

**PROPOSED RETAIL DEVELOPMENT,
AFAN WAY, PORT TALBOT
PLATES**



Plate 1 – Tar Tank beneath Unit D.



Plate 2 – Interior of Tar Tank

**PROPOSED RETAIL DEVELOPMENT,
AFAN WAY, PORT TALBOT
PLATES**



APPENDIX 5 - Quantum Investigation Report

BURROWS YARD,

AFAN WAY,

PORT TALBOT

Supplementary Phase II Ground Investigation – Interpretative Report

Report No. G762/IR

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0. FOREWORD

The following Conditions and Notes on Site Investigation Procedures should be read in conjunction with this report.

0.1. General

Recommendations made and opinions expressed in the report are based on the strata observed in the excavations, together with the results of site and laboratory tests. No responsibility can be held for conditions which have not been revealed by the Exploratory Holes or which occur between Exploratory Holes. Whilst the report may suggest the likely configuration of strata, both between Exploratory Holes and below the maximum depth of investigation, this is only indicative and liability cannot be accepted for its accuracy.

Unless specifically stated, no account has been taken of possible subsidence due to mineral extraction below or close to the site.

0.2. Investigation Procedures

Cable percussive Borehole drilling, windowless sample and Trial Pitting / trenching techniques for ground investigation have been employed within the project. All Exploratory Hole operations, sampling and logging of soils, rocks and in-situ testing complies with the recommendations of the British Code of Practice BS 5930 (1999), 'Site Investigations' as superseded in part by BS EN ISO 14688-1 (2002) and 14688-2 (2004), British Code of Practice BS 10175 (2001) 'Investigation of Potentially Contaminated Sites' and BS 1377: 1990, 'Methods of Test for Soils for Engineering Purposes'.

0.3. Routine Sampling

Representative bulk, disturbed and environmental samples of the different strata are taken following completion of logging. These samples are sealed and labelled in clear plastic bags and 2kg plastic tubs. Soil samples obtained for environmental testing are sampled and sealed in borosilicate amber jars or in specialist vessels where required. All samples are returned from site to QGL's laboratory for controlled storage within 24 hours of sampling to await test scheduling/requirements.

0.4. In-Situ Testing

In-situ testing comprised:

- Standard Penetration Tests in Boreholes
- California Bearing Ratio

0.5. Groundwater

Where possible, the depth of entry of any influx of groundwater is recorded during the course of excavation or boring operations. The rate of inflow into the excavation or Borehole is monitored during the course of the excavation or during boring procedures. Upon encountering any water strikes, work is temporarily halted and the water levels monitored for a standard twenty minute period recording the change in water level at the end of the twenty minutes.

Groundwater conditions observed in the excavations are those appertaining to the period of investigation. It should be noted, however, that groundwater levels are subject to diurnal, seasonal and climatic variations and can also be affected by drainage conditions or other causes.

0.6. Retention of Samples

After satisfactory completion of all the scheduled laboratory tests on any sample, the remaining material is discarded. Further to notifying the Engineer/ Client with one week's notice all soil and/or rock samples will be discarded 28 days after submission of the approved final report.

1. INTRODUCTION

1.1. General

Upon the instructions of the Client, Neath Port Talbot County Borough Council (NPTCBC), Quantum Geotechnical Limited (QGL) was commissioned to undertake a Phase II Ground Investigation on a brownfield parcel of land located between Afan Way, Isaacs Place and Water Street in Port Talbot. The Client proposes to construct a number of retail and residential properties with associated infrastructure and an access road. Early stage proposed layout of the development is shown on a plan at the rear of Appendix I, as supplied by the Client, reference; *'Figure 2: Proposed Site Layout'*.

The development is split into two areas:

- A Retail Zone in the south-east, comprising a retail unit in the south-west (Unit A) and a combined retail and residential unit in the south-east (Unit B, comprising a retail ground floor and two storeys of residential apartments above), along with associated parking for shoppers and residents. The retail zone will be accessed off Afan Way on the south-eastern boundary, with parking access off Water Street on the north-eastern boundary.
- A Residential Zone in the north-west, comprising one- and two-storey private dwellings with associated private gardens and a new access off Isaacs Place on the western boundary.

In this interpretative report the following will be included: a factual account of the fieldwork; the strata encountered including contamination and groundwater observations and monitoring results; Comparison between historical and current contamination levels; Guidance and recommendations on contamination and geotechnical issues are made, including proposed further investigation required and allowable bearing capacities, foundation design of intended structures, ground improvement required and pavement design parameters.

1.2. Previous Studies

The site has previously been subject to a number of investigations which have been summarised in a Preliminary Geo-Environmental Risk Assessment report, 'Proposed Residential And Retail Development, Afan Way, Port Talbot', prepared by Earth Science Partnership Limited (ESP Ltd) in June 2015. A copy of this report as supplied by the Client is presented within Appendix XI for ease of reference. The historical investigations reported and summarised therein were undertaken by:

- Ecologia Environmental Solutions Ltd, 2002
- Babbie Group, March 2004
- Ground Investigation Ltd, November 2004

- Ground Investigation Ltd, December 2006
- Ground Investigation Ltd, November 2007a
- Ground Investigation Ltd, November 2007b
- Ground Investigation Ltd, November 2007c and'
- Lee Remediation Ltd, July 2008

The ESP Ltd 2015 report, comprised a desk study review of historical Ordnance Survey maps, environmental data, geological maps and memoirs. In addition, a full review of all historical investigations and studies of the site is presented and summarised, drawing conclusions for further ground investigation to determine the present day ground conditions with particular focus on contamination in the form of hydrocarbons relating to the previous land-uses.

The conclusive findings of the reports are summarised below:

- Historical land uses and potential contaminations sources include a Petrol Filling Station and associated tanks in the east of the site, the Council Yard and fuel pump area to the west of the site, an infilled former pond area in the middle of the site and a Tar tank area to the north of site. An extracted plan from the ESP Ltd 2015 report is presented in Appendix I which presents all identified 'Potential Sources of Contamination' mapped based on past studies and overlain on the proposed new development layout. This is shown as '*Figure 5: Potential Sources of Contamination*' at the rear of Appendix I.
- Areas of the site are underlain by soils and groundwater which contain levels of contaminants which could pose an unacceptable risk to both future site users and nearby controlled waters i.e. River Afan.
- Ground investigations undertaken between 2002 and 2008, of the former petrol filling station area, unacceptably elevated levels in terms of human health risk from arsenic, petroleum hydrocarbons, benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, chrysene and dibenzo[ah]anthracene were identified.
- The likely source of the petroleum hydrocarbons beneath the former Petrol Filling Station area is the former underground fuel tanks. These tanks were removed in 2006, and the fuel pumps and supply pipes appear to have been removed shortly after.
- Secondary sources of petroleum contamination have been identified as elevated levels within the soils and dissolved in the groundwater in close proximity to the former Petrol; Filling Station tanks. A maximum of 1.3 metres of free phase hydrocarbon product was recorded within the shallow lying soils resting above the groundwater table to the west of the Petrol Filling Station between 2004 and 2008.
- Unacceptable elevated levels in terms of human health risk of vanadium, benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene and dibenzo[ah]anthracene were encountered in the former Council Yard area of the site.

- There are a number of potential sources of hazardous ground gas beneath the site.

The recommendations of the ESP Ltd 2015 report are summarised as follows:

- To conduct further intrusive investigation, Trial Pits to evaluate the scale of contamination present within the soils and groundwater in the area of the Petrol Filling Station, particularly by petroleum hydrocarbons, and across the former Council Yard.
- Install and monitor gas and groundwater wells.
- Assessment of the present day risks to controlled waters and human health in both the residential and retail zones.

This Ground Investigation Interpretative Report should be read in conjunction with the aforementioned earlier reports.

