 5.4**:

Table 5.4 Sample Locations, Depths and Targets

Location	Depth (m)	Contamination Targets
WS01	0.45	S1
WS01	1.5	S1
WS02	0.3	S1
WS03	0.5	S1
WS03	2.5	S1
TP01	0.5	S1
TP02	0.1	S1
TP03	0.1	S1

5.6.2 Soil Laboratory Analysis

During the site investigation works soil samples were taken and despatched to the accredited laboratories of Eurofins Chemtest for laboratory chemical testing. Soil samples were tested for the determinants listed in **Table 5.5**.

Table 5.5 Soil Laboratory Analysis

Metals & Metalloids	In-Organics	Organics	Others
Arsenic	Cyanide	Phenols	pH (acidity)
Cadmium	Sulphate	PAH	Asbestos
Chromium III		Petroleum Hydrocarbons	
Chromium VI			
Copper			
Lead			
Mercury			
Nickel			
Selenium			
Zinc			

The results are discussed in detail in **SECTION 6** and the laboratory test results certificates may be found in **Annex E**.

5.7 Soil Property Testing

5.7.1 In-situ Permeability Testing

During the site investigation three borehole soakaway tests were undertaken in WS01 to WS03 carried out in general accordance with BRE DG 365:2016.

Soakaway test results are summarised in **Table 5..**

Table 5.6 Summary of Soakaway Results

Trial Pit	Infiltration Rate (ms ⁻¹)
WS01	No Movement Observed
WS02	No Movement Observed
WS03	No Movement Observed

The test results are discussed in **SECTION 9.6**.

SECTION 6 Evaluation of Geoenvironmental Analytical Results

6.1 Assessment Methodology

Comparison of the analytical results has been made with the 2015 Suitable 4 Use Levels (S4UL) provided by Land Quality Management (LQM) Limited and the Chartered Institute of Environmental Health (CIEH) or provisional Category 4 Screening Levels (pC4SL).

Sulphate results have been compared to guidelines presented in British Research Establishment (BRE SD1:2015). Sulphate levels need only be considered for buried concrete risk assessment and are not human health related.

6.2 Soil Test Results

A summary of the chemical test results which include the regulatory soil guideline values used in a residential setting with plant uptake are given in the following tables. The complete results can be found in **Annex E**.

6.2.1 Inorganics & Miscellaneous

Eight samples were tested for a standard suite of inorganics, pH and organic matter. The summarised results are in **Table 6.1**.

Table 6.1 Summary of Soil Chemical Test Results – Inorganics & Miscellaneous

Substance	Threshold Value (mg/kg)	Source	Measured Concentrations (mg/kg)		Number of Exceedances
			Minimum	Maximum	
Arsenic	37	LQM/CIEH	6.3	19	0
Cadmium	11	LQM/CIEH	0.12	0.4	0
Chromium III	910	LQM/CIEH	6.6	21	0
Chromium VI	6	LQM/CIEH	< 0.50	< 0.50	0
Copper	2400	LQM/CIEH	22	43	0
Lead	200	pC4SL	17	59	0
Mercury (inorganic)	40	LQM/CIEH	0.05	0.13	0
Nickel	180	LQM/CIEH	10	50	0
Selenium	250	LQM/CIEH	0.25	0.81	0
Zinc	3700	LQM/CIEH	66	160	0
Cyanide	-	-	<0.5	<0.5	-
Boron	290	LQM/CIEH	<0.4	0.90	0
Sulphate (%)	0.24	BRE	<0.01	0.047	0
Organic Matter (%)	-	-	< 0.10	4.8	-
pH	-	-	8.1	8.4	-
Notes:					
- No available guideline					

6.2.2 Organics

Eight samples were tested for speciated polycyclic aromatic hydrocarbons. The summarised results are in **Table 6.2**.

