

WEPCo | Cardiff and Vale Colleges (CAVC)

Barry Waterfront Campus (BWC)

Geotechnical and Geo-Environmental Desk Study Addendum

Reference: VG0201-ARP-ZZ-ZZ-RP-G-00001

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Executive Summary

Site Information	<p>The Barry Waterfront Campus (BWC) development site sits within the National Grid Reference ST 11137 67414, covers an area of approximately 1.15ha and comprises impermeable hardstanding on the west, an existing private road along the northern boundary, and a graded grassed area on the east to facilitate future development. The site is currently a brownfield bounded on all sides by built development, with the Barry Docks to the East and a railway line to the North and West.</p>
Development Proposals	<p>The proposed development comprises the design of a new college campus throughout an area of approximately 1.15ha. The proposed development is for the design of a new college campus including 2No. three-storey connected buildings and a car parking area with 120No. standard parking spaces, site landscape and civil design for the proposed structures.</p> <p>The MIMWEP Stage 1 / RIBA Stage 2 design has been based on early-stage conceptual architectural plans and models. These designs are subject to ongoing development and detailed design through subsequent project stages.</p>
Expected Ground Conditions	<p>The published geology for the site comprises Tidal Flat Deposits (predominantly silt with the presence of clays and sand in the centre and the east of the site) overlying the Penarth Group (interbedded limestone and mudstone). The St. Mary's Well Bay Member (interbedded limestone and mudstone) is found in the western site boundary.</p> <p>Due to the site history, localised Made Ground deposits are anticipated to be encountered throughout the entirety of the site associated with historical land reclamation, the diversion of the Cadoxton River to the east, and recently grading in preparation for the site development.</p> <p>Review of available BGS boreholes and previous ground investigation on site and its vicinity indicate that the expected ground conditions within the construction depth will comprise Made Ground and Tidal Flat Deposits overlying mudstones of the Penarth Group. Groundwater level at the site has not yet been proven by a site-specific ground investigation, however the available information for the site indicates that groundwater can be present between 2.0 to 4.0m below ground level, which represents the aquifer in the Tidal Flat Deposits.</p>
Geotechnical Considerations	<p>Foundations – Due to the characteristics of the Tidal Flat Deposits (TFD) beneath the site, shallow foundations are not expected to be suitable at the site, warranting piled foundations to be adopted. The shear strengths of these deposits are expected to provide negligible contribution to the design of deep foundations, necessitating that pile foundations extend into the underlying limestone and mudstone bedrock, which varies between 5m and >20m depth. Continuous flight auger (CFA) or driven piles remain suitable options to assure support of the materials above the bedrock, however socket length and noise/vibration associated with them respectively need to be resolved to develop a foundation proposal for the development. This will be informed by the proposed ground investigation of the site.</p> <p>Excavation – Excavation in the site soils will be readily achievable using typical hydraulic plant such as excavators or backhoe loaders. It is anticipated that dry batter slopes up to 1v:2h should be achievable. Groundwater level at the site is in the order of 3mbgl, roughly coincident with the transition from Made Ground soils to the underlying Tidal Flat Deposits. Excavations to beyond approximately 2-3m depth may be challenging to control groundwater inflow and excavation face stability due to the Tidal Flat Deposits low strength and unsuitability to support plant and excavation equipment tracking directly on its surface.</p> <p>UXO – The site is located within a moderate-risk area for UXO due to the proximity to strategic targets such as the Barry Docks located east of the site.</p> <p>Buried Utilities – Utility records indicate the presence of public and private services across the whole site, including storm and combined drainage, high and low voltage electrical cables and potable water. The level of accuracy of these findings is very low and should not be relied upon for accurate offsets to features or to set out from on site, however it is believed there are a number of utilities that will need to be diverted to facilitate the development.</p>
Geo-environmental Considerations	<p>Unidentified contamination - Made Ground deposits were not fully penetrated and therefore there is a risk that unidentified contamination may be present at the base of the Made Ground. This will require investigation using appropriate techniques allowing for penetrating through the Made Ground.</p> <p>It is unclear if the site has been subject to remediation since the removal/demolition of the dock related in infrastructure. Historical infrastructure may still be in place and form preferential flow paths for contamination. The potential presence of remnant infrastructure requires investigation.</p> <p>Human health - The current GI information is inconclusive with respect to potential risks associated with lead and asbestos. This will require undertaking statistical analysis on available and any new data obtained from the site. Based on the site history, the risk of encountering asbestos remains high. This will require appropriate management during construction and remediation measures.</p>

	<p>Controlled waters - No quantitative controlled waters risk assessment has been completed as part of the HSP GI. No groundwater quality monitoring or soil leachate analysis have been undertaken. Risks to controlled waters require appropriate assessment.</p> <p>The nature of the TFD underlying the remainder part of the site is unknown. It may comprise granular deposits, which would provide a pathway for vertical contaminants migration into the underlying aquifer. This requires confirmation to allow for a controlled waters risk assessment and foundation works risk assessment in relation to the likely piled foundation solution.</p> <p>Ground gas – Based on previous GI information in vicinity to the site, a CS2 has been indicated (low gas risk). Ground gas monitoring will be required to confirm this and whether gas protection measures are required as part of the new building Made Ground.</p>
<p>Recommendations</p>	<p>A detailed UXO desk study and risk assessment is recommended to be completed to assess the risk posed by the development proposals.</p> <p>Due to the site’s very high Radon Potential levels, it is assumed that the proposed development requires radon protective measures.</p> <p>It is recommended that a non-intrusive utility survey is conducted that covers the entire site to detect and locate existing utility networks and confirm the findings of the original survey in order to inform future design and constraints.</p> <p>A foundation scheme which is compatible with the expected ground conditions has not yet been developed, and remains a risk to the feasibility of constructing the proposed buildings in the south of the site where rock levels dip away.</p> <p>It is recommended that a targeted ground investigation is completed to understand on site ground conditions and inform the detailed design.</p> <p>A watching brief is recommended to be undertaken during the intrusive works for the proposed development to identify any unexpected contamination.</p>

1. Introduction

1.1 Background

Ove Arup and Partners Limited ('Arup') have been commissioned by *WEPCo | Cardiff and Vale Colleges* (the Client) to provide multidisciplinary engineering services for Barry Waterfront Campus (BWC) a proposed development of a new college facilities located approximately 0.30 km southeast of Barry town centre in South Wales.

The ground engineering services that Arup have been commissioned to undertake include a Phase 1 geotechnical and geo-environmental desk study, in order to characterise the nature of potential ground-related constraints associated with the proposed development and complement previous studies on the location site. The specific objectives relating to this are outlined in Section 1.3.

1.2 Proposed Development

The proposed development is a new college campus throughout an area of approximately 1.15ha. The development will include two connected three-storey buildings and a car parking area with 120No. standard parking spaces, hard and soft site landscaping throughout the site.

Information regarding the proposed development has been gathered from the MIMWEP Stage 1 Report - Annex D - Outline Geotechnical & Structural Specification (VG0201-ARP-XX-XX-RP-S-00001_AnnexD) [1]. The MIMWEP Stage 1 / RIBA Stage 2 design has been based on early-stage conceptual architectural plans and models. These designs are subject to ongoing development and detailed design through subsequent project stages.

1.3 Objectives

The primary objective of this report is to complement and validate previous studies on the area, completed in 2020, with the following information:

- Review available information and obtain sufficient additional information to determine the nature of any potential ground constraints (geotechnical and geo-environmental) that may pose a risk to the development.
- In the context of potential risks posed by land contamination, identify a list of all potential contaminant linkages on site (source-pathway-receptor) and evaluate the significance of the pollutant linkages.
- Provide initial commentary of geotechnical and geo-environmental constraints and risks to the proposed development and provide recommendations from the report findings.
- Determine the requirements for site investigations to further define or mitigate any risks identified.

1.4 Sources of Information

The following sources of information have been used to inform the findings of this report. Note that the published guidance and/or standards are not listed below and are referred to where relevant in the report.

- Barry Waterfront Campus (BWC) - MIMWEP Stage 1 Report - Annex D: Outline Geotechnical & Structural Specification (VG0201-ARP-XX-XX-RP-S-00001_AnnexD), Arup 2022 [1].
- Barry Waterfront Campus (BWC) - MIMWEP Stage 1 Report - Annex H: Outline Civil Engineering Specification (VG0201-ARP-XX-XX-RP-C-00001_AnnexH), Arup 2022 [2].
- C3297 Phase I Geo-Environmental Assessment - Barry Waterfront, HPS Consulting 2020 [3].
- C3297 Phase II Geo-Environmental Assessment - Barry Waterfront, HPS Consulting 2020 [4].
- Groundsure Report as an annex to the C3297 Phase I Geo-Environmental Assessment - Barry Waterfront. This includes 1:1,250 1:10,000 and 1:10,560 scale Ordnance Survey (OS) maps from 1878

to the present day. The report also includes environmental sensitivity and permitting information, as well as geological sensitivity information (from Groundsure) [5].