1.3. Purpose of Ground Investigation

Having reviewed and considered the findings and recommendations in the report by Earth Science Partnership 'Preliminary Geo-Environmental Risk Assessment' Report dated June 2015, Ref; ESP.5897e.2274 Quantum Geotechnical Limited proposed the following supplementary ground investigation works in order to permit a more detailed assessment and coverage of the site and also determine whether the present day conditions (December 2015) have changed since the last investigation in 2007/08:

Proposed Residential Area:

- Trial Pitting to investigate shallow ground conditions and obtain environmental samples for geo-environmental testing purposes, to include several areas not previously investigated due to former structures existing on site.
- Trial Trenching to investigate former Tar tank area and areas surrounding former Council Yard re-fuelling station and location of now removed underground fuel storage tanks. Also to include the investigation of the former infilled pond area central to the proposed residential development site.
- Windowless Sample Boreholes to investigate shallow ground conditions for geo-environmental and geotechnical purposes and permit the installation of landgas and groundwater monitoring wells for continued monitoring to establish any landgas issues and whether any hydrocarbon related free product remains/ exists in this area of site.
- Cable Percussive Boreholes to investigate deeper lying ground conditions and permit the installation of monitoring wells both within the Made Ground and Natural Soil Deposits to aid assessment of any contaminant leachate migration into the underlying Natural Soils.
- In-situ California Bearing Ratio (CBR) testing to derive pavement design parameters for intended roads and parking areas.

Proposed Retail Area:

- Trial Pitting to investigate shallow ground conditions and obtain environmental samples for geo-environmental testing purposes, to include several areas not previously investigated as majority of past investigations focussed on the former Petrol Filling Station area.
- Trial Trenching to investigate the former filling station area where documented hydrocarbon pollution was observed in 2006/07 to assess if such contamination remains.
- Windowless Sample Boreholes to investigate shallow ground conditions for geo-environmental and geotechnical purposes and permit the installation of landgas and groundwater monitoring wells for continued monitoring to establish any landgas issues and whether any hydrocarbon related free product remains/ exists in this area of site. Also to allow determination of hydraulic gradient of underlying gravels beds.
- Cable Percussive Boreholes to investigate deeper lying ground conditions and permit the installation of monitoring wells both within the Made Ground and Natural Soil Deposits to aid assessment of any contaminant leachate migration into the underlying Natural Soils and permit geotechnical sampling to derive geotechnical parameters for potential ground improvement and foundation design for the large retail units proposed.
- In-situ California Bearing Ratio (CBR) testing to derive pavement design parameters for intended roads and parking areas.

Overall, this proposed supplementary phase of Ground Investigation aims to determine the present day scenario on site determining whether the previously identified land contamination issues have changed over the past decade and offer guidance and recommendations for updated remedial strategies to permit progression of the proposed re-development of the site into mixed commercial and residential end use.

1.4. Scope of Work

The general scope of work undertaken in the preparation of this assessment was as follows:

- Conduct an intrusive ground investigation to ascertain further geotechnical and environmental data for the proposed development.
- Provide an interpretative report offering recommendations on site suitability for the proposed development with recommendations on geotechnical and environmental issues.

General notes on the techniques employed by Quantum Geotechnical are described in the Foreword together with the limitations inherent in carrying out ground investigation work.

2. SITE DETAIL

2.1. Site Description

The proposed development site is a triangular shaped area of derelict land. It is bound by Water Street to the north and predominately terraced residential properties; Isaacs Place to the south-west with terraced residential properties and a former industrial works units; and Afan Way to the south-east followed by a MacDonalds restaurant, and a tyre depot

The National Grid Reference of the centre of the site is (SS) 275966 189794 and the postcode of the former petrol station on site was SA12 6LL.

A Site Location Plan is presented as Figure 1 in Appendix I with a collection of Site Photographs presented as Figure 1A.

The Afan River is located approximately 80m to the south-east behind the MacDonalds restaurant and tyre depot trending north-east to south-west.

There are two abandoned steel portal frame structures of previously proposed retail units in the west and north-western areas of the site and a small brick building, possibly an old electricity substation, exists in the south-west corner of the site. Large quantities of paving slabs, block paving, aggregate and drainage pipework materials are currently stockpiled towards the Water Street entrance to the site. It would appear that these have been stored on site for some time as some of the materials have degraded.

Large stockpiles of soil intermixed with occasional construction debris are present along the central and eastern areas of site, heavily overgrown. The origin of these is unknown, although it is possible that this material may have come from the foundation excavation of the two existing part-built steel portal frame structures on site.

SITE HAZARD: Areas of the site are overgrown with scrub vegetation and bramble and underfoot conditions can present a risk with random metal fragments protruding and open manholes/ ducts existing. Any such hazards were cordoned off during the investigative works.

SITE HAZARD: The site is sparsely covered in fly tipped materials and litter, particularly in the north-west corner of site alongside Isaacs Place. There are several areas where hundreds of Hypodermic Needles/ Syringes appear to have been dumped. These areas were cordoned off during the investigative works using temporary fencing.

SITE HAZARD: Anecdotal evidence suggests that potential Asbestos Containing Materials are present on the

ground surface in areas in small fragments particularly corrugated roofing sheets.

2.2. Site History

The land use history of the site is summarised in Table 1 as derived from past studies and shows the general evolution of the site to its present day condition.

Table 1: Site Land Use History

Date	Description	Location
1991 and ceased trading early 2004	Petrol Station including comprising three pump islands, above ground fuel tanks, below ground fuel tanks (removed December 2006), a car wash, a kiosk and associated infrastructure.	Eastern corner
1990 to present day	Electricity substation	Southern corner
1967 to 2005	Council (Corporation) Yard including pump island, below ground fuel tanks.	West of Site (On site of Tin Plate Works)
1961 - 1990	Mortuary	Eastern side of the terraced dwelling, to the north of the site.
1939	Above ground tanks (no longer shown on post 1961 maps)	Centre of site
1939	Wells (No longer shown on post 1967 maps)	Centre of site
1914 - 1950	Talbot Works (manufacturing bakery equipment)	East of site
Approximately 1897	Pond associated with the Tin Plate Works (shown to be backfilled and built over on historic maps 1917)	Centre of the site
1877 to between 1950 and 1961	Burrows Tin Plate Works comprising of a large building, railway sidings (demolished by 1961 and 1990)	West of the site
1877 to 1974	Terrace dwellings (demolished by 1974)	North of site

2.3. Topography

The site is relatively flat with occasional hummocky surfacing where stockpiles of soils have been placed. Elevations range between 5.48m OD and 6.63m OD (not including the stockpiles). Site levels were reported to fall from west to east across the site, being some 1.0 to 1.3m above the adjacent Water Street in the north-west.

2.4. Hydrology and Hydrogeology

The nearest major surface water feature is the River Afan, located 80m to the south-east, flowing north-east to south-west.

As stated in previous studies (ESP Ltd, June 2015) aquifer maps show the superficial deposits underlying the site are classed as a Secondary Undifferentiated Aquifer, whilst the bedrock (Coal Measures) are classed as

a Secondary A Aquifer.

Secondary A Aquifers generally correspond with the previously classified minor aquifers, and comprise permeable layers capable of supporting water at a local, rather than strategic, scale and in some cases form an important base flow to rivers. Secondary A Aquifers are sensitive to pollution.

Secondary Undifferentiated Aquifers are assigned by the Environment Agency where it has not been possible to categorise an aquifer in either Secondary A or B. In most cases this is attributable to a unit being classified as both minor and non-aquifers in different locations due to the variable characteristics of the rock type. These strata can be sensitive to pollution.

The site is not shown to be at a low risk from flooding from rivers and a low to medium risk of flooding from surface waters. 'Low' risk means that each year, this area has a chance of flooding of between 1 in 1000 (0.1%) and 1 in 100 (1%) and 'Medium' risk means that each year, this area has a chance of flooding between 1 in 100 (1%) and 1 in 30 (3.3%).

2.5. Statutory Service Information

QGL undertook full Cable Avoidance Tool (CAT) scans of each exploratory hole location as well as lifting and identifying any service covers proximal to the site. Safe digging practices in accordance with HS(G)47 were employed when breaking and excavating grounds with all traceable services demarcated prior to works commencing. A record of existing and former service plans were provided by the Client for use in conjunction with a CAT and signal generator.

It is unknown what buried services on site remain live or in use. There are several manhole covers that have been left open appearing to be not in use, buried gas pipes in the south-eastern corner in the area of the former Petrol Filling Station and also a small electricity sub-station in the south-west. A large culvert is also understood to cross the centre of the site in a north-west to south-east direction as reported in the 2004 Ground Investigation Limited report with the invert reported as 1.93m AOD (~4.3m bgl) falling in a south-easterly direction towards the River Afan.

2.6. Published Geology

The published geological map for the area of the site (1:10,560 scale, SS78NE) indicates the site to be underlain by Estuarine Alluvium overlying bedrock of the Llynfi Beds of the Upper Coal Measures.

Extracts of British Geological Survey sheets 247, solid and drift editions, at 1:50,000 scale are presented respectively as Figures 2 and 2A in Appendix I.

