Earth Science Partnership

Consulting Engineers | Geologists | Environmental Scientists

Proposed Hotel & Leisure (Commercial) Development
Site B, Porthcawl
Geo-Environmental & Geotechnical Assessment

Report Reference: ESP.7044d.3124_B.Rev1

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Proposed Hotel & Leisure (Commercial) Development Site B, Porthcawl

Geo-Environmental & Geotechnical Assessment

Prepared for:
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Bridgend County Borough Council
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Report Reference: **ESP.7044d.3124_B.Rev1**

Revision	Status	Date	Written by	Checked by	Approved by
0	Draft	May 2019	D Thomas BSc (Hons) FGS	H Davies MESci CGeol FGS	M Eynon BSc MSc CGeol EurGeol FGS ROGEP Specialist
Report updated following supplementary gas monitoring					
1	Final	September 2020	D Thomas BSc (Hons) FGS	H Davies MESci CGeol FGS	M Eynon BSc MSc CGeol EurGeol FGS ROGEP Specialist
		Signature:			

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Contents

Executive Summary – Site B Only

Bridgend County Borough Council (hereby referred to as the Council) are in the process of marketing a new development opportunity for a mixed-use scheme involving new commercial, leisure and residential uses in Porthcawl. This summary relates to the investigation of the proposed hotel and leisure facilities development (Site B) only (see Sections 1.1 and 1.2 for details).