- British Geological Survey (BGS), Sheet 263: Geological map of Cardiff, Solid and Drift (1:50,000) - 1986. Reviewed for site geological information [6].
- British Geological Survey (BGS), GeoIndex Onshore online database. Reviewed for geological mapping, and digital historical borehole records for the regional area [7].
- Environment Agency Online Flood Map for Planning. Reviewed for flood risk on site [8].
- Historic England online Aerial Photo Explorer. Reviewed to understand whether there was any historical aerial imagery of interest, particularly around the Second World War to understand UXO risks [9].
- Department for Environment, Food & Rural Affairs (DEFRA), MAGIC online database. Reviewed for aquifer designations, and general environmental sensitivity information [10].
- UK Health Security Agency (UKHSA) UK Radon online risk map. Review for radon potential on site [11].
- Zetica UXO bomb risk maps. Reviewed for UXO risk [12].
- Vale of Glamorgan Council Online Planning Applications Register (<https://vogonline.planning-register.co.uk/>) [13].
- Verification Report Remedial Works at West Pond, Barry Waterfront Development, WSP 2014 [14].
- Barry Waterfront: The Quays Remediation and Verification Strategy, WSP 2013 [15].
- Barry Waterfront: West Pond Remedial Action Plan, QDS 2012 [16].
- The Quays - Barry Waterfront: Review of Existing Site Data and Reports, WSP 2012 [17].
- Barry Waterfront: Asbestos Material Investigation, ASM Compliance Ltd 2012 [18].
- Barry Waterfront Development West Pond Ground Remediation Works – Plan & Sections (Drawing No: 3572_0106), Healer Associates 2010 [19].
- Barry Waterfront: Environmental Statement, Nathaniel Lichfield, and Partners 2009 [20].
- Barry Waterfront South Quay and West Pond Desk Study, Arup 2008 [21].
- Barry Dock Regeneration Dust and Asbestos Monitoring Baseline Survey, Wimpey Environmental 1996 [22].
- Innovation Quarter, Hood Road, Barry Waterfront, Barry Site Investigation Report, Integral Geotechnique 2015 [23].
- Waterfront Barry Geo-Environmental Site Investigation Report – West Pond, Arup 2008 [24].
- Barry Quays, Barry, Remediation and Verification Strategy, Idom Merbrook Ltd 2016 [25].
- The Barry Waterfront Consortium, Barry, Proposed School Site Contaminated Land Assessment and Remediation Method Statement, Idom Merebrook Ltd 2019 [26].

1.5 Limitations

This report has been prepared for Cardiff and Vale Colleges (the Client) and takes into consideration their particular instructions and requirements. It is not intended for, and should not be relied upon by, any third party and no responsibility is undertaken to any third party.

The interpretation of the ground conditions is based on the information obtained as part of this desk-based assessment, newly acquired third party information and available ground investigation information.

Reasonable skill, care and diligence has been exercised in carrying out this report within the timescales and information available.

2. The Site

2.1 Site Location and Description

The Barry Waterfront Campus (BWC) development site is in the vicinity of the docks along the Ffordd Y Mileniwm, approximately 0.30 km southeast of Barry town centre, in South Wales. The site is centred around National Grid Reference ST 11137 67414 and covers an area of approximately 1.15ha.

The site is generally bounded on all sides by built development including:

- the Ffordd Y Mileniwm (Millennium Way) to the Southeast, with a supermarket and residential properties beyond;
- a rail siding to the North and commercial development beyond;
- a road junction to the East with Barry Docks beyond;
- A primary school (Ysgol Gymraeg Sant Baruc) to the South with residential properties beyond;
- and to the West by a railway line with residential properties beyond.

The site is accessed via a gated road from Ffordd Y Mileniwm along the south-eastern boundary of the site.

The site is currently a brownfield area comprising of impermeable hardstanding on the west, an existing private road along the northern boundary, and a graded grassed area in the east to facilitate future development. Topographical surveys taken place on site indicate the site has been generally graded in preparation for development. The eastern grassed area has a high point at approximately +9.5mOD which slopes to +9.15mOD at the southern boundary, +9.0mOD at the eastern boundary and +8.5mOD along the northern boundary and in the western hardstanding area.

2.2 Site Constraints

During MIM Stage 1 and through discussions with the SuDS Approving Body (SAB) officer, Arup were made aware of an existing sea culvert that runs inside the site parallel to the northern boundary before it angles towards the centre of the site, leaving the site to the southwest into the adjacent site. From historical plans it is shown to be 8'x8' with a large easement, presenting a significant potential constraint to the proposed development, especially with regards to foundation design. There is uncertainty about whether it services existing properties, and as such demolition and removal is currently being avoided.

It has been advised, however, that any proposed substructures do not need to be designed to enable access to the culvert for future maintenance and that an engineering solution can be adopted to bridge over the culvert allowing the building footprint to extend over the culvert and within the easement. As a result of this, any site development and landscaping can be progressed within the easement zone, including provision of SuDS features, parking / hardstanding and utilities diversion permitted within the cover zone above the culvert.

The existing private rail tracks to the north of the site close the site boundary may also pose a constraint on groundworks in the vicinity, along with the numerous public and private buried utilities in all parts of the site identified during the non-intrusive utility survey.

The extent of the demolition of the infrastructure related to the docks is unknown. Therefore, there is a risk of encountering remnant foundations and services.

2.3 Site History

An update of the land use assessment of the site through the consultation of the available historical Ordnance Survey (OS) maps and historical aerial imagery is presented in Table 1 below.

Table 1 - Site History

Source	On Site	Off Site (within 500m of site boundary)
1878 to 1881	<p>The majority of the site is part of tidal flats of the Cadoxton River with foreshore and farmland in the north-western quadrant.</p> <p>The main river channel present in the south along the southern boundary, with a stream and confluence with the river present in the east.</p> <p>The inter-tidal Cadoxton River meets the Bristol Channel to the west of Barry Island.</p>	<p>Limekilns and a quarry are noted approximately 110m to the north of the site.</p> <p>Quarry 100m to the west, with further Old Limekiln and quarry noted approximately 160m east.</p> <p>The village of East Barry is noted approximately 120m west of the site.</p> <p>Barry Island is approximately 400m to the south.</p>
1898 to 1900	<p>The mapping indicates the area is as part of the Barry Docks (land reclaimed from the inter-tidal Cadoxton River) with Cadoxton River now diverted 2km to the east.</p> <p>The northeast of the site is occupied by railway sidings, with a small building in the south and the west of the site occupied by marshland and open water bounded by the masonry edge of the dock with a track running northwest to south at the crest of the dock.</p>	<p>Significant land reclamation and industrial development is recorded in the surrounded area including the formation of Barry Docks with Barry Railway, numerous railway sidings and coal tips (coal unloading areas from rail to ship) approximately 75m to 750m to the east of the site with open water (known as West Pond, unnamed on the mapping) immediately to the south of the site.</p> <p>Goods Shed and sidings are shown immediately to the north of the site boundary.</p> <p>Locomotive Repairing Works and associated sheds and tracks are shown approximately 50m to the north of the site.</p> <p>Significant expansion of residential housing is shown in East Barry now shown as Barry approximately 120m north and west of the site</p>
1915 to 1921	<p>One additional building and sidings are noted.</p>	<p>Expansion of the goods shed approximately 10m to the north of the site is noted from 1920.</p>
1936 to 1956	<p>Two further buildings and tanks are noted in the south of the site.</p> <p>Additional buildings are noted along the trackway in the west of the site from 1954.</p>	<p>West Pond to the south of the site appears to have been infilled from 1936 onwards with the addition of buildings and sidings in this area.</p> <p>Barry Railway is now recorded as the Great Western Railway from 1936.</p>
1965 to 1982	<p>A coal yard inclusive of enclosures is noted in the north of the site from 1972. Railway sidings are no longer shown in this area.</p> <p>The buildings and tanks in the south of the site are no longer shown.</p> <p>An additional roadway is noted from 1972 in the west with crossroads in the south of the site.</p>	<p>The Goods Shed to the north of the site is noted as 'disused' from 1971.</p> <p>The Locomotive Repair Works is no longer present to the north from 1971 with a Pump House noted approximately 100m to the north.</p> <p>Panel Beating Works is shown approximately 125m to the northeast.</p> <p>An oil storage terminal and associated large storage tanks are located 50m to the southeast of the site.</p> <p>A laboratory is shown immediately to the south of the site from 1972.</p> <p>Further residential development within the town of Barry to the west of the site.</p>
1990 to 2010	<p>Railway sidings and the coal yard are no longer shown from 1990.</p> <p>The crossroads in the south of the site are no longer present from 2003 and replaced by an access road extending northwards to the former goods shed adjacent to the north of the site.</p> <p>Former coal yard enclosures are no longer noted on site from 2003.</p>	<p>The oil storage terminal is no longer present from 2003, with a reduction in the number of tanks noted on the 1993 mapping.</p> <p>A roundabout is present immediately to the east of the site from 2003.</p> <p>The Vale of Glamorgan Steam Railway is noted immediately to the west of the site from 2010.</p>
2020	<p>No significant development on site.</p> <p>The western area of the site appears to be used as a car park.</p>	<p>Commercial and residential development is noted in the surrounding area, with residential and retail (supermarket) development to the south of the site and a business park to the north beyond Hood Road.</p>

Source	On Site	Off Site (within 500m of site boundary)
		The Hood Road Station (part of the heritage railway) is shown immediately adjacent to the northern boundary.
2021	Land reclamation on site in preparation for development.	Land reclamation works along the southwestern. Construction of a warehouse structure adjacent to the southern boundary of the site.
2022-2023	Land reclamation and temporary works on site in preparation for development.	No significant development or change in the vicinity of the site.