3. FIELDWORK

3.1. General

Fieldwork comprising light cable percussive boring, Windowless sampling, Trial Trenches, Trial Pitting and in situ testing was carried out between the 2nd December 2015 and 14th December 2015. Due to presence of a gas main, asbestos and buried concrete obstructions, a number of Windowless sample holes (QWS13, QWS15, QWS16 and QWS17) terminated at shallow depths.

Site supervision and attendance by an Engineering Geologist from Quantum was undertaken on all aspects of the site works and subsequent reinstatement works of all exploratory hole locations. All service plans were held onsite, with all Site Personnel inducted by QGL and briefed of the pertinent Risk Assessments and Method Statements relating to the tasks to be undertaken. No incidents or near misses were recorded during the fieldworks, with the works being incident free.

No deviations from the Standards and Procedures adopted for the works were recorded.

All Borehole locations were subject to the hand excavation of a 1.2m deep service/ utility inspection pit prior to any drilling. Also each area of investigation was fully CAT ('Cable Avoidance Tool') scanned prior to breaking ground.

A summary of the fieldworks is outlined below;

- 6 No. Light cable percussive Boreholes (QBH01 – QBH06);
- 19 No. Windowless sample holes (QWS01, QWS01A, QWS02, QWS03, QWS04, QWS05, QWS05A, QWS06, QWS07, QWS08, QWS09, QWS10, QWS11, QWS12, QWS14O and QWS14N, QWS16, QWS17);
- 22 No. Machine excavated Trial Pit holes (QTP01 – QTP21 and QTP02A);
- 4 No. Machine excavated Trial Trench holes (QTT01 – QTT03 and QTT01B)
- 11 No. In-situ California Bearing Ratio tests (QCBR02 – QCBR12)
- 6 No. Combined land gas and groundwater monitoring installations to a shallow depth and deeper depth.
- 10 No. Combined land gas and groundwater monitoring installations to a shallow depth
- Photo-Ionisation Detector (PID) readings of selected soil samples for volatile organic compounds (VOCs)
- Oil/ Water Interface readings of installed monitoring installations
- Multi-parameter monitoring of selected water samples from installed monitoring installations.

3.2. Exploratory Hole Locations

The exploratory hole locations were set out by a QGL Engineering Geologist in agreement with the scope of the investigation targeting previously investigated areas as well as obtaining new information from areas which have not undergone ground investigation. During the ground investigation, the cable percussive rig could not operate under the steel portal frame structures due to limited headroom therefore the proposed location of QBH01 had to be moved approximately seven metres to the south.

An Exploratory Hole Location Plan is presented as Figure 2 in Appendix I, and exploratory hole coordinates and levels are presented on the engineer's log sheets in Appendices II, III and IV.

3.3. Cable Percussive Boreholes

Light cable tool percussive techniques were used to sink six (QBH01 – QBH06) Boreholes through the overlying made ground and superficial deposits. Representative bulk disturbed, small disturbed samples and environmental samples were recovered from each Borehole throughout the boring works for geotechnical and geo-environmental characterisation of the underlying ground conditions. On completion the Boreholes were installed with combined land gas and groundwater monitoring installations to a shallow depth specified by Quantum's Engineering Geologist. Table 2 details the termination depths of the light cable percussive Boreholes and strata at the termination depth.

Table 2: Light Cable Percussive Boreholes termination depth

Exploratory Hole ID	Termination Depth (mbgl)	Terminating Strata	Notes/Reason for Termination
BH1	6	Very dense to dense reddish brown sandy GRAVEL and COBBLES	Very dense ground conditions
BH2	6.5	Very dense to dense medium brown sandy GRAVEL.	Very dense ground conditions
BH3	6.5	Dense to very dense sandy GRAVEL with low cobble content.	Dense ground conditions
BH4	7.7	Medium brown very gravelly SAND with medium cobble content	Gravelly Sand
BH5	6.6	Very dense to dense medium brown sandy GRAVEL with low cobble content.	Very dense ground conditions
BH6	6.5	Medium brown very gravelly SAND with medium cobble content.	Gravelly Sand

Completed geotechnical engineering logs for Boreholes are presented within Appendix II.

3.4. Windowless Sample Holes

Windowless Sample Hole techniques were used to sink 19 holes (QWS01, QWS01A, QWS02, QWS03, QWS04, QWS05, QWS05A, QWS06, QWS07, QWS08, QWS09, QWS10, QWS11, QWS12, QWS13, QWS14O, QWS14N, QWS16 and QWS17) through the made ground and superficial deposits. Plastic liner

tubes were driven into the ground until refusal was encountered. The Borehole was uncased and penetration depended on the ground conditions encountered. After obtaining a sample the plastic liner tubes were sealed.

Representative disturbed, bulk and environmental samples were taken directly from the recovered tubes throughout, for geotechnical and geo-environmental characterisation of the underlying ground conditions. On completion the Boreholes were installed with combined land gas and groundwater monitoring installations to deep and shallow depths. Table 3 below details the termination depths of the Windowless sample Boreholes and strata at the termination depth. Any groundwater observations are shown on the respective log in the Appendices.

Complete geotechnical engineering logs for Windowless Sample logs are shown in Appendix III.

Table 3: Windowless Sample Hole termination depth

Exploratory Hole ID	Termination Depth (mbgl)	Terminating Strata	Notes/Reason for Termination
QWS01	0.1	Made ground	Possible presence of asbestos
QWS01A	0.3	Made ground	Brick culvert
QWS02	2	Made Ground	Refused due to gravels
QWS03	5	Clay	Collapsing and reached target depth
QWS04	2.2	Made Ground	Refused due to gravels
QWS05	0.85	Made Ground	Terminated due to services
QWS05A	3	Clay	Collapsing
QWS06	1.25	Made ground	Terminated due to concrete
QWS07	2	Clay	Collapsing
QWS08	0.1	Made Ground	Refused due to gravels
QWS09	0.2	Made ground	Possible presence of asbestos
QWS10	2.5	Sand	Collapsing
QWS11	2.5	Clay	Collapsing
QWS12	4	Sand	Collapsing
QWS13	0.01	Made Ground	Terminated due to concrete and presence of gas main
QWS14O	0.01	Made Ground	Terminated due to concrete
QWS14N	2.3	Sand	Collapsing
QWS16	0.3	Made Ground	Terminated due to concrete and presence of gas main
QWS17	0.01	Made Ground	Terminated due to concrete and presence of gas main

3.5. Machine Excavated Trial Pits and Trenches

Twenty-two machine excavated Trial Pits and four machine excavated Trial Trenches were undertaken during the fieldwork period at locations detailed on the exploratory hole plan presented as Figure 2 in Appendix I. Representative disturbed, bulk and environmental samples were taken throughout, for geotechnical and geo-environmental characterisation of the underlying ground conditions. The purpose for each Trial Trench is detailed in Table 4

Table 4: Purpose of Trial Trenches

Exploratory Hole ID	Purpose of Trial Trench
QTT01 / QTT01B	Trench to locate and identify former Tar Tank - presumed to still be buried - Tar was pumped and removed in 2007 but structure is believed to remain in-situ.
QTT02	Trench to observe and sample shallow soils within area of former petroleum underground storage tank (Tank 1). Tank removed in 2007.
QTT03	Trench to observe and sample shallow soils within area of perceived former petroleum underground storage tank (Tank 1). Tank believed to have been removed in mid 1980s.

On completion, the Trial Pit / trenches were backfilled with arising in reversed order. Table 5 details the termination depths of the Trial Pits / trenches, strata at the termination depth and reasons for termination.

During the Trial Pitting exercise, hydrocarbon odour was encountered in QTP12, a slightly hydrocarbon odour was encountered in QTP06 and a very strong hydrocarbon odour was encountered in QTP09 and QTP10.

During the Trial Trenching exercise, a strong hydrocarbon presence in the groundwater and superficial deposits was encountered in QTT01, QTT01A and QTT02.

A complete set of engineer's Trial Pit logs are presented in Appendix IV. Any groundwater observations are shown on the respective log in the Appendices.