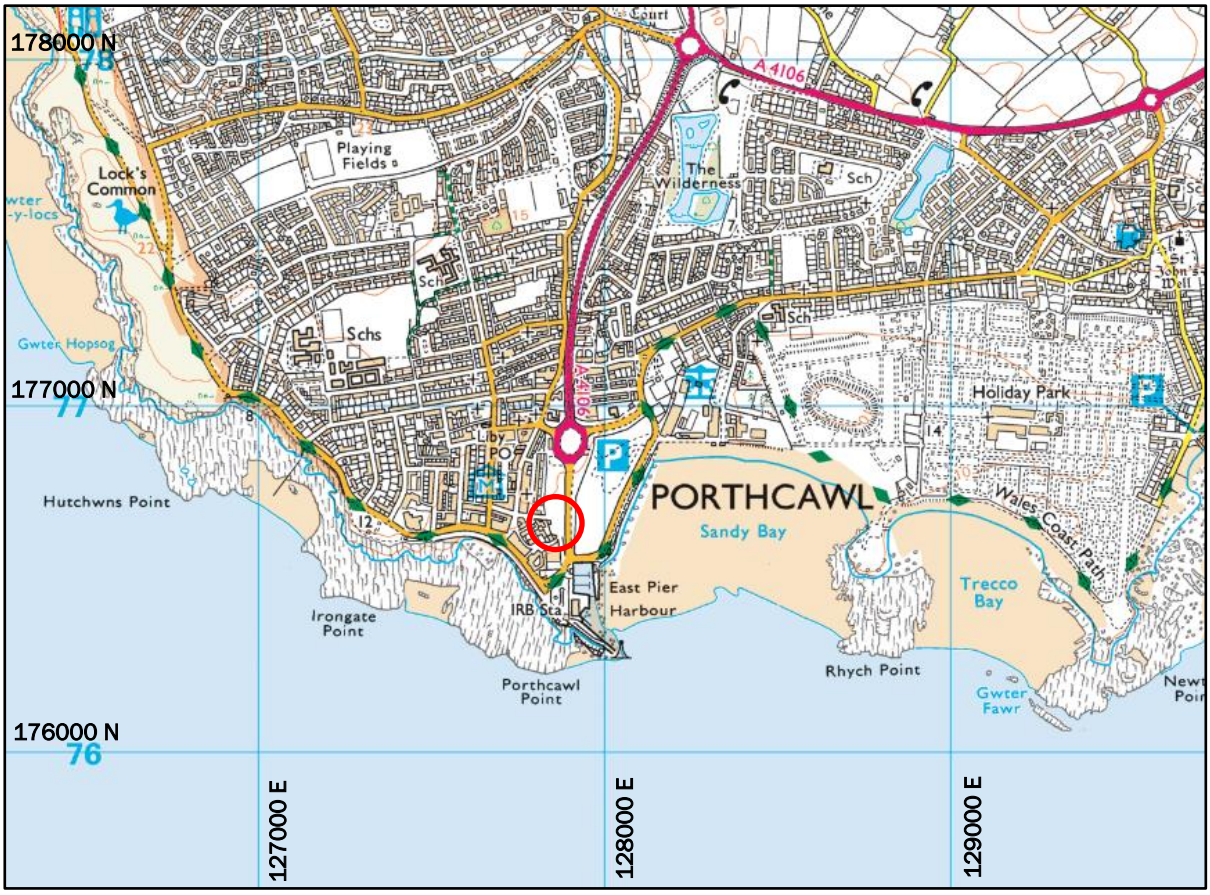
	Potential Hazard	Anticipated Risk	Discussion
Site Setting	*Current Site Status. (Section 2.1)*	-	*The site is currently the southern extent of Hilsboro Car Park and is largely an open, tarmacadam surfaced area. An electricity substation is located in the north west portion. The remnants of a disused building in poor repair is located in the north west*
	Identified Ground Conditions. (Section 5.1)	-	*The investigation has indicated the site to be generally underlain by covering of Made Ground and limited areas of Blown Sand deposits overlying weathered and competent Oxwich Head Limestone bedrock. A thin localised band of clay was also noted in one previous investigation point (DS, 2011), between 1.8m and 2.2m depth, overlying probable limestone bedrock. The bedrock depth generally increases in a easterly direction across the site.*
	Groundwater Conditions. (Section 5.2.1)	-	*The Blown Sands (where present) are classed as a Secondary A aquifer, whilst the bedrock Oxwich Head Limestone is classed as Principal Aquifer. Testing in neighbouring areas indicates the quality of the aquifers has been degraded naturally due to saline intrusion. Recent monitoring data indicates the groundwater beneath the site to generally be present at depths of around 7.0m below surface level within the bedrock. Potential shallower perched groundwater levels have also been identified in the Made Ground. Groundwater monitoring suggests tidal influence is limited.*
Geo-environmental	*Potential Contamination Sources (Section 2.2 and 3.1.2)*	*High*	*The site history has indicated several potentially contaminative historical land uses (see Table 5), including railway land, railway sidings, railway stations and a dock/dockland. The site is currently used as a car park and an electricity substation is located in the north west portion.*
	Chronic Risks to Human Health (Section 7.1.2 and 7.1.4)	*Low/ Moderate*	*Assuming an end use as a hotel and commercial leisure facilities and excluding the risks from asbestos, the levels of soil contamination recorded at the site as part of this initial assessment are not considered to pose a significant risk to future site users. No wide scale remedial measures are considered likely, however considering the past significant industrial history there is a potential for un-identified contamination, particularly within the area of the former railway land and the existing sub-station. Due to the presence of contaminants within the Made Ground soils across the site (including asbestos – see below) potential risks to construction workers are posed. The contractor should comply with the appropriate current Health and Safety at work legislation.*
	Asbestos (Section 7.1.1)	*Low/ Moderate*	*Qualitative analysis has identified chrysotile asbestos present as bundles of fibres in the general Made Ground in the north east of the site in the area of the former railway station (BH11, 0.5m). Further quantitative testing has identified that the levels of this asbestos is <0.001%. Previous testing off-site, has also identified two positive screens for asbestos within the general Made Ground soils. The remnants of a disused building in poor repair is located in the north west portion of the site. This may contain asbestos containing materials and an asbestos specialist should be contacted to survey the building prior to demolition to confirm potential risks.*
	Risks to Controlled Waters (Section 7.2)	*Low/ Moderate*	*We consider that the overall risk to controlled waters from the development of the site is likely to be low. Discussion with NRW will be required to confirm their opinion on the sensitivity of the aquifers considering their natural degradation to confirm the risk. We cannot discount that additional monitoring, testing and assessment may be required. Some risk mitigation is likely to be required if soakaways are used to dispose of surface water run-off.*
	Hazardous Ground Gas (Section 5.8.1 & 7.3)	*Low/ Moderate*	*Based on monitoring to date (twelve visits equating to monitoring over a three-month period) we consider that the site would be classified as Characteristic Situation CS-1 for a commercial development (CIRIA C665:2007), however given the extent of the Made Ground and historical land uses at the site, we recommend that the site should be upgraded to CS2 to ensure the safety of the future development and the site end users. Details discussed in Sections 5.8.1 and 7.3. If during construction any organic materials are encountered, they should be excavated and replaced.*
eotechnical	*Shrinkage or Swelling (Section 8.2.1)*	*Low*	*No significant shallow fine-grained soils have been encountered. Coarse grained soils are not susceptible to changes in moisture content therefore no further consideration is warranted at this stage. If fine grained soils are encountered as part of any future investigation this may require re-consideration by a geotechnical engineer.*
	Ground Dissolution (Section 8.2.2)	*Low/ Moderate*	*The site lies in an area susceptible to limestone solution, however no evidence has been identified by the desk study or during previous or current investigation of solution features on the site. We cannot discount that un-recorded solution features exist beneath the site and further investigation may be considered prudent by the purchaser to reduce the uncertainty of potential risks.*
	Weak/Compressible Ground (Section 8.2.3 and Section 8.3).	*High*	*Compressible soils have been encountered at shallow depth across the site (Made Ground and Blown Sands). Preliminary foundation and floor slab designs have been provided for shallow and deeper foundation solutions, considering the variation in rockhead across the site. Once the development location, proposed loadings and settlement tolerances are known, the available information should be reviewed to confirm the potential foundation options.*
	Collapsible Ground (Section 8.2.4)	*Low*	*The unconsolidated/uncompacted Made Ground and the Blown Sands (where present) are potentially susceptible to collapse compression during inundation. This would only likely occur if groundwater levels were to increase during the design life of the proposed development.*
	Running Sand (Section 8.2.5)	*Low/ Moderate*	*Generally limited Blown Sand deposits were identified across most of the site, with the only notable thickness identified in the north the site. Based on our understanding of the proposed development, no significant groundwater ingress is anticipated above 5m depth. However, the presence of perched water bodies cannot be discounted. Where groundwater ingress occurs within the Blown Sand deposits, the potential for running sands is considered high. The design of all excavations or bored foundation solutions (drainage, foundations etc) should consider this hazard where Blown Sand deposits are present. Tidal influence on groundwater levels is not considered to be significant.*
	Volumetrically Unstable Slag (Section 8.2.6)	*Moderate*	*The general Made Ground was noted to contain minor constituents of slag gravels across the site, however the overall content is not considered to be of significant risk. If any areas of high quantities of slag gravels are identified during the works, they should be removed and replaced with clean inert fill.*
	Underground Structures (Section 8.2.7)	*Low/ Moderate*	*It is likely that some underground structures and/or obstructions associated with the historical rail infrastructure remains, especially in the area of the former station. A rising main is present trending west to east across the approximate centre of the site (see Figures 3 and 5) and we understand that this will remain in its current location. Obstructions/structures will require consideration as part of the development design (in particular foundations), and where shallow, they may require removal (possibly with large excavators), diversion or protection as part of the site preparation works.*
Others	*UXO (Section 2.11)*	*Low*	*The preliminary assessment states "a detailed desk study, whilst always prudent, is not considered essential in this instance". No further assessment is considered necessary at this stage.*
	Flooding (Section 2.6.3 & 2.6.4)	*Moderate/ Low*	*The site is not indicated to be at risk of flooding by rivers and the sea. The British Geological Survey (BGS) has a high confidence in there being a limited potential for below surface clearwater flooding.*
	Invasive Plants (Section 8.1.1)	-	*No evidence of invasive plants was identified during the site works. A specialist survey across the site should be undertaken to confirm this.*
	Further Investigation Required? (Section 9.0)	*Yes*	*Once detailed development design layouts and proposals are known and the site-specific regulatory requirements are confirmed, some additional investigation, monitoring and assessment is recommended/may be required to further assess contamination risks preliminary assessed or to robustly finalise the geotechnical design advice provided in this report.*