Review of the historical site use indicates significant sources of potential contamination on site or in the immediate vicinity.

2.4 Geology and Ground Conditions

A review has been conducted of publicly available records held by the British Geological Society (BGS) near the Barry Waterfront Campus development site and is summarised in the following sections and presented in Figure 2.

2.4.1 Site Geology

Geology mapping indicates the following geological sequence of natural deposits at the site:

- Superficial geology comprising Tidal Flat Deposits (predominantly silt with the presence of clays and sands) expected from the centre of the site with increasing thickness to the south-east.
- Bedrock geology comprising interbedded mudstone and limestone of the Penarth Group and St. Mary's Well Bay Member.

Due to the site history, localised Made Ground deposits are anticipated to be encountered throughout the entirety of the site with different but significant thicknesses, associated with historical land reclamation campaigns and the diversion of the Cadoxton River to the east, and recently grading in preparation for the site development.

2.4.2 Nearby borehole records

There are no records of historical boreholes from the BGS database within the site boundaries, but 7No. borehole records within 250m of the site. The borehole records in reasonable proximity of the proposed works are summarised in the following table, along with previous ground investigation works carried out on site and in its vicinity between 2018 and 2020.

Table 2 - BGS borehole records and existing GI surveys

Reference	Method	Location	Year	Elevation	Depth	Groundwater
ST16NW375	Cable percussion	130m N of site	2005	+16.96mOD	4.3m	No water strikes
ST16NW376	Cable percussion	130m N of site	2005	+16.48mOD	1.5m	No water strikes
ST16NW379	Trial pit	130m N of site	2005	+16.16mOD	2.2m	No water strikes
Goods Shed Hood Road TP4	Trial pit	50m N of site	2018	-	2.5m	No water strikes
Goods Shed Hood Road WS1	Windowless sample hole	50m N of site	2018	-	3.0m	Moderate inflow at 2.3m b.g.l.
Goods Shed Hood Road WS2	Windowless sample hole	50m N of site	2018	-	3.0m	Standing groundwater at 3.0m b.g.l.

Reference	Method	Location	Year	Elevation	Depth	Groundwater
Goods Shed Hood Road WS3	Windowless sample hole	50m N of site	2018	-	3.0m	No water strikes
Barry Waterfront WS01	Windowless sample hole	On site	2020	-	3.0	No water strikes
Barry Waterfront WS02	Windowless sample hole	On site	2020	-	4.0	3.4m b.g.l.
Barry Waterfront WS03	Windowless sample hole	On site	2020	-	4.0	3.0m b.g.l.
Barry Waterfront WS04	Windowless sample hole	On site	2020	-	3.0	No water strikes
Confidential borehole WPBH18	CP	25m SE of site	c.2008	~ +8mOD	23m	Unknown
Confidential borehole WPBH2	CP	60m S of site	c.2008	~ +8mOD	>15m	Unknown
Confidential borehole WPBH3	CP	60m S of site	c.2008	~ +8mOD	>10m	Unknown
Confidential borehole WPBH1	CP	10m E of site	c.2008	~ +8mOD	~6m	Unknown

Reviewing the available borehole records, the bedrock geology can be seen to dip in a north-west to south-east direction beneath the site and surrounding area, described below:

- to the north of the site, bedrock is near surface and comprises interbedded limestone and mudstone, with ground elevation in the order of +16mOD at a distance of 65m from the site;
- to the south of the site in the reclaimed West Pond area, bedrock dips steeply beneath the reclaimed Cadoxton River channel, with Tidal Flat Deposits extending to approximately -16mOD. Ground levels here are approximately +8mOD;
- beneath the BWC site, the thickness of Tidal Flat Deposits is expected to be 3-5m thick in the north and increasing rapidly to >18m the south.

2.4.3 Natural Ground Stability Hazards

The Groundsure Report indicates the following in relation to natural ground stability hazards:

- The potential for **Collapsible Deposits** is listed as having a hazard potential from ‘negligible’ to ‘very low’ on site.
- The potential for **Compressible Deposits** on site is listed as having a hazard potential of ‘very low.’
- The potential for **Ground Dissolution Hazards** on site is listed as having a hazard potential of ‘negligible.’
- The potential for **Landslides** on site is listed as having a hazard potential of ‘very low.’
- The potential for **Running Sands Deposits** on site is listed as having a hazard potential of ‘very low.’

- The potential for **Shrinking or Swelling Clay Deposits** on site is listed as having a hazard potential of ‘negligible’ to ‘low.’ The low hazard potential is anticipated to be associated with the deposits and Made Ground.
- The **Radon Potential** for the entirety of the site indicates the proposed development is in a ‘very high’ probability radon area where the maximum radon potential varies between 10% and 30% above the Action Level [11]. The UK radon map was updated in December 2022 and supersedes the results within the Groundsure Report. The proposed development therefore is assumed to require radon protective measures.

2.4.4 Radon

Based on the British BGS GeoIndex online database [7], the site falls within a maximum radon potential of 10-30 %. Basic radon protective measures will be required at the site.

2.5 Hydrogeology

Aquifer designations for relevant geological units within the site are provided in the table flow. Aquifer designation have been obtained from the BGS GeoIndex online database [7] and corroborated by the Groundsure Report.

Table 3 - Aquifer Designations

Geological Unit	Aquifer Designation	Description
Tidal Flat Deposits	Secondary undifferentiated	‘Layers previously designated as both minor and non-aquifer in different locations due to the variable characteristics of the rock type.’
Penarth Group	Secondary B	‘Predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons, and weathering. These are generally the water-bearing parts of the former non-aquifers.’
St. Mary’s Well Bay Member	Secondary A	‘Permeable layers that are capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers.’

The groundwater vulnerability throughout most part of the site is assessed as high, pertaining to areas that provide protection from pollution, mainly associated with the mudstones and limestones of the Penarth Group encountered on site.

The available information for the site indicates that groundwater can be present between 2.0 to 4.0m below ground level, which represents the aquifer in the Tidal Flat Deposits. Other aquifers can be expected in the bedrock geology and will influence any foundations extending to those strata.

Based on the topography of the site and surrounding area and the nearby surface water features it is anticipated that the groundwater flow direction on site is to the south and east of the site, towards the Barry Docks.

2.6 Hydrology

2.6.1 Surface water features

The site is located 150m west of the Barry Docks, a facility that serves the South Wales chemical industry by handling cargo comprising timber, steel, coal, cement, aggregates, and specialist liquid bulks. The depth of water for two of the docks is 9.5m, whereas the third dock shows semi-tidal depths.

2.6.2 Flooding

The published flood risk map for planning indicates that the potential for river and coastal flooding to occur on site is essentially negligible but becomes moderate within 50m East of the site due to the proximity with the Barry Docks.

The majority of the site is within Zone B, areas known to have been flooded in the past evidenced by sedimentary deposits. Zone B is used as part of a precautionary approach to indicate where site levels should be checked against the extreme (0.1%) flood level. The western edge of the site is within Zone A which is considered to be at little or no risk of fluvial or tidal/coastal flooding. Although the college is classed as vulnerable development, vulnerable development is acceptable in Zone B if there is no Zone A alternative.

The risk of groundwater flooding is moderate in the centre and east of the site, with a negligible risk in the west. There are a number of possible sources of the surface water flooding. This could be a combination of rainfall landing directly on the site ponding in depressions or it could flow overland into the site from outside the site boundary.

If site levels are greater than the flood levels used to define adjacent extreme flood boundaries there is no need to consider flood risk further. For further details refer to other civils documents.