Table 5: Machine excavated Trial Pits / trench termination details

Exploratory Hole ID	Termination Depth (mbgl)	Terminating Strata	Notes/Reason for Termination
QTP01	1.3	Made Ground	Terminated due to concrete
QTP02	2	Made Ground	Terminated due to brick culvert
QTP02A	2.4	Sand	Terminated due to presence of water
QTP03	2.5	Clay	Maximum reach of excavator in encountered strata.
QTP04	2.1	Made Ground	Terminated due to concrete

Exploratory Hole ID	Termination Depth (mbgl)	Terminating Strata	Notes/Reason for Termination
QTP05	3.1	Clay	Terminated due to presence of water
QTP06	2.3	Clay	Terminated due to presence of water
QTP07	2.5	Clay	Terminated due to presence of water
QTP08	3.8	Clay	Maximum reach of excavator in encountered strata.
QTP09	3.1	Clay	Terminated due to presence of water
QTP10	3	Clay	Maximum reach of excavator in encountered strata.
QTP11	3.6	Clay	Maximum reach of excavator in encountered strata.
QTP12	3.6	Clay	Maximum reach of excavator in encountered strata.
QTP13	3.1	Clay	Maximum reach of excavator in encountered strata.
QTP14	3	Clay	Maximum reach of excavator in encountered strata.
QTP15	3.1	Clay	Terminated due to presence of water
QTP16	3.7	Clay	Maximum reach of excavator in encountered strata.
QTP17	3	Clay	Maximum reach of excavator in encountered strata.
QTP18	2.1	Clay	Terminated due to presence of water
QTP19	2	Made ground	Terminated due to presence of water
QTP20	2.1	Made ground	Collapsing
QTP21	3.1	Made ground	Terminated due to presence of water and collapsing

3.6. California Bearing Ratio Tests

Twelve California Bearing Ratio (QCBR 1 - 12) tests were carried out during the fieldwork period at the location detailed on the exploratory hole plan presented as Figure 3 in Appendix I. The testing was carried out in small hand dug pits (0.5m x 0.5m x 0.5m) to ensure the testing was carried out on the proposed founding strata in proposed pavement, parking and roadway areas. A small disturbed sample was taken after the test

to ascertain moisture content.

This method as described in BS1377 (part 9) covers the determination of the California Bearing Ratio (CBR) of a soil tested in situ, with a selected overburden pressure, by causing a cylindrical plunger to penetrate the soil at a given rate and comparing the relationship between force and penetration into the soil to that for a standard material. At certain values of penetration the California Bearing Ratio (CBR) is defined in the form of a percentage, as the ratio of the force exerted on the soil to a standard force that would be exerted on a specified crushed rock compacted and confined in a given manner.

Results of in-situ CBR testing including the moisture content results are presented in Appendix VI.

3.7. Land Gas & Groundwater Borehole Installations

Land gas and groundwater monitoring standpipes were installed within Boreholes QBH01 – QBH06 and QWS2A, QWS06, QWS07, QWS10, QWS12, QWS13 and QWS14N (see Table 6). An initial return monitoring visit was undertaken on the 18th - 22nd January 2016 where gas and groundwater levels and quality readings were taken. A further four monitoring visits were undertaken. A complete set of monitoring results are presented within Appendix VI.

Table 6: Monitoring Well details

Exploratory Hole	Response zones (mbgl)			
	50mm Ø Standpipe		19mm Ø Standpipe	
	Top depth	Bottom depth	Top depth	Bottom depth
QBH01	1	2.9	4	8
QBH02	1	2	3.5	6.5
QBH03	1	2	3.1	6.5
QBH04	1	2	3.5	7.7
QBH05	1	2	3	6.6
QBH06	0.5	2	2.5	6.5
QTP02A	1	2.4		
QTT02	2	4		
QWS02	0.9	2		
QWS06	0.25	1.75		
QWS07	0.25	1.25		
QWS10	1	1.9		
QWS12	0.5	3		
QWS13	0.5	3		
QWS14 N	0.2	1.2		

3.8. In-Situ Testing

3.8.1. Standard Penetration Testing

Standard penetration tests (SPTs) were undertaken throughout the made ground and superficial deposits at 1.00m centres within light cable percussive Boreholes.

This is a dynamic test as described in BS1377:1990 - Part 9 and is a measure of the density of the soil or rock. Within fine grained or cohesive soils, the test incorporates a small diameter tube (650mm length, 50mm external diameter and 35mm internal diameter) with a cutting shoe known as the 'split barrel sampler'. The sampler is forced into the soil dynamically using blows from a 63.5kg hammer dropped through 760mm. The sampler is initially advanced 150mm into the soil with seating blows, then the number of blows required to advance the sampler each 75mm increment up to a depth of 300mm is recorded. This cumulative total number of blows over the 300mm test is referred to as the "N" value. For coarse gravels and bedrock the split barrel is replaced by a 60° cone. SPT results are detailed within the relevant Borehole Logs.

3.9. Soil and Groundwater Sampling

Bulk, disturbed and environmental samples were taken within the overlying superficial / Made Ground deposits for strata identification and laboratory testing purposes. All samples are returned from site to Quantum's laboratory for controlled storage within 24 hours of sampling to await test scheduling/requirements. Sample type and sample depth are all recorded on the Engineering Geologist's Exploratory Hole Logs found within the appropriate Appendix.

Each of the Environmental Soil Samples were subjected to Photoionisation Detector (PID) monitoring to screen for volatile gas emissions associated with hydrocarbons. PID monitoring is discussed further in Section 5.8.

4. LABORATORY TESTING

4.1. General

The laboratory testing was scheduled by Quantum and comprised a number of geotechnical and geo-environmental tests on selected soil, soil leachate and groundwater samples obtained during the investigation.

4.2. Geotechnical Laboratory Testing

All the geotechnical soil testing work was carried out in accordance with the procedures stipulated in the various sections of BS 1377:1990 Parts 1 - 9 Methods of test for soils for civil engineering purposes. Table 7 details the tests undertaken.

Table 7: Geotechnical laboratory testing

Type of Test	Standard	Number of Tests
Moisture Content	BS1377:1990 Part 2	14
4 Point Liquid Limit and Plastic Limit	BS1377:1990 Part 2	10
Particle Size Distribution by Wet Sieve	BS1377:1990 Part 2	15
Particle Size Distribution: Sedimentation by pipette	BS1377:1990 Part 2	9
Dry Density/Moisture Content Relationship (2.5kg hammer)	BS1377:1990 Part 4	5
One-dimensional consolidation properties, test period 5 days	BS1377:1990 Part 5	5
Undrained strength of a single 100 mm diameter specimen in triaxial compression without the measurement of pore pressure	BS1377:1990 Part 7	5
Suite C (Brownfield site – pyrite absent Schedule 1.19.6) pH, Total Sulphate as SO ₄ , Water Soluble Sulphate (2:1 Leachate Equivalent), Water Soluble Chloride (2:1), Total Sulphur Water Soluble Nitrate (2:1) as NO ₃ , Mg	MCERTS	18

A full set of geotechnical laboratory test certificates are provided within Appendix VII.

4.3. Geo-environmental Laboratory Testing

Geo-environmental testing was carried out on selected soil, soil leachate and groundwater samples gained from the ground investigation. Table 8 details the geo-environmental testing undertaken on samples obtained and results are included within Appendix VIII.

Table 8: Geo-environmental laboratory testing summary

Type of Test	Accreditation	Number of Tests
Contamination testing Suite E (Soil samples Schedule S1.20.3) (incl. As, B, Cd, Cr (total), Cu, Pb, Hg, Ni, Zn, pH, Water soluble sulphate (as SO ₄), OM, TPHs, PAHs, Phenols, Cyanide (total), As)	MCERTS / ISO17025	13 soil
Contamination testing Suite E Extra (Soil samples Schedule S1.20.3) incl. L1.1a, L1.1b, L1.1c, L1.1d, L1.1e & L1.1f) (incl. TPH CWG, VOCs, Chlorinated solvents, PCBs, BTEX & MTBE and Tin.	MCERTS / ISO17025	28 soil
Contamination testing Suite F (Soil Leachate samples Schedule S1.20.3) (incl. As, B, Cd, Cr (total), Cu, Pb, Hg, Ni, Zn, pH, TPHs, PAHs, Phenols, Cyanide (total))	MCERTS	2 leachates
Contamination testing Suite F Extra (Soil Leachate samples Schedule S1.20.3) (incl. TPH CWG, VOCs, Chlorinated solvents, PCBs, BTEX & MTBE, Tin, TOC and Hardness).	MCERTS	14 leachates
Contamination testing Suite F (Water samples Schedule S1.20.3) (incl. As, B, Cd, Cr (total), Cu, Pb, Hg, Ni, Zn, pH, TPHs, PAHs, Phenols, Cyanide (total))	MCERTS	7 waters
Contamination testing Suite F Extra (Water Leachate samples Schedule S1.20.3) incl. L1.2a, L1.2b, L1.2c, L1.2d, L1.2e, L1.2f, L1.2g & L1.2g (incl. TPH CWG, VOCs, Chlorinated solvents, PCBs, BTEX & MTBE, Tin, TOC and Hardness).	MCERTS	13 waters
Suite H (Inert waste landfill Schedule S1.20.5)	MCERTS / ISO17025	6 soils
TPH CWG	MCERTS	16 soils
PAH Speciated USEPA 16	MCERTS	9 soils
Coal Tar	None	2 soils
Loss on Ignition	MCERTS	1 soils

5. GROUND CONDITIONS ENCOUNTERED

5.1. General

The sequence of deposits encountered during the investigation is detailed within the Engineering Geologist's logs presented within Appendices II, III and IV. The following sections summarise the findings of the exploratory holes.