Note: The above is intended to provide a brief summary of the conclusions of the assessment. It does not provide a definitive assessment and must not be referenced as a separate document. Refer to the main body of the report for details.

1 Introduction

1.1 Background

Bridgend County Borough Council (hereby referred to as the Council) are in the process of marketing a new development opportunity for a mixed-use scheme involving new commercial, leisure and residential uses in Porthcawl. The initial phases include sites to the east of Porthcawl Town Centre (see Insert 1), at the northern section of Salt Lake Car Park (Site A) and at the south end of Hillsboro Place Car Park (Site B). The re-development of Site A and B forms part of a first phase of the wider site's regeneration and is set within the adopted masterplan for the area called the Seven Bays Project Supplementary Planning Guidance (SPG) (2007).



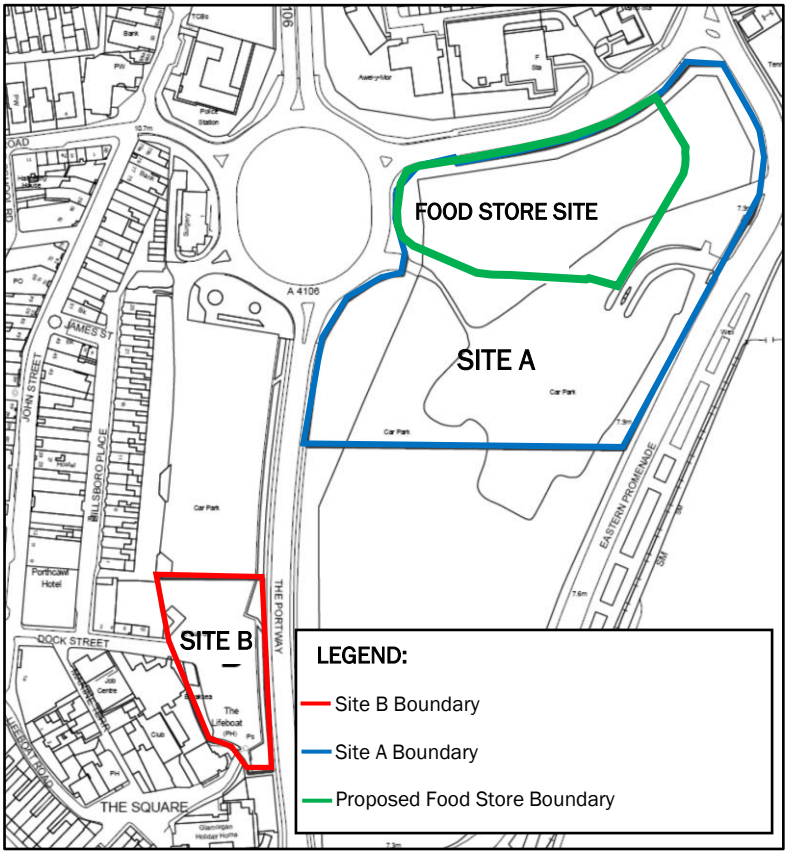
Insert 1 *- Site B Location Plan from Ordnance Survey 1:25,000 (OS License No.: AL100015788).*

The Earth Science Partnership Ltd (ESP), Consulting Engineers, Geologists and Environmental Scientists, were instructed by the Client to undertake an integrated geotechnical and geo-environmental investigation and initial assessment to preliminary identify and evaluate potential ground hazards which could impact on the proposed development in Site A and Site B (see Insert 2 below).