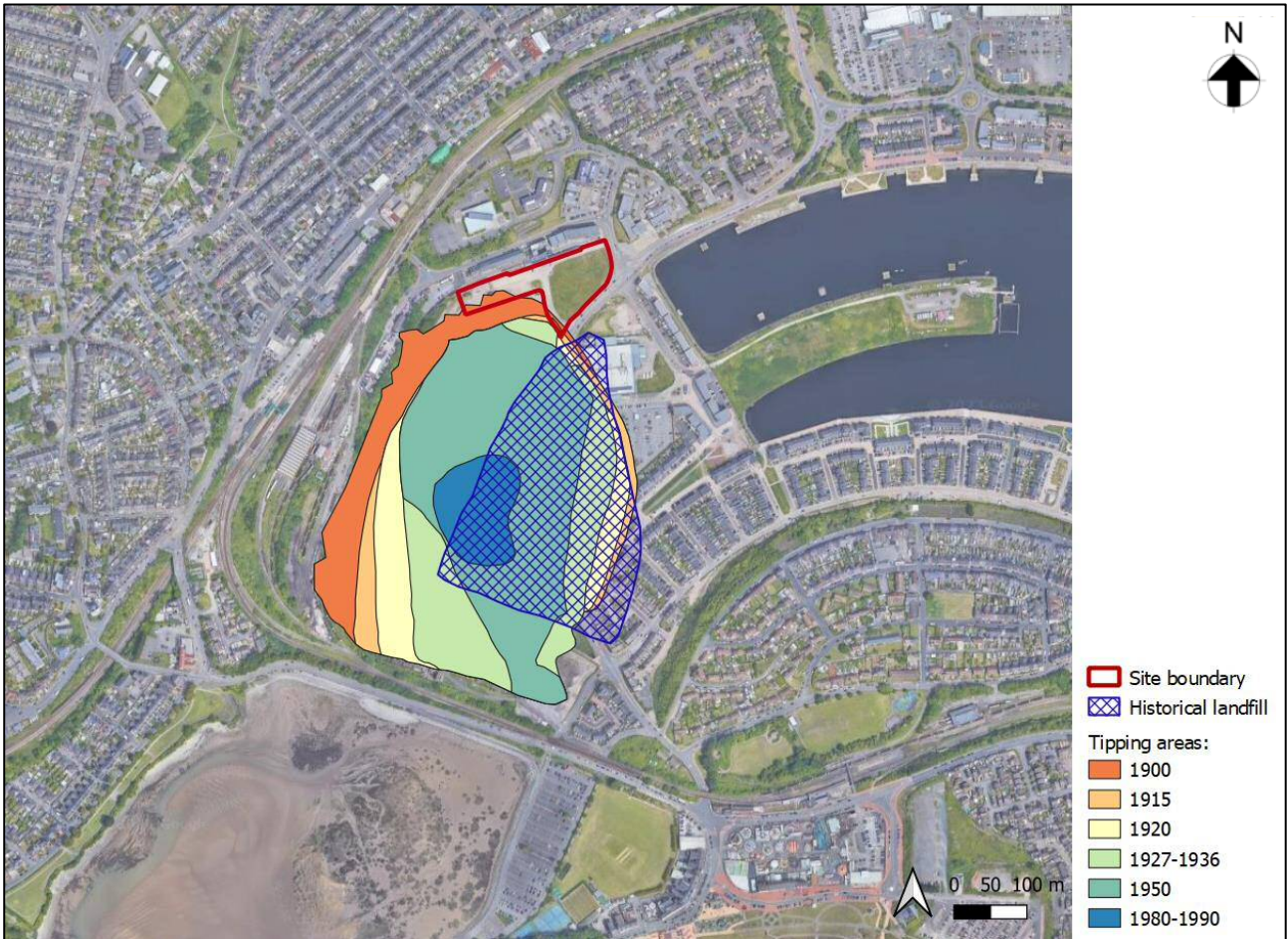
2.7 Environmental Setting

A summary of the environmental setting is presented below, based on information presented in the HSP desk study [3].

2.7.1 Waste and Landfill Facilities

There is a single record of EA Historical registered landfill site recorded within a 250m radius of the site. This relates to an Unknown Operator approximately 10m south, with a last recorded use of December 1955. Refer to section 2.3 for details on the infilling of the land (West Pond) to the south off-site.

A summary of the history of the land infilling and the location of the historical landfill are shown in Picture 1 below. It should be noted that the site may be encroaching on the early 1900s tipping operations. The extent of these operations is unknown and may extended further into the site than indicated by historical plans.



Picture 1 - History of land infilling and historic landfill location

There are eight records of Waste Exemptions within 250m of the site, these records belong to two locations and relate to the sorting and de-naturing of controlled drugs for disposal situated approximately 80m northwest and 240m north west of the site.

2.7.2 Industrial Land Use

There are a number of records of current industrial activities recorded within a 250m radius of the site as reported in the HSP desk study [3]. The key ones are summarised below:

- Electrical substation (electrical feature) approximately 30m south east.
- Electrical Features approximately 90m south west, 120m north and 120m east.
- Moorings and Unloading Facilities approximately 110m south east and 210m east.
- Vehicle Breakdown and Recovery Services 150m north west.
- Petrol and Fuel Stations approximately 190m south.
- Industrial Repairs and Servicing 230m north east.

There are 101No. historical industrial activities within a 250m radius of the site. With 16 records on site relating to eight records of Railway Sidings recorded from 1898 to 1991, six records of Docks recorded from 1898 to 1991 and 2 records of Locomotive Repair Works recorded from 1898 to 1921. Other pertinent records within a 100m radius of the site relate to Unspecified Ground Workings, Goods Sheds, Unspecified works, Docks, Pumping House, Unspecified Tanks, Chimneys, and a Coal Tip.

2.7.3 Licensed Discharges to Controlled Waters

There is a single record of Registered Radioactive Substance Authorisations recorded within 250m of the site. This relates to a record of Disposal of Radioactive Waste for an operator approximately 145m southeast of the site, the licensed is recorded to have been revoked in January 2015.

No Part A (2) Activities have been identified within a 250m radius of the site. However, there are two records of Licensed pollutant release Part B within 250m of the site, these relate to a Dry-Cleaning process 170m west and a Petrol Vapour Recovery process 214m west.

2.7.4 Pollution Incidents

No Environment Agency Recorded Pollution Incidents to Controlled Water have been recorded within a 250m radius of the site.

2.8 Unexploded Ordnance

Available Zetica UXO risk mapping indicates that the site is located within an area deemed to be moderate risk of UXO. A Zetica UXO bomb risk map was obtained for the site and is enclosed. The Zetica risk mapping identified 3No. Luftwaffe targets within 1.0km of the site associated with Barry Docks, located east of the site.

Based on the above, it is recommended that a detailed UXO desk study and risk assessment is undertaken for the site to assess the risk and mitigation strategy for the proposed works.

2.9 Planning Applications

Barry Town Council are the statutory consultees to the Vale of Glamorgan Council, the local planning authority for Barry. The Vale of Glamorgan Council online planning portal [13] was accessed to identify relevant planning applications registered to the site. The following table summarises the applications made concerning the land to the south of Hood Road in Barry Waterfront.

Application	Date	Approximate location	Status
1994/00144/OUT - Comprehensive redevelopment	25/02/1994	Entirety of site and Barry Waterfront	Approved
2007/00172/RG3 - Outline planning application for the site to be used for an education facility	08/02/2007	Entirety of site	Approved
2009/00946/OUT – Outline planning application for the development of vacant land at Barry Waterfront for residential (C3), retail (A1), cafes, bars, and restaurants (A3), hotel (C1), offices (B1) and community and leisure uses (D1 and D2).	13/08/2009	Land directly south of site	Approved
2018/01358/1/FUL - 2018/01358/FUL: Change of use, conversion and alterations to the Goods Sheds to provide a mixed use scheme	05/06/2019	Land directly to the north of site	Approved
2021/00379/FUL – Planning application for the construction of a new primary school, access, car parking, landscaping, and associated works	18/03/2021	Land directly south west of site	Approved
2022/00661/SC1 - Screening Opinion on the requirement of an Environmental Impact Assessment for the proposed development of the CaVC Barry Waterfront Campus (BWC)	24/05/2022	Entirety of site	Determined

3. Geo-Environmental Review

A review of available information for the site in relation to contaminated land has been carried out (sources included in section 1.4). HSP carried out a desk study [3] and ground investigation and assessment for the site [4] the findings of which are briefly summarised below. This section is an addendum and contains additional information to that presented by HSP.

3.1 HSP Desk Study, Ground investigation & contamination assessment (2020)

The main sources of contamination are associated with the land reclamation and later use of the site as a dockland as summarised below [3]:

- **On-site:** Railway – tracks/sidings, Coal Yard, Unknown Tanks, Made Ground (Infilled Land) (Inorganic and organic contaminants including heavy metals, metalloids, acids/alkalis, TPH, PAHs, sulphate, asbestos, and ground gases).
- **Off-site:** Barry Docks (east), Locomotive Repair Works, Railway – lines/ sidings (north and north west), historic Landfill (south), Coal Handling/Yard (north) and Oil Storage Terminal (south east) (Inorganic and organic contaminants including heavy metals, metalloids, acids/alkalis, TPH, PAHs, sulphate, asbestos, and ground gases).