Table 6.2 Summary of Soil Chemical Test Results – Speciated Polycyclic Aromatic Hydrocarbons and Phenol

Substance	Threshold Value (mg/kg)	Source	Measured Concentrations (mg/kg)		Number of Exceedances
			Minimum	Maximum	
Naphthalene	2.3	LQM/CIEH	<0.1	<0.1	0
Acenaphthylene	170	LQM/CIEH	<0.1	<0.1	0
Acenaphthene	210	LQM/CIEH	<0.1	<0.1	0
Fluorene	170	LQM/CIEH	<0.1	<0.1	0
Phenanthrene	95	LQM/CIEH	<0.1	<0.64	0
Anthracene	2400	LQM/CIEH	<0.1	<0.1	0
Fluoranthene	280	LQM/CIEH	<0.1	3.0	0
Pyrene	620	LQM/CIEH	<0.1	3.0	0
Benzo(a)anthracene	7.2	LQM/CIEH	<0.1	2.1	0
Chrysene	15	LQM/CIEH	<0.1	2.8	0
Benzo(b)fluoranthene	2.6	LQM/CIEH	<0.1	2.3	0
Benzo(k)fluoranthene	77	LQM/CIEH	<0.1	0.96	0
Benzo(a)pyrene	2.2	LQM/CIEH	<0.1	2.1	0
Indeno(123cd)pyrene	27	LQM/CIEH	<0.1	1.3	0
Dibenzo(ah)anthracene	0.24/0/28*	LQM/CIEH	<0.1	0.27*	0
Benzo(ghi)perylene	320	LQM/CIEH	<0.1	1.4	0
Total PAH	-	-	<2.0	<2.0	-
Phenol	120	LQM/CIEH	<0.1	<0.1	0

Notes:

Thresholds based on 1.0% soil organic matter

* - When sample TP02, 0.10m was corrected for Soil Organic Matter the guideline was not exceeded

- No available guidelines

Eight samples were tested for petroleum hydrocarbon. The summarised results are shown in **Table 6.3**.

Table 6.3 Summary of Soil Chemical Test Results – Petroleum Hydrocarbons

Substance	Threshold Value (mg/kg)	Source	Measured Concentrations (mg/kg)		Number of Exceedances
			Minimum	Maximum	
Aliphatic					
PH C5 – C6 Ali	42	LQM/CIEH	<1.0	<1.0	0
PH C6 – C8 Ali	100	LQM/CIEH	<1.0	<1.0	0
PH C8 – C10 Ali	27	LQM/CIEH	<1.0	9.1	0
PH C10 – C12 Ali	130	LQM/CIEH	<1.0	<1.0	0
PH C12 – C16 Ali	1100	LQM/CIEH	<1.0	3.7	0
PH C16 – C21 Ali	65000*	LQM/CIEH	<1.0	3.9	0
PH C21 – C35 Ali	65000*	LQM/CIEH	<1.0	26	0
PH C35 – C44 Ali	65000	LQM/CIEH	<1.0	<1.0	0
Aromatic					
PH C5 – C7 Arom	70	LQM/CIEH	<1.0	<1.0	0
PH C7 – C8 Arom	130	LQM/CIEH	<1.0	<1.0	0
PH C8 – C10 Arom	34	LQM/CIEH	<1.0	13	0
PH C10 – C12 Arom	74	LQM/CIEH	<1.0	7.9	0
PH C12 – C16 Arom	140	LQM/CIEH	4.3	15	0
PH C16 – C21 Arom	260	LQM/CIEH	<1.0	15	0
PH C21 – C35 Arom	1100	LQM/CIEH	24	38	0
PH C35 – C44 Arom	1100	LQM/CIEH	<1.0	<1.0	0
Notes: PH – Petroleum Hydrocarbon Ali – Aliphatic Arom – Aromatic Thresholds based on 1.0% soil organic matter * – Ali C16-21 and C21-C35 based on criteria for Ali EC >16-35					

6.2.3 Asbestos Testing

All made ground soil samples were scheduled for asbestos screening. Asbestos was not detected

SECTION 7 Ground Gas Risk Assessment

7.1 Gas Risk Characterisation

7.1.1 Gas Source

Ground gas associated with the decomposition and degradation of thick made ground soils is considered a potential source of carbon dioxide and methane gas at the site.