The information obtained will help inform the Client's evolving masterplan and form part of the site marketing particulars for these specific areas to enable prospective bidders to understand ground characteristics and enable decisions regarding scheme layout and costings associated with construction and site remediation.

1.2 Study Site and Proposed Development (Food Store Site)

This report relates to the investigation of the proposed hotel and commercial leisure facilities (such as a restaurant or café), hereafter known as Site B (indicated by the red boundary on Insert 2 below). The report for the proposed food store (within Site A) has been previously issued under separate cover (report ref: ESP.7044d.3112_C) and should be read if detailed context of this area is needed. The report for the investigation of Site A will be reported under separate cover (see Section 1.4).



***Insert 2** - Overview of Investigation Areas*

No formal designs or proposed development layout plans have been provided at this time. For the purposes of this report, we have assumed that the hotel will comprise a typical multi-storey large building and the leisure facilities will comprise typical commercial portal framed structures, with external areas of car parking, hard-standing and limited landscaping. We understand that there will be no significant changes to the current ground levels.

Based on the above, we understand that the proposed structure(s) would be classified as Geotechnical Category 2 (BS5930:2015). An investigation layout plan is presented as Figure 1.

1.3 Objective and Scope of Works

Investigation works at Site B, the food store site and Site A were undertaken simultaneously.

The objective of the investigation was to obtain information on the geotechnical character and properties of the ground beneath the sites, potential risks posed by contamination and ground gas, and to allow an initial assessment of these ground conditions with particular reference to the potential impact and constraints on the proposed developments. This includes review of

extensive existing site information, and targeted additional works in areas where insufficient information was available.

The scope of works for the investigation was mutually developed with the client within an agreed tender budget, and comprised a desk study review of available historical investigation information, historical Ordnance Survey maps, environmental data, geological maps, memoirs and data, and further desk study information, a field reconnaissance visit, the supervision and direction of cable percussion boreholes, windowless sample drill holes, rotary drill holes, geotechnical and geo-environmental laboratory testing, assessment of foundation options, risks to human health and controlled waters, and reporting.

The contract was awarded on the basis of a competitive tender quotation, hosted by the Sell 2 Wales portal. The terms of reference for the assessment are as laid down in the Earth Science Partnership tender return package of 17th October 2018 (ref: ESP.7044d.Porthcawl Tender - Method Statement ME 17.10.18 & ESP.7044d.It1 Investigation BoQ 17.10.18). Gas and groundwater monitoring in Site B was undertaken between December 2018 and February 2019.

The main investigation for all areas was undertaken in November and December 2018.

1.4 Supplementary Works

Following the main investigation, the Client commissioned additional works to undertake supplementary gas monitoring at the site, which was undertaken between November 2019 and February 2020. No other supplementary works were undertaken.

This report supersedes the original ESP report (ESP. 7044d.3124_B), May 2019), for Site B and has been updated following completion of the additional gas monitoring.

1.5 Report Format

The reports for the three separate areas (Food Store, Site A and Site B), will be produced individually and the references will be as per Table 1 below. A plan of the three areas is shown as Insert 2. This report is for the Site B area only.

Table 1: *Summary of Reports for Porthcawl Investigation*

Report Reference	Area of Investigation	Issue Date
ESP.7044d.3123_A	Site A	Original - 29th May 2019
		Revised – September 2020
ESP.7044d.3124_B	Site B	Original - 14th May 2019
		Revised – September 2020
ESP.7044d.3112_C	Proposed Food Store	Original - 1st February 2019
		Revised – September 2020

The report includes desk study and field reconnaissance reports (Section 2), details of the investigation undertaken of Eurocode EC7 and BS5930:2015 (Section 4), along with the Preliminary Risk Assessment stage (Section 3) and Generic Quantitative Risk Assessment (Section 5) of CLR11. A preliminary evaluation of the resulting risks and any remedial measures potentially required to mitigate identified unacceptable risks from contamination and hazardous ground gas is included in Sections 6 and 7. However, it should be appreciated that this is a preliminary evaluation only and will not generally meet the requirements of the Options Appraisal report of CLR11.

A preliminary risk register, identifying potential geotechnical hazards from the desk study review, is presented as Section 2.9, with a full assessment of the geotechnical conditions including foundation and floor slab options, the feasibility of soakaways, etc. in Section 8 – this complies the relevant elements of the Geotechnical Design Report of BS EN 1997-2 (Eurocode 7) and BS5930:2015. The geotechnical risk register is updated using the findings of the intrusive investigation and assessment in Section 8.2. The report concludes with a summary of any further surveys/ investigations/ assessments recommended (Section 9).

The assessment of the potential for hazardous substances (contamination) or conditions to exist on, at or near the site at levels or in a situation likely to warrant mitigation or consideration appropriate to the proposed end use has been undertaken using the guidance published by CIRIA (2001). This is discussed in more detail in Section 3.2.1 and in Appendix A.

1.6 Limitations of Report

This report represents the findings of the brief relating to the proposed end use and geotechnical category of structure(s) as detailed in Section 1.1. The brief did not require an assessment of the implications for any other end use or structures, nor is the report a comprehensive site characterisation and should not be construed as such. Should an alternative end use or structure be considered, the findings of the assessment should be re-examined relating to the new proposals.