The ground investigation carried out on site in June 2020, comprised 12No. windowless sample boreholes with a good distribution across the site [4].

The scope of the GI included the following:

- Dry weight soil testing completed on 10No Made Ground samples for the following determinands: metals, speciated petroleum hydrocarbons, PAHs, and asbestos.
- Ground gas monitoring of 3No installations with response zones targeting the Made Ground (3No rounds were undertaken in July and 1No in October 2020).

The ground conditions encountered generally comprised hardstanding or topsoil, overlying Made Ground deposits of fill, with natural Tidal Flat Deposits encountered within four locations across the site underlying the Made Ground. No evidence of significant contamination was encountered however Made Ground materials were recorded to contain clinker, ash, and slag. The thickness of Made Ground was proven in the western site area only, at between 0.8 and 3.5m bgl. The remainder of the window samples were undertaken in the raised land area occupying the eastern site area, where they terminated within the Made Ground at between 1 and 3m bgl.

Perched groundwater was encountered within Made Ground deposits in four exploratory locations during the intrusive works. The depth of encounters ranged between 2.50m and 2.60m bgl. Groundwater levels have been monitored on three of four occasions during the ground gas monitoring visits. Groundwater levels were encountered at depths between 1.80 and 2.94m bgl.

The geoenvironmental assessment carried out by HSP [4] indicated the following:

- **Human Health:** The results of the laboratory analysis were screened against GACs including the Defra Category 4 Screening Levels (C4SL) and LQM and CIEH S4ULs for a residential without homegrown produce. There was a single exceedance of lead (510mg/kg) in the western part of the site (WS02 at 0.6m bgl; refer to Figure 6). Asbestos of Spray coated Chrysotile, Crocidolite and Amosite were also identified in the same sample (asbestos quantification testing indicated 0.20%).
- **Waste classification:** The same sample (WS02 at 0.6m bgl) was also characterised as containing hazardous properties on account of TPH at 1200 mg/kg. Description of materials encountered in that location is similar to materials across the site.
- **Ground gas:** Gas concentrations were monitored on four occasions (3No. boreholes installed, response zones within the Made Ground). The results indicated that methane was not recorded

above the monitor limit of detection (<0.1%vol). Carbon dioxide was recorded at a maximum concentration of 16.3% vol in air in WS01. Steady state gas flows were recorded during the monitoring visits. The ground gas assessment carried out by HSP in accordance with CIRIA C665 indicated that the site falls in a Characteristic Situation 2 (gas protection measures required for the proposed development).

- **Water Supply:** The chemical results show exceedances of the threshold values for PE and PVC pipes. It is therefore considered that specialist materials are likely to be required for water supply pipes at the site. Confirmation of supply pipes should always be sought from utility providers.

No sampling and testing of leachate and groundwater was carried out as part of the GI and by extension no quantitative controlled waters risk assessment was completed.

3.2 Further review of land condition and remediation

3.2.1 Historical land contamination

The land within and in vicinity to the site (including the area immediately in the south of the site, known as West Pond) has been subject to numerous intrusive investigations and assessments since 1992 as well as being the subject of two asbestos investigations [17] [25]. A summary of the land contamination is presented below (also shown in Picture 2):

- Predominantly heavy metals were encountered within the site area.
- Asbestos contamination was indicated in the area immediately in the south of the site (West Pond) both within the soil to depths >3.5m and as sheeting, lagging and gaskets at surface, due to breaking up of redundant railway steam engines (Previous investigations show that the west pond area was generally overlain by Made Ground materials up to 11.6m thick).
- Mobile, liquid organic pollutants including tars and other chemicals were indicated in the southeast of the site, where the old tank farm was present, predominantly at depths >3mbgl within reworked alluvium / Made Ground.
- Additional oils and tars were encountered directly north of the site where the Locomotive Repair Works were.

3.2.2 Remedial works

Associated British Ports (ABP) and the Welsh Development Agency (WDA) formed a Joint Initiative with the objective of transforming the derelict area around No. 1 Dock at Barry into high quality development plots during the 1990s. In order to do this, it was felt that three major issues had to be addressed:

- site clearance and removal of any residual soil contamination due to previous industrial uses,
- reprofiling of the site to form new development areas,
- incorporation of new roads and infrastructure to service the sites.

The remedial works were designed by Arup and implemented by Nuttall Construction. The work was carried out and completed on areas of the former Barry Docks including the majority of West Pond area in late 1990s. Reclamation undertaken comprised:

- Removal of slabs, foundations, shallow services, and general debris as part of an overall site scrape.
- Removal to an on-site Waste Management Facility of isolated areas of contamination identified by testing of the formation. In addition, the top 100 mm was removed and disposed of due to asbestos contamination. Material taken to the on-site disposal facility (located in East Quay) was also tested to confirm its compliance with the waste management licence.

The western part of West Pond was remediated to achieve residential end use standards, as per standards adopted at the time of the remediation works (I.C.R.C.L. (Interdepartmental Committee on Redevelopment of Contaminated Land), whereas the remaining part of West Pond including the Old Tank Farm part, was

remediated to the then adopted commercial end use standards. However, due to lack of suitable materials, capping was not installed in all areas (see Picture 3) leaving formation material at the ground level. In addition, other material has been imported since the completion of this contract and stockpiled on site.

Contaminated material was also removed from North Quay, West Pond (south of the site) and East Quay. Soil samples were taken from the formation surface prior to placement of the capping layer (25m grid). The capping across the site was tested on a 25m grid. The test results showed that they are within the allowable limits for the designated end use in each area [21]. The former Woodham's Yard (scrapyard / railway engine dismantling) directly north off-site, was subject to a 600mm soil strip which was disposed of within the on-site treatment facility.

It is unclear whether the BWC site itself has been subject to remediation since the removal/demolition of the dock related in infrastructure. Historical infrastructure may still be in place and form preferential flow paths for contamination.

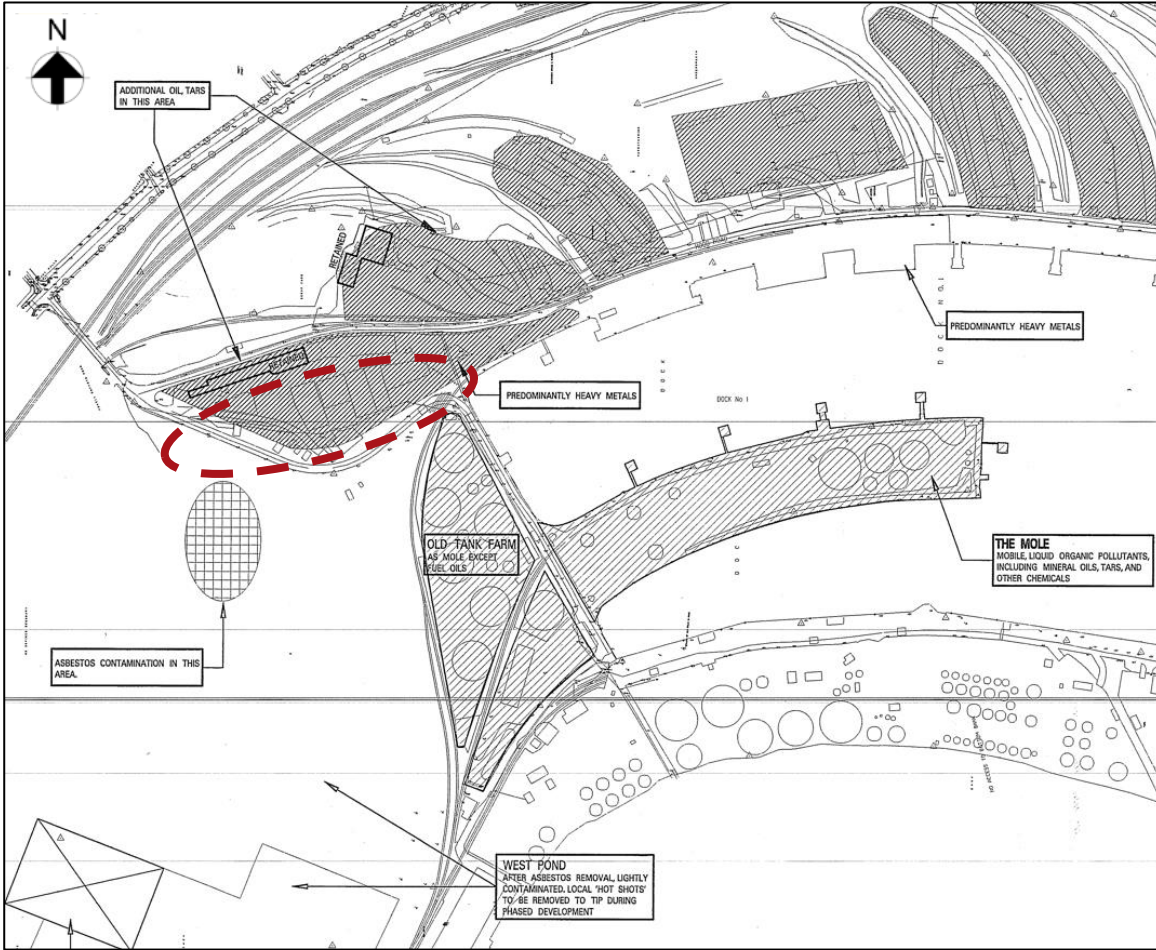
3.2.3 West Pond investigations and assessments