5.2. Ground Conditions

A summary of the ground conditions encountered, including the depth to the base of each stratum, is provided in Table 9.

Table 9: Generalised sequence of strata encountered

Stratum	Typical Description	Typical Depth Ranges (mbgl)	Notes	Retail / Residential Zone
MADE GROUND - Topsoil	Brown sandy gravelly CLAY with low cobble content and frequent rootlets.	GL – 0.25	Encountered in QTP02, QTP02A, QTP06, QTP14, QTP17, QTP18,	Retail / Residential
MADE GROUND - Tarmac	Asphalt	GL – 0.2	Encountered in QTP01 and QTP02	North of site Residential
MADE GROUND- Hardcore	Grey slightly sandy GRAVEL.	GL – 0.4	Encountered in QTP05, QTP17, QTT03	Residential
MADE GROUND - Granular	Black mottled brown sandy GRAVEL with medium to high cobble content and low boulder content.	GL – 3.1*	Encountered across site	Retail / Residential
Possibly Mixed MADE GROUND and NATURAL GROUND	Medium dense brown slightly silty gravelly very clayey SAND with wood fragments.	1.25 – 1.8	Encountered in QWS07, QTP09, QTP11, QTT02, QTP18, QTT01B	Retail / Residential
NATURAL GROUND – Estuarine Deposits	Soft wet blueish grey CLAY. Frequent plant remains.	1.4 – 3.6	Encountered in QTP09, QTP11, QTP12, QTP12, QTP13, QTP14, QTP15, QTP16, QTP18, QWS03, QTT01 QTT01	Retail
NATURAL GROUND – Estuarine Deposits	Very soft to soft grey silty CLAY interbedded orangish brown slightly silty very sandy CLAY	2.1 – 3.7	Encountered in QBH03, QBH04, QBH05, QWS03, QWS05A, QWS07, QWS11, QWS13,	Retail / Residential

Stratum	Typical Description	Typical Depth Ranges (mbgl)	Notes	Retail / Residential Zone
			QWS14N	
NATURAL GROUND – Estuarine Deposits	Grey mottled light brown sandy CLAY.	2.0 – 3.0*	QBH01, QBH02, QBH06, QTP03, QT05, QTP06, QTP07, QTP08, QTP14, QTP15, QWS05A, QWS11	Retail / Residential
NATURAL GROUND – Fluvial glacial deposits	Very dense to dense medium brown sandy GRAVEL	3.5 – 6.6*	QBH1 – QBH6, QTT01, QTT01B, QTT02, QWS05	Retail / Residential

* End of Exploratory Hole

5.2.1. **Made Ground**

The strata interpreted as Made Ground was encountered in all exploratory holes undertaken as part of the fieldwork and comprised black sandy Gravel with medium to high cobble content and low boulder content. The made ground is predominantly made up of fine to coarse angular sandstone, mudstone, limestone, brick, concrete, slag, metal, plastic, glass and concrete. In QBH01 between 2.4 – 3.1m depth, the made ground was speckled red. In QTP18 this layer was encountered as purplish grey slightly sandy Clay with low cobble content. Cobbles were sub-rounded to sub-angular brick, lime and sandstone.

Densities of the made ground vary between medium dense and very dense ('N' values 20 – 50+). Two Trial Pits (QTP01 and QTP02) in the north of the site encountered asphalt at shallow depth that required breaking out with mechanic plant.

5.2.2. **Mixed Layer**

The strata interpreted as Mixed Layer was encountered underlying the Made Ground and above the natural deposits. It comprised of medium dense brown slightly silty gravelly very clayey Sand with wood fragments and was encountered mainly in the east of the site with the exception of Trial Pit QTP18 where it was encountered at 0.5 – 0.9m depth. This layer is interpreted as an intermediate layer between the overlying Made Ground and the underlying Estuarine Alluvium Deposits which has been reworked through past demolition or groundworks.

5.2.3. **Estuarine Alluvium Deposits**

The strata interpreted as Estuarine Alluvium Deposits were encountered underlying the Made Ground and mixed layer. This layer comprised of soft wet blueish grey Clay, very soft to soft grey silty Clay with interbedded orangish brown slightly silty very sandy Clay and grey mottled light brown sandy Clay.

This unit was encountered in the retail area as soft wet blueish grey Clay in the east corner of the site (under

the former petrol station location). In Trial Pits QTP10, QTP11 and QTP14 the unit becomes gravelly with low cobble content of sandstone. In Trial Pit QTP12 the unit is stiff, gravelly with low cobble content of sandstone between 3.1 – 3.6m depth. In Trial Pits QTP14, QTP15 and QTP16, this unit is described to have a stiff consistency.

This layer was encountered as very soft to soft grey silty Clay interbedded with orangish brown slightly silty very sandy Clay in exploratory holes QBH03, QBH04, QBH05, QWS03, QWS05A, QWS07, QWS11 and QWS14N. This layer is interpreted an intermediate layer between the overlying Estuarine Alluvium Deposits and the underlying Fluvial Glacial Deposits.

This layer was logged as soft grey mottled light brown sandy Clay in the central to west areas of the site with a stiff consistency in Trial Pits QTP14 and QTP15.

5.2.4. Fluvial Glacial Deposits

The strata interpreted as Fluvial Glacial Deposits were encountered underlying the Estuarine Alluvium Deposits. The layer comprised of very dense to dense medium brown sandy Gravel or gravelly Sand. Sand is fine to coarse. Gravel is subrounded to subangular fine sandstone. This unit was revealed in all cable percussive Boreholes and in QTT01, QTT01B, QTT02 and QWS03. Depths encountered ranged from 4.7mbgl in QBH01 in the north of the site to an average of 3.5mbgl for the remainder of the site. It is anticipated that this layer underlies the entire site.

5.3. Groundwater Conditions

Groundwater ingress into exploratory holes was recorded and detailed on the exploratory hole logs presented in Appendices II, III and IV and summarised in Table 10. The groundwater conditions observed in these exploratory holes are those appertaining to the period of the investigation. However, it should be noted that groundwater levels are subject to diurnal, seasonal and climatic conditions or may vary due to other causes.

Table 10: Summary of Groundwater within exploratory holes

Exploratory Hole	Depth Encountered (mbgl)	Depth Following 20min Observation Period (mbgl)	Remarks
QBH01	4.7	4.7	-
QBH02	3.5	3.5	Medium groundwater flow
QBH03	4.5	4.5	-
QBH04	4.5	4.5	-
QBH05	3.5	3.5	Medium groundwater flow
QBH06	3.7	3.7	Medium groundwater flow
QTP02A	1.6	1.6	Seepage
QTP04	2.1	2.1	Seepage

Exploratory Hole	Depth Encountered (mbgl)	Depth Following 20min Observation Period (mbgl)	Remarks
QTP06	1.6	1.6	Low groundwater flow
QTP09	2.5	2.5	Seepage
QTP13	2.6	2.6	Seepage
QTP15	1.9	1.9	Medium groundwater flow
QTP17	2.8	2.8	Seepage
QTP18	1.9	1.9	Seepage
QTP19	1.9	1.9	Seepage
QTT01	1.7	1.7	Seepage
QTT01	3.5	2.9	Fast groundwater flow
QTT01	3.7	2.9	Fast groundwater flow
QTT02	4.0	4.0	Medium groundwater flow
QTT03	1.9	1.9	Seepage
QWS04	1.9	1.9	Low groundwater flow
QWS14 O	1	1	-

5.4. Visual Evidence of Soil Contamination

Suspected Asbestos was encountered in QWS01 at 0.1m depth and in QWS09 at 0.2m depth. These exploratory holes were cancelled due to the potential human health risk to operatives.