Shallow mine workings, if present, are also viable source of gas.

7.1.2 Gas Migration Pathways

Made Ground observed at the site contained irregular layers of granular material and will likely have adequate permeability to permit the horizontal and vertical migration of hazardous gasses.

7.1.3 Potential Receptors

Potential receptors are future site residents.

7.2 Gas Screening Value

Two ground gas monitoring wells were installed, in WS01 and WS03.

Six round of gas monitoring have been carried. The installations were tested for carbon dioxide, methane, oxygen, carbon monoxide and hydrogen sulphide using a Gas Analyser GA2000/5000.

Recorded gas concentrations are summarised in **Table 7.1**.

Table 7.1 Measured Gas Concentration Summary

Gas	Minimum (% V/V)	Maximum (% V/V)
Methane	0	0
Carbon Dioxide	1.1	12.6
Oxygen	1.9	19.7

Methane levels peaked at 0% V/V. Carbon dioxide levels varied between 1.1% and 12.6% V/V. Oxygen concentrations varied between 1.9% and 19.7% V/V.

The gas flow rate from the boreholes was also assessed, a maximum flow rate of 0.1/hr was recorded.

Based on a flow rate of 0.1/hr (monitor lower limit of detection) and the highest recorded carbon dioxide concentration 12.6%, a gas screening value of 0.0126l/hr is calculated, as follows:

$$*(12.6/100) \times 0.1 = 0.0126 \text{ l/hr}$$

The results to date are presented in **Annex F**.

7.3 Conclusion

With reference to Table 8.5 of CIRIA report C665, the site is classified as 'Gas Characteristic Situation 2' (CS2) on account of the peak carbon dioxide concentration being above 5%.

Any gas protection measures should be designed and validated as detailed in Section 8.2.2.

SECTION 8 Quantitative Risk Assessment

8.1 Contaminants of Concern

All substances tested for were found to be present at concentrations below their respective human health threshold level.

Mitigation measures to deal with soil contamination is therefore not required.

8.2 Mitigation and Remedial Measures

As stated above mitigation/remedial measures are not required on site to deal with contaminated soils. However, the following general recommendations should be adhered to.

8.2.1 Human Health

As good practice, construction workers should adhere to good site management, COSHH, good standards of hygiene and appropriate health & safety on site, with personal protection equipment (PPE) and dust suppression where appropriate.

All imported soils should be validated as clean and suitable for use in accordance with 'Requirements for the Chemical Testing of Imported Soils for Various End Uses and Validation Cover Systems'.

For proposed new supply water pipes, the UK Water Industry Research publication 'Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites (Report 10/WM/03/21)' should be consulted.

In accordance with EC Regulation 1272/2008 and Environment Agency Guidance WM3 soils destined for off-site disposal should be classified on the basis of their hazard phrases prior to disposal. Soils are classified as a mirror entry waste and should be classified on the basis of their specific chemical properties.

If during earthworks ground conditions are encountered that are markedly different to those found during the investigation then the ground should be subject to additional sampling and testing and any necessary remedial measures designed and implemented before continuing with the works.

8.2.2 Ground Gas

To mitigate against the risk to future site users from ground gas full protection measures will be required in all structures. Reference should be made to guidance publication BR 211:2015 for further details on required protection elements. Verification of the installed protection measures is highly recommended. Terra Firma Wales Ltd. offer a comprehensive ground gas protection system verification service.

To protect the future site users from identified ground gas, proposed structures will need to incorporate within its construction a suitable ground gas protection system. The ground gas protection system should be designed, verified, installed and validated in accordance with the British Standard 8485:2015+A1:2019 and CIRIA guidance C735:2014. In addition, NHBC guidance may also need to be adopted depending on the requirements of the proposed development guarantor.