A GI was carried out within the West Pond in 2008. The field works covered the whole West Pond area (starting directly south of the site and extending all the way to the South Quay. The Geo-Environmental Site Investigation Report and the DQRA [24] concluded that the areas proposed for commercial end-use may be redeveloped without the need for remedial works. The areas in the more impacted part of the site (south eastern area), would require remediation to address hydrocarbon contamination including Light Non Aqueous Phase Liquid (LNAPL) impact, and thus removing the risk posed by the site to groundwater. It was also considered that the infiltration of rainwater and the subsequent migration of contaminants would be greatly reduced by the introduction of buildings and extended areas of hardstanding, in addition to placement of soils to raise the ground level for flood prevention purposes.

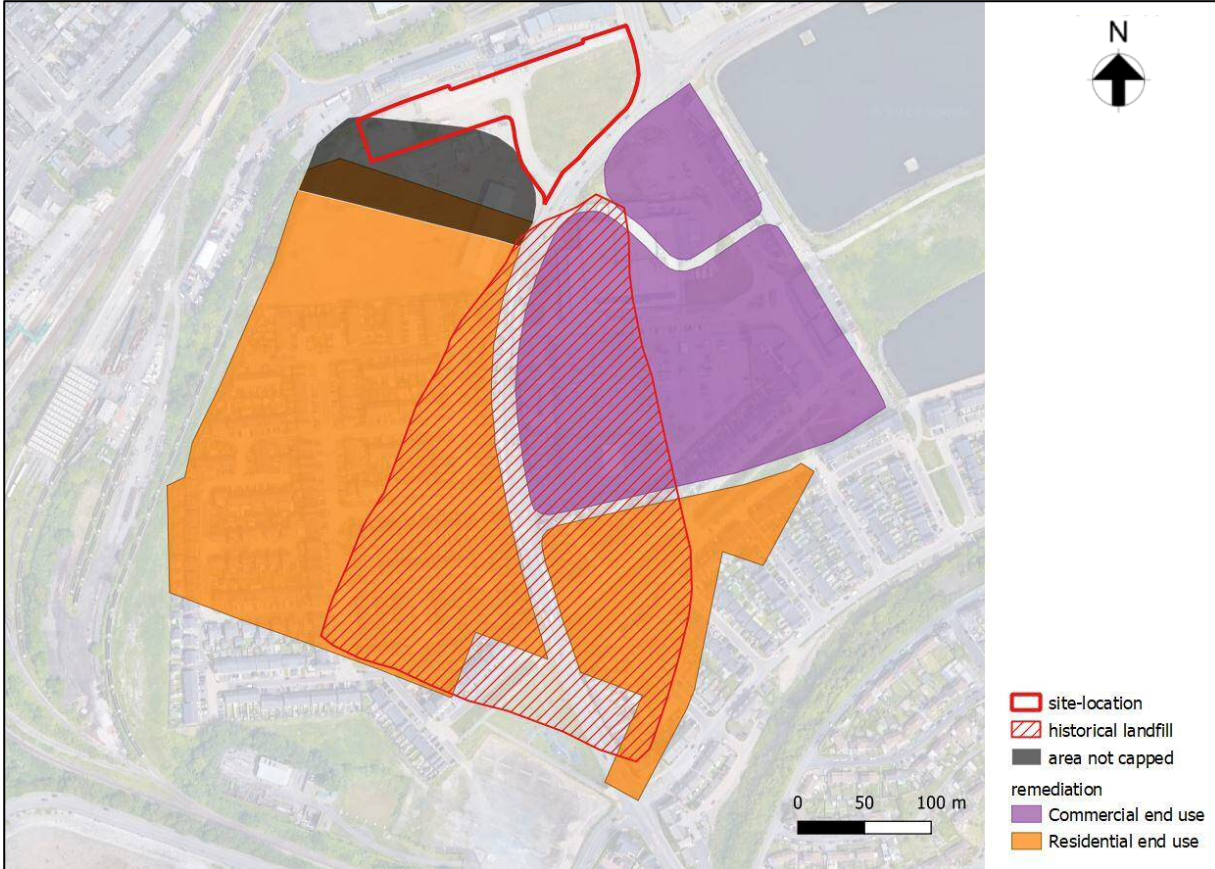
Visual evidence of asbestos was noted in the form of asbestos sheeting in one location between 0.6-1.6m and 3.3-3.7m, in the southern part of the West Pond. However, no free fibres were detected during subsequent chemical analysis at this location. Laboratory analysis did record free fibre asbestos (chrysotile) at 0.3m. However, no visual evidence of potential ACMs was noted during the field observations. No other asbestos was encountered during this phase of investigation (132 No. soil samples were tested for asbestos).

In 2012, following commencement of the earthworks in West Pond, ASM Compliance Limited at the request of Cuddy Group completed an Asbestos Material Investigation of Soil, after the identification of potential asbestos containing materials at surface during initial enabling works at the Site. The investigation comprised the excavation of up to 40 No. trial pits excavated to a maximum depth of 4.0mbgl and a surface walkover to assess the extent of asbestos contamination within soil across parts of the West Pond area. Selected soil samples and visual asbestos samples were submitted for laboratory testing. The investigation identified the presence of asbestos (predominantly chrysotile, although some crocidolite and amosite were also encountered) from surface to at least 3.5mbgl. The assessment identified that asbestos was present in both solid and free fibre form and was more prevalent in the west of West Pond, than the eastern side. The western area was the last to be in-filled and subject to use as a railway engine breakers yard and scrapyard. However, it should also be considered that the assessment works have been more focused on the West Pond than other areas of the development [17].

With regards to ground gas, the Arup 2008 intrusive assessment included the assessment of ground gas risk in accordance with CIRIA 665 and NHBC. The assessment comprised the monitoring of 39 No. monitoring wells, 29 No, of which were installed within the Made Ground, 8 No. within the alluvium and 2 No. within the bedrock. Six monitoring visits were completed between May and July 2008. Methane concentrations ranged from 0%v/v to 18%v/v and carbon dioxide from 0%v/v to 12.0%v/v. The highest methane concentration of 18%v/v was recorded in one location installed within the underlying bedrock and therefore, the assessment for the residential site (western section of West Pond) was completed using the highest recorded methane concentration from the Made Ground (12.5%v/v). Similarly, the highest flow reading (>20l/hr) was recorded in the same location within the bedrock and a flow rate of 5.7l/hr recorded in alluvium was utilised. The assessment concluded that the residential development area was predominantly CIRIA Characteristic Situation (CS) 2 or NHBC Amber 1 [24]. The 2008 report also states that the West Pond site is located in an area where full radon protection measures are required in all new residential properties.



Picture 2 - Barry Waterfront area contamination summary (approximate site location is shown in red dashed line)



Picture 3 - Extent of remediation in vicinity to the site

3.3 Land Redevelopment

The majority of the land surrounding the site has been redeveloped in the recent years. The West Pond has been redeveloped for residential use since 2015 and land southeast of the site has been redeveloped for commercial use (Asda Barry Superstore). The land directly southwest of the site remained vacant until 2022, when a Primary school (Ysgol Gymraeg Sant Baruc) was constructed, whereas the land adjacent to the north has been redeveloped as a residential block of apartments.