Where preventative, ameliorative or remediation works are required, professional judgement will be used to make recommendations that satisfy the site specific requirements in accordance with good practice guidance.

Consultation with regulatory authorities will be required with respect to proposed works as there may be overriding regional or policy requirements which demand additional work to be undertaken. It should be noted that both regulations and their interpretation by statutory authorities are continually changing.

This report represents the findings and opinions of experienced geo-environmental and geotechnical specialists. Earth Science Partnership does not provide legal advice and the advice of lawyers may also be required.

1.7 Digital Copy of Report

This report is issued as a digital version only.

2 Desk Study and Field Reconnaissance Visit

The information presented in this section was obtained from desk-based research of sources detailed in the text, including historical maps (Appendix B), an environmental data report (Appendix C), exploratory hole records from previous investigations (provided by the Client) at the site and on adjacent land (Appendices D1-D3) and information provided by BCBC Council (Appendix E).

The site boundary in the environmental data report (Appendix C) and geological data report (Appendix D) is for the whole of Site A (see Insert 2). All distances stated in the reports are from the Site A boundary and not the Food Store site boundary and therefore where features are noted to be on-site this does not necessarily mean they are. Clarification has been provided throughout the report text to avoid confusion.

The site description is based on site visits and inspections throughout the works between November and December 2018 and general views of the site are included as a series of photographs within the Plates section of this report.

2.1 Site Location and Description

The site is located between the Portway and the Town Centre on the southern end of Hillsboro Car Park and comprises an irregular shaped parcel of land shaped parcel of land of around 100m length (north to south) and 45m width (east to west), occupying an area of around 0.45ha.

An electrical substation is located in the north west portion (owned by Western Power Distribution) with the remainder of the site being used as a public car park, owned by the Client. The remnants of a disused building in poor repair is also located in the north west portion of the site. The National Grid Reference of the centre of the site is (SS) 281854, 176665 and the postcode is CF36 3YR A Site Location Plan is presented as Insert 1.

It is bounded by:

- To the north: the wider hardstanding area of Hillsboro Car Park;
- To the east: immediately by The Portway road, trending north to south, followed by the south margins of Salt Lake car park;
- To the south: immediately by a restaurant and car parking area named The Square and further commercial/leisure facilities. A small harbour is located approximately 90m south east; and
- To the west: immediately by Breaksea Care Home, commercial offices and leisure facilities, with Dock Street entering the site in the north west, which trends west into the town of Porthcawl.

Vehicular access to the site is gained via Dock Street in the north west. The site can also be access from the wider Hillsboro car park from the north.

We are not aware of a tree survey having been undertaken at this stage, however there are no significant trees at the site. A small area of rough vegetation is located in the west of the site, which will likely be cleared as part of the development works.

The general topography in the area is relatively flat, gradually sloping to the coast to the east/south east. The site itself is generally flat and level.

A topographical survey has been provided by the Client, which indicated a height of around 8.5m to 9m AOD at the site. The Client has also provided a series of service plans (services are also shown on the constraints plan) showing the locations of recorded underground services in the vicinity of the site (see Appendix R).

Following completion of the investigation, a survey was undertaken in March 2019 by Dwr Cymru Welsh Water (DCWW) in order to locate a rising foul sewer which extends across Site B (and trends east and north towards Site A and the food store site). The results of the survey were provided to the Client in March 2019.

Site observations and the available plans indicate the following services to be present at the site:

- Underground rising foul sewer main, trending west to east across the north area of the site. The main extends east beneath Dock Street and follows a straight line across Site B, before extending north to the east of The Portway;
- Underground BT cables, which enter the site in the north west and terminate just inside the access road from Dock Street; and
- An electrical substation is located in the north west area of the site, with all cables trending west away from the site.
- No gas pipes are indicated on site, but are noted to be present beneath Dock street adjacent to the site to the west.

2.2 Site History

2.2.1 Published Historical Maps

The site history has been assessed from a review of available historical Ordnance Survey County Series and National Grid maps. Extracts from the historical maps are presented in Appendix B and the salient features since the First Edition of the County Series maps are summarised in Table 2 below.