A large amount of used hypodermic needles were encountered on the surface in the north-western area of the site.

Olfactory evidence of contamination of the soil is summarised in Table 11

Table 11 Summary of Visual Evidence of Soil Contamination

Exploratory Hole	Depth Encountered (mbgl)	Remarks	Strata	Location
QTP09	1.80 – 3.8*	Very strong hydrocarbon odour	Sandy CLAY	East
QTP10	0.90 – 3.1*	Strong hydrocarbon odour	Sandy CLAY	East
QTP12	1.30 – 2.20*	Strong hydrocarbon odour	Sandy CLAY	North East
QTT01	1.70 – 3.70*	Very strong hydrocarbon odour	Sandy CLAY and GRAVELs	East
QTT01B	3.50	Very strong hydrocarbon odour	GRAVELs	East
QTT02	4.0 - 4.30	Strong hydrocarbon odour	GRAVELs	North East

*End of Hole

An oily sheen was observed on the gravels in Trial Trench QTT01B at depths of 3.50 – 3.70m depth and in Trial Trench QTT02 at depths of 4.0 – 4.30m depth.

5.5. Visual Evidence of Contaminated Groundwater

An oily sheen was observed on groundwater encountered in Trial Pits QTP06 and QTP21; and Trial Trenches QTT01, QTT01B and QTT03 and windowless sample hole QWS04. A slightly hydrocarbon odour was observed in Trial Pit QTP06 and a strong hydrocarbon odour was observed in Trial Trench QTT01.

5.6. Visual Evidence of Contaminated Surface Water

There were no indications surface waters or controlled waterways were contaminated on or adjacent to site during the fieldworks.

5.7. Evidence of Buried Structures

A stone wall was encountered at 1.40m depth in Trial Trench QTT01.

A brick wall was encountered in QTT02 below 0.30m depth. Brick and stone walls were encountered in the north, south and west sides of the pit.

A brick culvert was encountered in Windowless sample hole QWS01A and in Trial Pit QTP02 at depths of 0.3m and 0.5m depth respectively. The culvert was approximately 1m wide and trends east to west.

Concrete obstructions were encountered during field works and findings are summarised in Table 12.

Table 12 Summary of Concrete Obstructions Encountered

Exploratory Hole	Depth Encountered (m bgl)	Remarks	Location on Site
QWS06	1.25	-	West
QWS13	-	Encountered at surface	East
QWS16	-	Encountered at surface	East
QWS17	-	Encountered at surface	East
QTP04	2.10	-	West
QTP19	0.70 – 1.20	In south end of pit	West

The locations of concrete obstructions correspond to former council buildings recorded in the historical plans in the west of the site and the former petrol station in the east of the site.

5.8. Photo-Ionisation Detector Readings

A RAE Systems Mini Rae 2000 Photo-Ionisation Detector with a 10.6eV lamp was used onsite to monitor any volatile organic compounds emitting from all soil samples. The soil samples were obtained and sealed in air tight jars allowing for sufficient headspace for gases to accumulate. The PID probe is then inserted into the lid of the jar and peak readings in ppm units obtained.

Average readings ranged from 1.1 to 382ppm and Peak readings ranged from 2.0 to 536ppm with noticeable high readings in;

- Trial Trench QTT01 at 2.50m in Estuarine Fluvial Deposits: Peak Reading 493ppm
- Trial Trench QTT01 at 3.60m depth in Glacial Gravels Deposits: Peak Reading 434ppm
- Trial Trench QTT01B at 2.50m depth in Estuarine Fluvial Deposits: Peak Reading 120ppm
- Trail Pit QTP09 at 3.0m depth: Peak Reading 472ppm
- Trial Pit QTP10 at 2.80m depth in Estuarine Fluvial Deposits: Peak Reading 312ppm
- Borehole QBH02 at 0.30m depth in Made Ground: Peak Reading 536ppm

The Photo-Ionisation Detector Readings are presented in Appendix IX.

5.9. Oil/ Water Interface meter

Table 13 presents the interface meter readings which show the depth (column height) of hydrocarbon free phase product resting above the groundwater within the installed groundwater monitoring standpipes taken during the initial return monitoring visit.

Table 13 Free Phase Hydrocarbon Product Records

Exploratory Hole	Pipe Diameter (mm)	Depth of Free Product from Ground Level (mm)	Depth of Groundwater from Ground Level (mm)	Level of Free Product above Groundwater (mm)
QBH01	50	2200	2010	10
QBH02	50	1885	1890	5
QBH03	50	1590	1590	0
QBH05A	50	1720	1720	0
QBH06	50	1287	1290	3
QTP02A	50	1600	1650	50
QTT02	50	1317	1320	3
QWS02	50	Dry	Dry	Dry
QWS06	50	Dry	Dry	Dry
QWS10	50	1560	1610	50
QWS12	50	1800	1800	0
QWS14N	50	1357	1358	1

6. GEO-ENVIRONMENTAL CONSIDERATIONS

6.1. General

The purpose of the investigation is detailed in Section 1.3. Overall the Ground Investigation was conducted to determine the present day scenario on site and if any changes have occurred over the past decade since the last phases of ground investigation had taken place.

The potential risks to the development have been assessed by consideration of the potential pollution linkages (PPL). For a risk to exist there must be a source of contamination, a receptor that may be harmed, and a pathway by which the receptor could be exposed to the contaminant. Only when all three factors are present can a pollution linkage, and consequently an unacceptable risk, exist. The conceptual site model (CSM) considers all three elements and the potential for pollution linkages that may exist.

Section 3 of the ESP Ltd 2015 Report focusses on the Conceptual Model for the site based on historical use and past ground investigation findings up to 2007. It outlines the potential sources, pathways and receptors. There are no perceived changes due to the CSM and as such extracts of Section 3 ESP Ltd 2015 are presented below for ease of reference;

Potential Sources:

Please refer to 'Figure 5: Potential Sources of Contamination' at the rear of Appendix I as presented by the Client for Source Reference ID locations and further information.

Source Ref;	Source Type	Location on Site	Status	Comments
S1	Underground fuel tank1	Former Petrol Filling Station	Removed from site in 2006	GIL Tank A.
S2	Underground fuel tank1	Former Petrol Filling Station	Removed from site in 2006	GIL Tank B.
S3	Underground fuel tank1	Former Petrol Filling Station	Removed from site in 2006	GIL Tank C.
S4	Underground fuel tank1	Former Council Yard (central area)	Removed in 2007	GIL Tank 1.
S5	Underground fuel tank1	Former Council Yard (central area)	Probably removed in 1980s.	GIL Tank 2.
S6	Underground tar tank1	Former Council Yard (northern area)	Emptied in 2007.	GIL 'tar tank'.
S7	Above ground fuel tank1 (red diesel)	Former Council Yard (southern area)	Not present in 2004.	Anecdotal evidence only. No further information
S8	Above ground 'turps' tank1	Former Council Yard (southern area)	Not present in 2004.	Anecdotal evidence only. No further information

S9	Above ground tank – unspecified contents ¹	Former Council Yard (western area)	Not present in 2004.	Shown on historical map of 1950. No further information
S10	Above ground tank – unspecified contents ¹	Former Council Yard (central area)	Not present in 2004.	Shown on historical map of 1950. No further information
S11	Underground fuel supply lines ¹	Former Petrol Filling Station	Present in 2004. May have been removed	
S12	Underground fuel supply lines ¹	Former Council Yard (central area)	No information.	Postulated only.
S13	Backfilled Pond	Former Council Yard (central area)	Backfilled prior to 1917.	Shown on historical map of 1899. No further information
S14	Historical Tank	Former Council Yard (central area)	Not present in 2004.	Shown on historical map of 1939. No further information
S15	Electricity Substation	Former Council Yard (southern area)	Identified in 2004.	Shown on historical map from 1975. No further information
S16	General Made Ground	Across site.		

¹Includes soils and groundwater impact around tanks

Potential Receptors:

As discussed in Section 1.1, the proposed site development will comprise retail units in the south and residential properties with private gardens, landscaping and vehicle parking areas in the north. The site is located some 80m from the River Afan and above a Secondary Undifferentiated Aquifer.