3.3.1 West Pond Residential development

Based on WSP Remediation and Verification Strategy for Barry Quays (2013) [15] and Idom Merebrook Ltd. Remediation and Verification Strategy for Barry Quays (2016) (including the West Pond site) [25] and Arup's remedial strategy for the West Pond site [24], the following remediation is anticipated to have been completed:

- A minimum of 600 mm of clean soil cover in private gardens with a basal robust geotextile layer to provide a marker layer.
- Increased capping measures along service runs to ensure their installation and future maintenance occurs within clean fill corridors to conform with the previously recommended remedial requirements to prevent follow-on works being exposed to existing Made Ground.
- A 450mm capping layer in public open space/communal landscaping areas.
- Verification testing of the placed cover by an independent environmental specialist by means of one inspection pit dug through the full depth of the cover in each of the front and rear gardens at a rate of one plot in five. In landscaped/POS areas one pit will be dug per 25 m x 25 m area or arrangements to be made to view clean cover as it is being placed.
- Gas protection measures comprising:
 - Reinforced concrete cast in situ floor slab (suspended, non-suspended or raft) with at least 1200 g DPM and underfloor venting
 - Beam and block or pre-cast concrete and 2000g DPM/ reinforced gas membrane and underfloor venting.
- Low-level gas protection measures comprising a membrane and ventilated sub-floor void to create a permeability contrast to limit the ingress of gas into the building for low rise housing with a ventilated underfloor void (150 mm).
- Basic radon protection measures current at the time of construction.
- Validation reports issued for each plot or group of plots inspected subject to the developer requirements to achieve interim sign off for the purpose of plot handing over. A final validation report for the completed development.

3.3.2 Asda Barry Superstore remediation (2014)

As part of the development of Asda Superstore (area of former Oil Storage Terminal), remediation works were carried out in 2014, which comprised abstraction of a total of 2,502m³ of LNAPL impacted perched groundwater, treatment and discharging during the treatment period [14]. A total of 600 litres of emulsified oil/water and LNAPL from the two phases has been recovered and disposed from site, together with the wash down and cleansing fluids from the groundwater treatment kit. LNAPL recovery diminished following two months of active abstraction (15th August to 15th October 2013).

Abstraction continued for a further month (15th October to 15th November 2013), during which time LNAPL recovery was not observed. Monitoring continued for a 3-month period, in which time no LNAPL rebound was observed.

The remediation works have successfully achieved the objectives set out, i.e., achieved a reduction in the dissolved phase contaminant mass and removal of identified LNAPL to maximum possible extents [14].

3.3.3 Primary School (Ysgol Gymraeg Sant Baruc) GI (2015)

A GI and assessment was carried out by Integral Geotechnique (IG) within the area comprising a part of the site and the land directly southwest off-site as part of the proposed development of the Ysgol Gymraeg Sant Baruc Primary School [23]. The findings of the assessment as reported by IG are summarised below:

- **Human Health:** Elevated concentration levels in the Made Ground (at shallow depth) of beryllium, lead, mercury, two polycyclic aromatic hydrocarbon compounds and asbestos were indicated. Although the proposed development was for a school/education purpose, the results have been screened against residential end use criteria values.

It was concluded by IG that remediation requirements can be integrated with the necessary rise of ground level and hence, the existing Made Ground materials will be capped by a combination of clean imported fill materials to raise site levels, access roads and car parking hard standing and the proposed building. Any soft landscaped areas will need to be capped by a minimal thickness of 600mm of clean imported subsoil/topsoil. Further sampling and testing for asbestos was recommended, to include quantification analysis in areas where asbestos has previously been detected and any occurrences of suspected asbestos contamination upon clearance of the site.

- **Controlled Waters:** The results of leachate testing carried out on samples of Made Ground identified elevated concentrations of copper, arsenic, and minor concentrations of petroleum hydrocarbons. The elevated leachable concentrations identified were not reflected in the groundwater. Copper, arsenic, and petroleum hydrocarbons identified within the Made Ground leachate were not identified at elevated concentrations within the groundwater. IG concluded that the underlying groundwater is not being impacted by the leachate from the Made Ground and groundwater was not found to be significantly contaminated.

IG concluded that the potential risk to groundwater quality beneath the site and subsequently, the nearby surface water, is low.

- **Radon:** The radon report obtained from the British Geological Survey indicated that Basic Radon protective measures are required at the site.

With regards to ground gas, as reported in the Contaminated Land Assessment and Remediation Method Statement by Idom Merebrook Ltd. for the proposed school site [26], gas monitoring has been undertaken on six occasions between February and October 2019. Levels of methane carbon dioxide and oxygen were recorded in each standpipe together with associated parameters including borehole flow and ambient air pressure. The monitoring rounds were undertaken at barometric pressures ranging from 984 to 1036 mb. Positive flow was not observed. Over the six monitoring rounds methane (CH₄) was detected at a maximum of 0.5 by volume (v/v) carbon dioxide (CO₂) was detected to a maximum of 9.8 v/v with a corresponding depleted oxygen concentration of 2.3 v/v.

BS8485:2015+A1:2019 has been followed to assess the recorded soil gas and flow conditions. The assessments concluded that the site is very low risk with respect to carbon dioxide and methane however given a carbon dioxide concentration of greater than 5 v/v was recorded a Modified Wilson Card Characteristic Situation 2 is considered appropriate.

3.3.4 Goods Shed, Hood Road GI 2018

The completed investigations identified localised evidence of hydrocarbon contamination with one location recorded exhibiting hydrocarbon odours. Asbestos was detected in one sample out of 8No tested (Chrysotile bundles at 0.003%). Ground gas monitoring indicated relatively low levels of ground gas with methane measured up to 0.2% and carbon dioxide up to 2.7% with flows up to 0.11/hr with a very low level of risk (CS1).

3.4 Conclusions

There is potential for contamination present on site based on its history (Railway – tracks/sidings, Coal Yard, Unknown Tanks, Made Ground - Infilled Land). It is unclear whether the site itself has been subject to remediation since the removal/demolition of the dock related infrastructure.

A GI was recently carried out on site. Elevated lead and asbestos were recorded in one location within the Made Ground. No statistical analysis was completed to determine the true mean concentration of lead for the site. However, Made Ground deposits were not fully penetrated and therefore there is a risk that unidentified contamination may be present at the base of the Made Ground. The site may be encroaching on the early 1900s tipping operations. The extent of these operations is unknown and may extend further into the site than indicated by historical plans. No sampling and testing of leachate and groundwater has been carried out as part of the GI and by extension no quantitative controlled waters risk assessment has been completed. Gas monitoring results indicated that the site falls in a Characteristic Situation 2 (gas protection measures required for the proposed development).

The potential for ground gas generation from the historical landfill and Made Ground off-site and migration under the site is unlikely based on gas monitoring that has occurred on the land directly southwest of the site. Made Ground A radon risk has been determined as likely throughout the West Pond site. As a result of this, basic radon protection will need to be incorporated into any design plans for the proposed development.

The site is located outside the historical landfill site. However, there is a risk of overspill, cross contamination into the site area.

The recent investigations within the site area encountered evidence of asbestos presence in one location. Considering the asbestos risk and presence within the land to the south of the site, the risk of encountering asbestos within the site remains high. This will require appropriate management during construction and remediation measures.

No quantitative controlled waters risk assessment has been completed and the site conceptual model has not been adequately developed. No groundwater quality monitoring or soil leachate analysis have been undertaken. Risks to controlled waters require appropriate assessment also to allow for a foundation works risk assessment.

There has been extensive development and remediation of the land in vicinity to site. It is considered that there has been sufficient investigation within the West Pond to assess the degree of contamination present; and appropriate mitigation works were completed. These works have been completed relatively recently and fully regulated by local authorities and planning regime, and therefore it is anticipated that the remediation works would be completed to the level suitable for current end use (residential and commercial development). Therefore, it is anticipated that the potential for any remaining contamination related to the land in vicinity to the site is low (the previously identified sources will have now been removed).

Based on the review of all available information, there are still gaps in the understanding of the Conceptual Site Model and completed assessments. Refer to section 4.2 for geo-environmental considerations.

4. Preliminary Considerations & Recommendations

4.1 Geotechnical Considerations

4.1.1 Foundation design

As discussed earlier in the Desk Study, the bedrock level is dipping steeply to the south-east beneath the site, with indicative depths between 5mbgl in the north and greater than 20mbgl outside the southern site boundary.

The loose and soft to firm nature of the sands, silts, and clays which comprise the Tidal Flat Deposits (TFD) beneath the site are anticipated to be lightly overconsolidated for the current stress state, and as such their shear strength and stiffness will be relatively low. Due to these characteristics, shallow foundations are not expected to be suitable at the site, warranting piled foundations to be adopted.

The shear strengths of these deposits are expected to provide negligible contribution to the design of deep foundations, necessitating that pile foundations extend into the underlying limestone and mudstone bedrock at depth.

The low strength and stiffness of the TFD, together with water in the granular materials, will preclude open bored piling techniques to construct piled foundations. Continuous flight auger (CFA) or driven piles therefore remaining suitable options to assure support of the materials above the bedrock.

Driving piles to bedrock will result in significant noise and vibration to the surrounding environment, and as such it is expected that these will be difficult to obtain permission to use.

CFA piles have a typical maximum installation depth in the order of 25m, which could be a suitable foundation option in the north of the site where bedrock is anticipated within 15m of ground level. However, CFA is expected to be prohibitive in the south of the site where bedrock is expected at 20m depth, leaving limited remaining penetration length to resist foundation loads.