Table 2: *Review of Historical Maps*

Date	On-Site	In Vicinity of Site
1880	The site is located within the dockland of Porthcawl Dock, which is located east. A number of railway lines extend south/south east across the site from the north and extend beyond the south boundary to a number of industrial buildings and the outer basin of the dock. The remainder of the site is shown to be rough ground with patches of vegetation in the north west.	Porthcawl Dock is located some 30m east of the site and is approximately 400m in length (north to south). A number of railway lines associated with the Dock are within 100m of the site boundary, extending north and south. The Ship and Castle Hotel is located on the south west boundary and The Knights Arms Hotel is located adjacent to the site to the west, with a number of other unnamed buildings. A saw mill is shown approximately 40m north of the site, with a shipbuilding yard and smithy some 250m north east at the north extent of Porthcawl Dock. A tank is shown on the railway line some 120m north of the site. To the south, a smithy is shown approximately 70m from the site, adjacent to the outer basin of the dock. An area of likely residential properties are shown to the west of the site, with an old limekiln and quarry some 250m west of the site. Porthcawl train station is located approximately 380m north of the site, with the town of Porthcawl to the east of this. Porthcawl beach is located some 170m east of the site. A further beach is also located 170m south of the site. Porthcawl Harbour and the east and west piers are located some 250m south east of the site.
1884 - 1900	Dock Street is shown to enter the site marginally in the north west. A small square unnamed structure is also shown in the west, with a further unnamed building marginally encroaching on the site north of Dock Street.	The old limekiln, quarry, shipbuilding yard/smithy and the smithy previously identified are no longer shown. Further railway lines have been constructed to the north, trending south/south east to the dock, where a number of coal tips are now indicated on the west edge of the dock. Further residential development has been noted to the north west and west of the site as well as the expansion of Porthcawl to the north east. The developments north west of the site are where the previously identified saw mill was located, no demolished. A gasometer and gas works are shown some 500m north east of the site and a water works is located adjacent to this.
1914 - 1919	The number of railway lines across the site has reduced to two and the square structure formerly identified in the west is no longer shown. No rough ground is indicated.	The coal tips are no longer indicated on the west of the dock. Significant expansion of Porthcawl town is noted to the west, south west and north west of the site.
1943 - 1948	The railway lines are no longer indicated at the site. A station with associated railway lines (off site) has been constructed in the east of the site and the majority of the site now appears to be surfaced with hardstanding . The building encroaching on to the site in the north west has expanded, extending further into the site and small structure is now identified in the west	The Smithy identified to the south of the site is no longer indicted. New railway lines extending to the station located on the site are identified, extending to the north. A tank is noted some 100m south west of the site within an area of probable commercial buildings. Porthcawl dock appears to have been infilled and a miniature railways is now shown along its east margin, with Eastern Promenade road now indicated to trend south west to north east along the edge of Porthcawl beach Porthcawl Sands). The gasometer, gas works and water works are no longer indicated and Coney Beach fair is shown in their former locations. The town of Porthcawl has expanded further.
1965 - 1966	Porthcawl station is now shown to be disused, although the structure remains. No further significant changes identified.	The former infilled dock is now shown to be a car park and there are no longer any railway lines indicated across this area. The town of Porthcawl has expanded further. A garage is indicated 110m north west.
1969	The station structure is now shown to have been removed. No further significant changes identified.	Further expansion of Porthcawl is shown and the majority of the railway lines to the north/north east of the site are now shown to be removed/dismantled. The tank to the north of the site is no longer indicated.
1976 - 1995	The site now resembles its present day layout and forms part of a larger car park. An electrical substation is indicated in the north west of the site. The structure along the west boundary is now indicated to likely be associated with the Breaksea building (known to now be a care home).	The Portway road has now been constructed and trends north along the east boundary of the site, extending to further road developments associated with the expansion of Porthcawl to the south and north of the site. A car park is now shown to the north of the site, extending some 150m north. The lifeboat public house is now named for the building adjacent to the south west boundary. The garage previously identified appears to have been removed between 1991 and 1993.
2002 - Present	The site layout was as it is today.	The area was similar to its present day lay out.

2.3 Previous Investigations and Assessments

The Client has provided a number of previous investigations and assessments undertaken in the area, which includes some works undertaken specifically within Site B. A summary of the previous investigation information provided to ESP at the time of writing this report is detailed below in Table 3 in chronological order. The table also includes several previous investigation records without an accompanying report (extracted from previous reports for ease of reference).

Table 3: *Summary of Previous Investigations*

Report Title & Description (Reference)	Date	Undertaken By	ESP Reference
Proposed Swimming Pool, Porthcawl (F4222) *Borehole Records only*	Jun, 1979	Norwest Holst Soil Engineering Ltd	NH, 1979
Porthcawl – Proposed Marina Development (S/25037) *Trial Pit Records only*	Apr, 1987	James & Nicholas/Wimpey Laboratories	WL, 1987
Structural Investigation into Condition of Harbour Walls & Breakwater, Porthcawl (DV5107/01) *Borehole Records only*	Mar, 1997	Bridgend County Borough Council	BCBC, 1997
Initial Site Investigation Works at Salt Lake Car Park, Porthcawl. (DSV/TNO/KJC/W99134-36) *Cable tool boreholes, laboratory testing and groundwater monitoring*	Dec, 1999	Johnson Poole & Bloomer	JPB, 1999
Phase 1 Environmental Assessment for Porthcawl Regeneration Area (P8078/G205/B) *Desk Study Assessment*	Dec, 2007	Jubb Consulting Engineers Ltd	JUBB, 2007
Porthcawl Regeneration – Hillsboro Place Car Park (2312.003) *Trial Pit Records only*	May, 2008	Bridgend County Borough Council	BCBC, 2008
Extended Phase 1 Desk Study for Porthcawl Harbourside (CIV10285-2200-101) *Desk Study Assessment & Preliminary Investigation (trial pits undertaken by Integral Geotechnique)*	Jul, 2008	Waterman Civils Consulting Engineering	WC, 2008
Pre-Acquisition environmental Assessment Summary Report – The Portway, Porthcawl (10-3283.03) *Desk Study Assessment*	Sept, 2011	Delta Simmons Environmental Consultants	DS, 2011
Porthcawl Regeneration Site Investigation – Desk Study (G201/DS) *Desk Study Assessment*	Mar, 2013	Quantum Geotechnical	QG, 2013
Porthcawl Regeneration Site Investigation – Phase II Ground Investigation – interpretive Report (G201/IR) *Desk Study Assessment*	Mar, 2013	Quantum Geotechnical	QG, 2013
Porthcawl Sandy Bay PAR Geotechnical Desk Study	Dec, 2016	Ove Arup & Partners Ltd	ARUP, 2016