It is recommended that a specialist consultant is retained to prepare a risk assessed ground gas protection system Verification Plan for the proposed development. The Verification Plan will detail the required protection measures based on the perceived risk associated with the complexity of design, experience of the installer, size of the site and gas characteristic situation. The Verification Plan also details the step-by-step process and requirements to allow for the completion of a Validation Report. Terra Firma (Wales) Ltd offer Verification and Validation services.

Validation of installed ground gas protection systems by an independent third party will be required upon completion of the development. Validation may only be achieved if processes prescribed in the Verification Plan are undertaken.

8.2.3 Aquatic Environment

Site specific mitigation and remedial measures are not required with respect to the aquatic environment.

However, during the construction period, there is a risk to the environment/adjacent sites from de-watering, digging foundations, moving contaminated soil, drainage misconnections, discharges to local surface waters or the ground, runoff from construction materials and/or exposed ground, wheel washings and oil or chemical spills.

The risk is considered to be negligible as any adverse effects will be easily preventable by due diligence to good construction practise and housekeeping in preventing surface runoff and the spillage of materials.

The basic measures that should be taken are as follows:

- Prepare a drainage plan and mark the manholes to prevent pollutants accidentally reaching the surface water sewers;
- Carry out any activities that could cause pollution in a designated, bunded area, away from rivers or boreholes. Where possible it should drain to the foul sewer;
- Use settlement ponds to remove silty water;
- Store all oils and chemicals in a fully bunded area to prevent leaks or spills;
- Get advice on whether you need an environmental permit and apply in good time

SECTION 9 Engineering Recommendations

A significant thickness of made ground was encountered in the boreholes and trial pits. We have therefore recommended the use of earthworks and raft foundations.

9.1 Preparation of Site

Areas of vegetation including all roots should be stripped and removed from beneath the proposed development site.

Allowances should be made for any temporary/permanent support works to any existing adjacent structure necessary as a result of the proposed works.

Contingencies should be made for the protection/diversion of any underground/overhead services present beneath/above the site brought about as a result of the proposed works.

Any reduced levels should be brought up to the required levels with suitable inert mainly granular materials. Department of Transport (DTP) type 2 sub-base or similar should be used and compacted in layers to the requirements of the Specification for Highway Works.

Allowances should also be made for the excavation of any soft spots/areas and their replacement with well compacted imported granular materials.

In accordance with EC Regulation 1272/2008 and Environment Agency Guidance WM3 soils and other materials destined for off-site disposal should be classified on the basis of their hazard phrases prior to disposal. Soils are classified as a mirror entry waste and should be classified on the basis of their specific chemical properties. Terra Firma (Wales) Ltd offer this service if required.

9.2 Foundation and Floor Slab Solution

Due to extensive filling of the site from past adjacent developments, it is recommended that a reinforced concrete raft type foundation, founded upon 1.0m below foundation level, of recompacted site won or imported suitable materials be employed.

The re-compaction should comprise the excavation of 1.0m of made ground to at least 1.0m outside the plan areas of the buildings, the removal of any deleterious materials (i.e. timber, plastic, etc), and the re-compaction in layers of suitable site won or imported soil to Series 600 of the Specification for Highway Works. The materials should be compacted to within 95% of their optimum moisture content. To this end samples of the materials should be taken and tested in the laboratory in order to determine their optimum moisture content/maximum dry density relationship together with grading analysis. A Compaction Specification can then be prepared.

Should the natural moisture content of the materials be +or- 5% of the optimum moisture content then measures should be taken to either reduce or increase the moisture content as appropriate.

Earthworks should be built up from a level platform and, if changes in level are necessary, built upon steps. Earthworks should be validated with in-situ Plate Load Testing.

If this is not feasible or after the removal of deleterious materials, there is a shortfall of fill then an appropriate clean source of mainly granular materials should be sought.

Following the above earthworks an allowable bearing pressure of 50kN/m² can be used for design purposes. For the given foundation and allowable bearing pressure following the above earthworks maximum settlements should not exceed 25mm with angular distortions of less than 1:750 will results.