The proposed ground investigation of the site will provide more information to support the development of a foundation design, however on the basis of the above, all reasonable measures should be taken to arrange buildings within the north of the site, such that buildable foundation solutions can be pursued. Reducing the foundation depths will also have cost, programme, and quality benefits to the substructure of the building.

4.1.2 Excavations

Excavation in the site soils will be readily achievable using typical hydraulic plant such as excavators or backhoe loaders. It is anticipated that dry batter slopes up to 1v:2h should be achievable.

Groundwater level at the site is in the order of 3mbgl, roughly coincident with the transition from Made Ground soils to the underlying Tidal Flat Deposits. This groundwater level may be in hydraulic connectivity with the impounded Barry Docks to the east (though retarded by the low permeability of TFD soils), and less likely to be tidally influenced by Barry Harbour much further to the southwest and the Bristol Channel beyond. Zones of low permeability soils within the TFD could however reduce immediate inflow to excavations unless sandy soils are encountered. Excavations to beyond approximately 2-3m depth may be challenging to control groundwater inflow and excavation face stability.

The Tidal Flat Deposits are of low strength and therefore unsuitable to support plant and excavation equipment tracking directly on its surface. As such, a working platform of Class 6F material may be required if site levels are to be reduced.

The Contractor should assess and take cognisance of weather conditions when planning any earthworks, in particular the time of year when planning the excavation or placement of clay materials, to ensure it is not degraded during the works.

4.1.3 Buried Utilities

The positions of existing services on site have been reviewed using information provided by statutory authorities together with a limited non-intrusive utility survey carried out in 2020, indicating numerous

public and private buried utilities in all parts of the site and its surrounds. Services present across the site include storm and combined drainage, high and low voltage electrical cables and potable water.

The majority of services are public services although there are a number of private services. All public utilities will have an associated easement and connectivity should be retained throughout and after the works unless agreed otherwise with the utility provider.

The assessment shows a Western Power Distribution apparatus located within Ffordd y Mileniwm with a spur extending into the site following the western side of the internal road. There is also an electrical route running along the northern boundary which then leaves the site north and enters the Goodsheds development. An underground BT supply is located within Ffordd y Mileniwm with a spur extending just into the site terminating near the road site entrance.

The paper records show a Dŵr Cymru Welsh Water (DCWW) water main running within the site boundary from the east to the central road. The records also shown a main from Ffordd y Mileniwm following the internal road before running northwest across the site. There is a 300mm diameter DCWW combined sewer that starts at the western extent of the scheme. This runs east before routing northeast to a chamber near the internal junction spur. This then continues southeast, crossing the internal road and running just inside the eastern building plot before joining the combined network in Ffordd y Mileniwm.

There is also a combined storm-sewer pipe running north to south through the site which serves the Goodsheds development (located immediately north of the rail line) and connects to the existing 300mm diameter combined sewer within this site. Paper records show this running just east of the internal road although the exact route has not been surveyed, and once confirmed could be diverted to facilitate the building development.

The Wales and West gas supply is shown on the paper records located within Ffordd y Mileniwm with a spur extending into the site following the western site of the internal road. Spurs enter the site across the eastern boundary from the Hood Road footway also.

There are two main private utilities shown on the paper records and the non-intrusive survey. Both of them are networks of storm drainage pipes, most likely located along the western portion of the site.

The non-intrusive survey also shows a cluster of services in the northeast corner of the site. The layout implies that these could have been for a previous site compound, but it is unclear the status of these or whether these are still present.

The level of accuracy of these findings is very low and should not be relied upon for accurate offsets to features or to set out from. It is recommended that a non-intrusive utility survey is conducted that covers the entire site to detect and locate existing utility networks and confirm the findings of the original survey in order to inform future design and constraints. These further surveys could include techniques such as vacuum excavation to physically expose the utilities for detailed surveying. There are a number of utilities that will need to be diverted to facilitate the development.

4.1.4 UXO

The Zetica UXO bomb risk mapping identifies the site as being within a moderate-risk area. In addition, a number of strategic targets and Luftwaffe targets were identified within 1.0km of the site. Based on the above and the penetrative ground works expected for supporting the proposed structures, it is recommended that a detailed UXO desk study and risk assessment is undertaken for the site in the context of the proposed works.

4.2 Geo-Environmental Considerations

Following the geoenvironmental review of available information for the site the following data gaps and conceptual understanding of the site:

- It is unclear whether the site itself has been subject to remediation since the removal/demolition of the dock related in infrastructure. Historical infrastructure may still be in place and form preferential flow paths for contamination. The potential presence of remnant infrastructure requires investigation (e.g., trial pitting).

- Made Ground deposits were not fully penetrated and therefore there is a risk that unidentified contamination may be present at the base of the Made Ground, particularly in the eastern site area, where ground level has been raised. This will require investigation using appropriate techniques allowing for penetrating through the Made Ground.
- Human health risk assessment is inconclusive with respect to potential risks associated with lead and asbestos. This will require undertaking statistical analysis on available and any new data obtained from the site. Even though the site is located outside the historical landfill site, there is a risk of overspill and cross contamination. In addition, the risk of encountering asbestos should remain high, even though only one sample of out of 10 encountered asbestos. This will require appropriate management during construction and remediation measures.
- Historical plans indicate that the site may be encroaching on the early 1900s tipping operations. The extent of these operations is unknown and may extended further into the site than indicated by historical plans. The potential presence of tipped materials requires investigation (e.g., trial pitting targeting the southern site area).
- No quantitative controlled waters risk assessment has been completed and the site conceptual model has not been adequately developed. No groundwater quality monitoring or soil leachate analysis have been undertaken. Risks to controlled waters require appropriate assessment.
- Where Made Ground was fully penetrated (western site area) it was found to be underlain by cohesive Tidal Flat Deposits (TFD). The nature of the TFD underlying the remainder part of the site is unknown. It is likely to include lenses of granular deposits, as encountered in the site vicinity, which could provide a pathway for vertical contaminants migration into the underlying aquifer. This requires confirmation to allow for a controlled waters risk assessment and foundation works risk assessment in relation to the likely piled foundation solution.
- Understanding of groundwater regime in the site area is currently limited, particularly in the eastern site area. The presence of perched water in the eastern area has not been confirmed. Based on previous work within the area, the low permeability of TFD soils is unlikely to reflect changes in dock water level as changes in groundwater level for the purpose of contaminant migration. This requires confirmation to allow for a controlled waters and foundation works risk assessment (as per above).
- Ground gas monitoring concluded a very low risk but due to 2No elevated CO₂ readings in WS01 the risk level was increased to Characteristic Situation 2 (CS2). The second reading appears erroneous due to oxygen readings indicating oxygen levels below level of detection, which is unlikely. No flow was recorded in any of the monitored locations. The GI carried out as part of the Primary School site directly southwest off-site has also indicated a CS2. Further ground gas monitoring will be required to confirm this and the requirement for protection measures as part of the new building.
- There has been extensive development and remediation of the land in vicinity to site which has rendered it suitable for its intended use (residential and commercial development). It is considered that there has been sufficient investigation within the West Pond to assess the degree of contamination present; and appropriate mitigation works were completed. It is anticipated that the potential for any remaining contamination related to the land in vicinity to the site is low.

4.3 Recommendations

4.3.1 Ground Investigation

Based on the above findings, it is recommended that a targeted ground investigation is completed to understand on site ground conditions and inform the detailed design. The ground investigation may include the following:

- Boreholes and or trial pits to confirm ground conditions, groundwater level and collect soil samples for laboratory analysis. These ground investigation proposals will be finalised once the design criteria for the structures is understood.

- Cone penetration testing to confirm the composition of the Tidal Flat Deposits and infer strength, stiffness, piezometric response, permeability, settlement risk, interbedding, and thickness.
- Groundwater monitoring and sampling for chemical testing to inform on design and controlled waters risk assessment.
- Ground gas monitoring to confirm the ground gas regime under the site and the requirement for protection measures as part of the new building.
- Chemical testing of soil and leachate samples from Made Ground to inform on the human health and controlled waters risk assessment and potential for reuse on other sites.

4.3.2 UXO

A detailed UXO desk study and risk assessment is recommended to be completed by a specialist practitioner to assess the potential UXO hazard in the context of the proposed development.

4.3.3 Buried Utilities

A non-intrusive utility survey for the entire site is recommended to locate, expose, and undertake a detailed survey of existing utility networks and confirm the findings of the original survey in order to inform future design and constraints.

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Figures

Figure 1 - Site Location Plan

Figure 2 - Existing Site Layout

Figure 3 - Published Bedrock Geology Plan

Figure 4 - Published Superficial Geology Plan

Figure 5 - Exploratory Hole Records

Figure 6 - Ground Investigation Conducted on Site (2020)

Figure 7 - Rock Depth Below Ground Level

Figure 8 - Constraints Plan

Figure 9 - Zetica Bomb Risk Map