With regards to Table 3, we have identified the following previous intrusive investigations to have exploratory holes within the food store site area:

- Bridgend County Borough Council (BCBC, 2008);
- Delta Simmons (DS, 2011); and
- Quantum Geotechnical (QG, 2013).

Pertinent information from the above investigations will be referred to in subsequent sections where relevant and general information on the site has been reviewed from all previous works for this report.

The relevant previous investigations and records are presented in chronological order in Appendices D1 to D3. A plan identifying previous investigation points pertinent to the Site B development is presented as Figure 4.

2.4 Archaeological Setting

A full archaeological assessment was not included within the brief, but we have not been advised of, or identified, any obvious evidence of any significant archaeological features on the site. .

2.5 Contact with Regulatory Bodies & Local Information Sources

At the time of issue of this report, no pertinent information has been received from the Local Authority with regards to Site B. If any pertinent information is received, it will be forwarded under separate cover. It should be appreciated that responses may contain salient information on the site which could not be taken into account during the preparation of this report.

2.6 Hydrology

2.6.1 Surface Water Features

The nearest major surface water feature to the site is the seawater within the harbour some 75m to the south east and the seawater within Sandy Bay (to the east) and Porthcawl Point (to the south), with the mean high-water mark approximately 130m to the south west and south east at its closest point.

Reference to the Natural Resources Wales website (NRW, 2019) indicates that the water quality with regards to bathing water standards within Sandy Bay, is reported as ‘excellent’ for 2018. The water quality is also noted to be excellent in Rest Bay (approximately 2.5km north west) and Trecco Bay (approximately 1km east).

2.6.2 Surface Water Abstractions

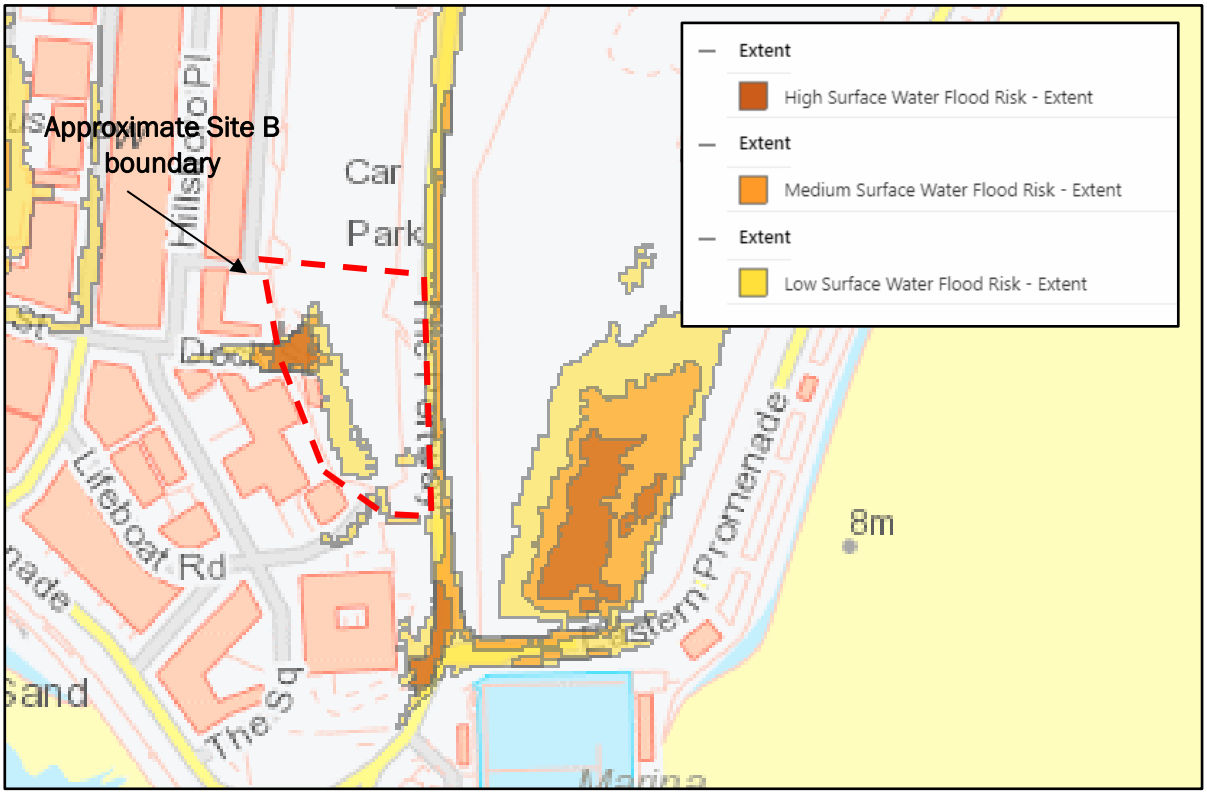
The environmental data report (Appendix C) indicates that there are no surface water abstractions within 2km of the site.