The most vulnerable receptors with regards to any contamination or hazardous ground gas present are considered to be:

- Future residents in the north, the critical receptors being young children playing in private garden areas;
- Future employees and site visitors (e.g. shoppers) in the south, the critical receptors being employees outside during their break periods;
- Construction and maintenance workers;
- Buried concrete; and
- The surface water in the River Afan.

It should be noted that the currently proposed development includes more vulnerable human receptors (residents) than in the previous development proposals (retail only) and a potential increased level of risk from any contamination present.

Potential Pathways:

The following are considered the most likely migration pathways with regard to any contamination or hazardous ground gas present beneath the site.

Site Users:

- Ingestion of soils and inhalation of dust in garden areas.
- Ingestion of soils and inhalation of dust in landscaping areas.
- Ingestion of edible plants and dust associated with such plants.
- Dermal contact with contaminated soils.
- Exposure to asbestos containing materials within the shallow soils.
- Potential explosive risk from flammable ground gas/vapours on site.
- Potential explosive risk from toxic ground gas/vapours on site.
- Chronic exposure to unacceptable levels of radon.
- Organic contaminants permeating from soils and groundwater into plastic water supply pipes.

Construction and Maintenance Workers:

- Exposure to asbestos containing materials within the shallow soils;
- Ingestion of soils and inhalation of dust across site.
- Dermal contact with contaminated soils.
- Potential explosive risk from flammable or toxic ground gas/vapours from onsite sources.

River Afan:

- Leaching of mobile contaminants to the groundwater beneath the site, and then on to the nearby surface water course.

Buildings:

- Sulphate attack on buried concrete
- Potential explosive risk from flammable ground gas/vapours from onsite sources

By adopting the CLEA approach to human health risk assessment as defined in CLR11, a human health risk assessment has been undertaken for the proposed development adopting the most sensitive model of Residential with Plant Uptake (1 – 6% Soil Organic Matter) threshold values for the residential area and a partially sensitive model of public open space around residential dwellings threshold values for the retail area. For the purposes of this report this assessment deals only with the human health and material handling aspects of the soils encountered.

The assessment criteria used in this assessment is that presented by LQM/CIEH in their publication *The LQM/CIEH S4ULs for Human Health Risk Assessment (2015)*. The S4ULs (Suitable for Use Levels) used have been derived in accordance with UK legislation, national as well as Environment Agency policy and using a modified version of the Environment Agency CLEA software and available guidance provided to the contaminated land practitioner community for the purpose of deriving Generic Assessment Criteria (GAC).

The LQM/CIEH S4ULs are intended for use in assessing potential risks posed to human health by contaminants in soil and are transparently derived and cautious 'trigger values' above which further

assessment or remedial action may be necessary.

By using the LQM/CIEH S4AULs, Quantum Geotechnical acknowledges *Copyright Land Quality Management Ltd reproduced with permission; Publication Number S4AUL3409. All Rights Reserved.*

The test certificates are presented in Appendix VIII along with summary tables of the respective assessment criteria utilised.

6.1.1. Human Health Risk Assessment

The concentrations of potential heavy metals, organics, inorganics and sulphate derived analytes, as listed in Section 4.3, within the tested soil samples obtained from the ground investigation have been compared to assessment criteria as described above.

The concentrations of contaminants tested and exceedances are summarised in Table 14 for the Residential Zone and Table 15 for the Retail Zone. Both historical investigation exceedances and current QGL Ground Investigation exceedances are presented in both scenarios.

Table 14 Summary of *Soil* Contaminants and Exceedances in the *Residential* Zone

Determinand	Results Range (mg/kg) in historical investigations	Results Range (mg/kg) in QGL ⁽¹⁾ investigations	LQM/CIEH S4ULs (2015) (mg/kg) Residential with Plant Uptake End Use ⁽²⁾	Exceedances from historical Investigations	Exceedances from QGL Investigation	Borehole and Depth of Exceedance in QGL investigation	Strata in QGL investigation
Residential Zone							
Arsenic	18-23	<1.0 - 1900	37	No	Yes	QTT03 1.0m QWS05A 0.60m QTP02 1.90m QTP03 0.6m QTP04 0.60m	Made Ground Made Ground Made Ground Made Ground Made Ground
Boron (water soluble)	<0.5 – 18	0.4 – 7.2	290	No	No	-	-
Cadmium	<0.1 – 0.5	<0.2 – 3.9	11	No	No	-	-
Chromium Total / III ⁽³⁾	13 - 890	16 - 60	6	Yes	Yes	QBH01 1.0m QBH02 0.6m Mound 2 QTT03 0.5m QTT03 1.0m QWS02 0.6m QWS03 1.0m QWS03 3.70 QWS04 2.00m QWS05A 0.60m QTP01 0.60m QTP02 1.90m QTP03 0.6m QTP04 0.60m	Made Ground Made Ground Made Ground Made Ground Made Ground Made Ground Made Ground Silty Clay Made Ground Made Ground Made Ground Made Ground Made Ground Made Ground
Copper	32 - 262	4.5 - 770	2400	No	No	-	-
Lead ⁽⁴⁾	24 - 170	18 - 840	200	No	Yes	QTT03 0.5m QTT03 1.0m QWS03 1.0m QWS04 2.00m QTP01 0.60m QTP02 1.90m	Made Ground Made Ground Made Ground Made Ground Made Ground Made Ground
Mercury	0.12 – 0.22	<0.3 – 2.6	40	No	No	-	-
Nickel	9 - 53	14 - 74	130	No	No	-	-
Tin	No data	62 - 910	-	-	-	-	-

Determinand	Results Range (mg/kg) in historical investigations	Results Range (mg/kg) in QGL ⁽¹⁾ investigations	LQM/CIEH S4ULs (2015) (mg/kg) Residential with Plant Uptake End Use ⁽²⁾	Exceedances from historical Investigations	Exceedances from QGL Investigation	Borehole and Depth of Exceedance in QGL investigation	Strata in QGL investigation
Residential Zone							
Zinc	63 - 303	97 - 1800	3700	No	No	-	-
Inorganics							
pH ⁽⁵⁾	No data	4.2 – 7.9	<5	-	Yes	QTP08 1.0 – 1.50m	Made Ground
Total Cyanide ⁽⁶⁾	No data	<10	34	-	No		
Water Soluble Sulphate (2:1 Leachate Equivalent)	No data	0.1 – 1.8	0.5	-	Yes	QTP08 1.0 – 1.50m	Made Ground
Organic Matter	No data	2.1 – 8.7	-	-	-	-	-
Total Sulphate as SO ₄ ⁽⁵⁾	No data	500 - 36000	2400	-	Yes	QTP08 1.0 – 1.50m	Made Ground
Water Soluble Sulphate (2:1 Leachate Equivalent) ⁽⁵⁾	No data	0.1 – 1.8	0.5	-	Yes	QTP08 1.0 – 1.50m	Made Ground
Water Soluble Chloride (2:1) ⁽⁵⁾	No data	29 - 130	-	-	-	-	-
Total Sulphur	No data	280 - 15000	-	-	-	-	-
Water Soluble Nitrate (2:1) as NO ₃	No data	2.3 – 9.1	-	-	-	-	-
Total Phenols							
Total Phenols (monohydric) ⁽⁷⁾	<0.5	<1.0	120	No	No	-	-
Speciated PAHs							
Naphthalene	<5.0	<0.05 – 0.55	2.3	Potentially	Yes	QBH01 1.0m QBH02 0.60m	Made Ground Made Ground
Acenaphthylene	<5.0	<0.1 – 0.65	170	No	No	-	-
Acenaphthene	<5.0	<0.1 – 1.1	210	No	No	-	-
Fluorene	<5 - 20	<0.1 - 2.4	170	No	No	-	-
Phenanthrene	<5 - 16	<0.1 – 21	95	No	No	-	-
Anthracene	<5.0	<0.1 – 5.4	2400	No	No	-	-