The raft/reinforced strips should be designed to span a crown hole of 3m with a 1.5m cantilever capacity on corners.

In order to protect the formations, from the effect of frost heave and or thermal shrinkage the foundations should be a minimum depth below the finished ground level of 0.9m.

We understand that the properties may be built as split level. If significant cut excavations are to be carried out for the buildings, it may be economical to construct a box type structure with integral reinforced concrete raft and reinforced concrete walls.

Allowances should be made for the removal of any 'soft spots and their replacement with well-compacted granular materials. Department of Transport (DoT) Type 2 materials or similar could be used and should be compacted in layers to the specification for Highway Works.

All foundation formations should be inspected by a suitably qualified Engineer before being concreted.

9.3 Excavations and Formations

Most of the shallow excavations will be possible with normal soil excavating machinery.

Shallow groundwater flows were encountered during the investigation. Any water inflows together with rainwater infiltration should be dealt with by conventional pumping techniques. However, it should be noted that during times of heavy rainfall a higher water table will be encountered.

The sides of any excavations deeper than 1.20m, or shallower if unstable, should be supported by planking and strutting or other proprietary means.

The sub-formations/formations are likely to be susceptible to loosening, softening and deterioration by exposure to weather (rain, frost and drying conditions), the action of water (flood water or removal of groundwater) and site traffic.

Formations should never be left unprotected and continuously exposed to rain causing degradation, or left exposed/uncovered overnight, unless permitted by a qualified engineer.

Construction plant and other vehicular traffic should not be operated on unprotected formations.

As a minimum the formation/excavation surfaces must be protected by blinding concrete immediately after exposure.

Allowances should be made for the removal of soft spots/areas and their replacement with well compacted granular materials.

Allowances should also be made for special precautions to prevent formation deterioration in addition to the above.

9.4 Protection of Buried Concrete

When the results are compared with Table C1/C2 of BRE Digest 1:2005, it indicates that buried concrete should generally conform to Class AC-1.

9.5 Access Roads and Car Parking Areas

For car parking and road areas, formations within the made ground a CBR value of 2% may be used for design purposes.

Allowances should be made for the removal of any 'soft spots/areas' and their replacement with well-compacted granular materials as previously described.

Please note that the Local Council / Highways Authority may require in-situ CBR testing to be undertaken before a road is adopted. In-situ CBR Testing should be performed following earthworks to verify the performance of the engineered fill.

9.6 Storm Water Drainage

During the site investigation three falling head permeability soakaway test was undertaken in the boreholes. No movement was observed during the test periods.

It is considered that soakaway storm water draining is unsuitable at the site.

9.7 Retaining Walls

Due to the sloping nature of the site, retaining walls may be required. The existing steepness of any embankments should not be increased. Any cuts should be undertaken in small sections and in such a way so as not to induce any instability to the ground.

Effective shear parameters for retaining wall design are presented in **Table 9.1**.

Table 9.1 Effective Shear Stress Parameters

Stratum Description	Bulk Unit Weight (γ) kN/m ³	Effective Cohesion (c') kN/m ²	Effective Angle of Shearing Resistance (ϕ') degrees
Made Ground and stiff clay	17-19	0	30
Hughes Member Bedrock	19	15	40-50

The parameters are based on experience in similar ground conditions.

The materials to be in-filled behind the retaining wall should be placed at or close to its optimum moisture content/maximum dry density and compacted in layers as per the requirements of the Specification for Highway Works. During the earthworks suitable in-situ testing should be carried out to ensure that the compaction process is achieving the required maximum dry density to achieve at least 95% compaction.

The acceptability of the filling works should be verified by appropriate on-site testing. A certification report should also be prepared on the earthworks by a suitably qualified Geotechnical Engineer.

Appropriate drainage should be incorporated in the design to prevent the build-up of hydrostatic pressure.

Appropriate cutting and benching of the existing slope should be conducted prior to the replacement of any imported fill to minimise the risk of any slip surfaces forming on the interface between the existing imported materials.