Determinand	Results Range (mg/kg) in historical investigations	Results Range (mg/kg) in QGL ⁽¹⁾ investigations	LQM/CIEH S4ULs (2015) (mg/kg) Residential with Plant Uptake End Use ⁽²⁾	Exceedances from historical Investigations	Exceedances from QGL Investigation	Borehole and Depth of Exceedance in QGL investigation	Strata in QGL investigation
Residential Zone							
Fluoranthene	<5.0 - 20	<0.1 – 23	280	No	No	-	-
Pyrene	<5.0 - 15	<0.1 – 16	620	No	No	-	-
Benzo(a)anthracene	<5.0 - 10	<0.1 – 15	7.2	No	Yes	QTP05A 0.60m QTP17 0.40m QTP18 0.35m QTT03 0.50	Made Ground Made Ground Made Ground Made Ground
Chrysene	<5.0 – 8.0	<0.05 – 10	15	No	No	-	-
Benzo(b)fluoranthene	1.0 - 13	<0.10 – 14	2.6	Yes	Yes	QBH02 0.60m QTP04 0.60, QTP05A 0.60m QTP16 0.60m QTP17 0.40m QTP18 0.35m QTP19 0.50m QTT03 0.50	Made Ground Made Ground Made Ground Made Ground Made Ground Made Ground Made Ground Made Ground
Benzo(k)fluoranthene	5.0 – 8.0	<0.10 – 5.2	77	No	No	-	-
Benzo(a)pyrene	5.0 – 7.0	<0.10 – 11	2.2	Yes	Yes	QBH02 0.60m QTP05A 0.60m QTP16 0.60m QTP17 0.40m QTP18 0.35m QTP19 0.50m QTT03 0.50m	Made Ground Made Ground Made Ground Made Ground Made Ground Made Ground Made Ground
Indeno(1,2,3-cd)pyrene	5.0 – 7.0	<0.10 – 4.7	27	No	No	-	-

Determinand	Results Range (mg/kg) in historical investigations	Results Range (mg/kg) in QGL ⁽¹⁾ investigations	LQM/CIEH S4ULs (2015) (mg/kg) Residential with Plant Uptake End Use ⁽²⁾	Exceedances from historical Investigations	Exceedances from QGL Investigation	Borehole and Depth of Exceedance in QGL investigation	Strata in QGL investigation
Residential Zone							
Dibenz(a,h)anthracene	1.0 - 12	<0.1 – 1.4	0.46	Yes	Yes	QWS02 2.0m QWS05A 2.20m QTP05A 0.60m QTP17 0.40m QTP18 0.35m QTP19 0.50m QTT03 0.50m	Made Ground Made Ground Made Ground Made Ground Made Ground Made Ground Made Ground
Benzo(ghi)perylene	5.0 – 7.0	<0.05 - 11	320	No	No	-	-
Mono aromatics							
Benzene	<0.025	<1.0	0.087	No	No	-	-
Toluene	<0.025	<1.0	130	No	No	-	-
Ethylbenzene	<0.025	<1.0	47	No	No	-	-
p & m-xylene	<0.025	<1.0	59 (m-Xylene) 56 (p-Xylene)	No	No	-	-
o-xylene	No data	<1.0	60	No	No	-	-
MTBE (Methyl Tertiary Butyl Ether)	No data	<1.0	-				
Petroleum Hydrocarbons ⁽⁹⁾							
TPH C10 - C40	No data	<10 - 16000	1600	-	-		
TPH-CWG - Aliphatic >EC5 - EC6	<0.20	<0.1	42	No	No	-	-
TPH-CWG - Aliphatic >EC6 - EC8	<0.40	<0.1	100	No	No	-	-
TPH-CWG - Aliphatic >EC8 - EC10	<10	<0.1	27	No	No	-	-
TPH-CWG - Aliphatic >EC10 - EC12	<10	<0.1	130	No	No	-	-
TPH-CWG - Aliphatic >EC12 - EC16	<10	<2.0 - 18	1100	No	No	-	-
TPH-CWG - Aliphatic >EC16 - EC21	Included within Ali ES21 – ES35	<8.0 - 810	6500	No	No	-	-

Determinand	Results Range (mg/kg) in historical investigations	Results Range (mg/kg) in QGL ⁽¹⁾ investigations	LQM/CIEH S4ULs (2015) (mg/kg) Residential with Plant Uptake End Use ⁽²⁾	Exceedances from historical Investigations	Exceedances from QGL Investigation	Borehole and Depth of Exceedance in QGL investigation	Strata in QGL investigation
Residential Zone							
TPH-CWG - Aliphatic >EC21 - EC35	<20 - 424	16 - 8300	6500	No	Yes	QWS04 2.00m	Made Ground
TPH-CWG - Aromatic >EC5 - EC7	No data	<0.1	70	-	-	-	-
TPH-CWG - Aromatic >EC7 - EC8	No data	<0.1	130	-	-	-	-
TPH-CWG - Aromatic >EC8 - EC10	<10	<0.1	34	No	No	-	-
TPH-CWG - Aromatic >EC10 - EC12	<10	<1.0 – 1.9	74	No	No	-	-
TPH-CWG - Aromatic >EC12 - EC16	<10	<2.0 – 490	140	No	No	QWS04 2.00m	Made Ground
TPH-CWG - Aromatic >EC16 - EC21	<10 - 34	<10 - 120	260	No	No	-	-
TPH-CWG - Aromatic >EC21 - EC35	<10 - 99	<10 - 5800	1100	No	Yes	QWS04 2.00m	Made Ground
Chlorinated Solvents							
Total Chlorinated Solvents (µg/mg)	No data	<100					

Notes:

- (1) QGL = Quantum Geotechnical Limited (2). GAC from LQM/CIEH S4ULs 2015. (3) Historic investigations – in the absence of Chromium VI, all chromium present likely to be Chromium III, GAC for Chromium III adopted. QGL investigation tested for Total Chromium. (4). GAC from DEFRA C4SL. (5) WAC GAC from BRE 2005 (6). Cyanide GAC from AtRisk adopting most sensitive end use for acute risk. (7) Historical investigation state Phenols only were tested. (8) Historic investigations state Boron was tested. (9) Petroleum Hydrocarbons should be assessed as Aliphatic and Aromatic compounds - the most sensitive threshold values were utilised. (10) All Units mg/kg unless otherwise stated

Residential Zone – Soil Contaminant Test Result Highlights

In Trial Pit QTP02 at 1.90m depth, in Made Ground, a very high level of Arsenic, 1900mg/kg, was encountered. In Trial Pit QTP02, in Made Ground, a high level of Chromium Total, 60 mg/kg, was encountered. Within the natural ground, in Windowless Sample QWS03 at 3.0m depth, in silty Clay, a raised level of Chromium Total, 32 mg/kg, was encountered. In Trial Pit QWS03 at 1.0m depth, in Made Ground, a raised level of Lead, 840 mg/kg, was encountered.

Elevated **Polycyclic Aromatic Hydrocarbons** (PAH) were recorded in several locations within the Made Ground material;

Windowless Sample Holes		Cable Percussive Boreholes		Trial Pits		Trial Trenches	
ID	Depth (mbgl)	ID	Depth (mbgl)	ID	Depth (mbgl)	ID	Depth (mbgl)
QWS02	0.6	QBH01	1.0	QTP04	0.6	QTT03	0.5
QWS03	1.0	QBH02	0.6	QTP05	2.2	QTT03	1.0
QWS05A	2.2			QTP16	0.6		
				QTP17	0.4		
				QTP18	0.35		
				QTP19	0.5		

Elevated **Total Petroleum Hydrocarbons** (TPH) were recorded in several locations within the Made Ground material;

Windowless Sample Holes		Cable Percussive Boreholes		Trial Pits		Trial Trenches	
ID	Depth (mbgl)	ID	Depth (mbgl)	ID	Depth (mbgl)	ID	Depth (mbgl)
QWS04	2.0			QTP01	0.6	QTT03	1.0
QWS05A	2.2			QTP03	0.6		
				QTP04	0.6		
				QTP17	0.35		
				QTP18	0.35		

Asbestos screening identified Asbestos to be present on site within the Made Ground material;

Windowless Sample Holes			Cable Percussive Boreholes			Trial Pits		
ID	Depth (mbgl)	Asbestos Type	ID	Depth (mbgl)	Asbestos Type	ID	Depth (mbgl)	Asbestos Type
QWS02	0.6	Chrysotile – Loose fibres	QBH01	1.0	Insulation Lagging and Amosite – Loose fibres	QTP01	0.6	Chrysotile – Loose fibres
QWS04	2.0		QBH02	0.6	Chrysotile – Loose fibres	QTP02	1.9	
QWS05A	0.6					QTP04	0.6	
QWS02	0.6	Amosite – Loose fibres						

Slightly elevated levels of 0.002 – 0.015mg/kg of Polychlorinated biphenyls (PCBs) were encountered in Boreholes QBH01 at 1.0m depth and QBH02 at 0.60m depth, in Made Ground.

No Volatile Organic Compounds (VOCs) were encountered above the respective limit of detection levels.