2.6.3 Flooding (Rivers, Seas and Surface Water)

From a review of topographical plans and flooding maps presented in the environmental data report the site is not indicated to be at risk of flooding by rivers and the sea. An area some 50m east of the site indicated to be at low risk from flooding (Zone 2 flood area), while the area of Sandy Bay beach 130m to the east and the harbour 75m south are identified to be of high risk of flooding from the sea (Zone 3 flooding).

Environment Agency/Natural Resources Wales Zone 2 floodplains estimate the annual probability of flooding as between 1 in 1000 (0.1%) and 1 in 100 (1%) from rivers and between 1 in 1000 (0.1%) and 1 in 200 (0.5%) from the sea. Zone 3 shows the extent of a river flood with a 1 in 100 (1%) or greater chance of occurring in any year or a sea flood with a 1 in 200 (0.5%) or greater chance of occurring in any year.

Reference to digital mapping on the Natural Resources Wales (NRW) website (NRW, 2019) indicates that an area in the west of the site is at low risk of surface water flooding, with an area of medium to high risk also indicated in the north west (see Insert 3 below).



Insert 3 *- Surface Water Flood Risk Map (NRW, 2019)*

2.6.4 Flooding (Groundwater)

The environmental data report (Appendix C) indicates that the British Geological Survey (BGS) has a high confidence in there being a limited potential for below surface clearwater flooding, which suggest that "*given the geological conditions there may be a groundwater flooding hazard to basements and other below surface infrastructure*".

2.7 Geology

2.7.1 Published Geology

The published 1:10,560 scale geological map for the area of the site (Sheet SS87NW) indicates the site to be underlain by bedrock of the Carboniferous Oxwich Head Limestone. No superficial deposits are indicated across the majority of the site, however a small area of blown sand may encroach onto the site in the north. Given the historical development of railway land, railway station and now a carpark, a covering of Made Ground is likely present beneath the hardstanding surface. A large area of Made Ground is also indicated to the east, associated with the infilled dock and the reclamation of the sea front.

Mercia Mudstone Group and Mercia Mudstone Group Marginal Facies bedrock is indicated in areas to the west, which is located unconformably above the Carboniferous Limestone.

Reference to the published 1:50,000 scale geological map for the area of the site (Sheet 262) and the up-to-date mapping available on the website of the British Geological Survey (BGS, 2019) indicates a similar succession. Normal faulting is indicated in the area with the faults generally striking north to south.

2.7.2 Previous Investigations

The previous investigations (see Appendices D1 to D3) have been read and utilised to form a background overview of the geological conditions of the area. The following sections identify specific previous investigation points pertinent to the development of Site B, as summarised in Section 2.3. The positions of the investigation points are shown on Figure 4.

2.7.2.1 Bridgend County Borough Council (BCBC, 2008)

BCBC undertook a trial pit investigation in 2008 for the *'Porthcawl Regeneration, Hilsboro Place Car Park'* investigation. Five trial pits were constructed as part of the works and one was undertaken within the boundary of Site B (PIT4).

The trial pit was excavated to a depth of 3.1m below surface level and identified a ground model comprising Made Ground (car park surfacing and associated sub base gravel and sand layers) to a depth of 0.7m, followed by Made Ground of clinker, bricks and cobbles to a depth of 1.9m. This was underlain by sand to a depth of 2.7m below ground level, however there was uncertainty as to whether this was natural or fill. Between 2.7m and 3.1m depth, the dig was noted to be hard, with unstable side preventing visual confirmation that rock had been reached. A copy of the trial pit record is presented in Appendix D1. The position of the trial pit is shown on Figure 4.

2.7.2.2 Delta Simmons (DS, 2011)

DS undertook a windowless sampling investigation in 2011 as part of their *'Pre-Acquisition environmental Assessment Summary Report – The Portway, Porthcawl'*, for a proposed Tesco supermarket. Ten windowless sample drill holes were constructed across their site, of which, three were located within the north portion of Site B (WS01, WS01A and WS02). WS01 was terminated in the Made Ground at 0.7m depth due to obstruction by 20mm reinforcement bar.

The general ground model identified comprised Made Ground to a maximum depth of 1.8m, followed by firm clay to a depth of 2.2m in WS01A. In WS02, the Made Ground was underlain by sand, proven to a depth of 4.0m below surface level. A Copy of the investigation point records and investigation point plan are presented in Appendix D2. The position of the investigation points are also shown on Figure 4.

2.7.2.3 Quantum Geotechnical (QG, 2013)

QG undertook a Phase 2 intrusive investigation in 2013 across a wider site area as part of their *'Porthcawl Harbourside Development'* works. The investigation comprised a number of trial pits and rotary drill holes, with one trial pit positioned within the Site B boundary (TP1).

The trial pit was excavated to a depth of 0.7m below surface where it was terminated in Made Ground due to a concrete slab/buried floor. The Made Ground comprised reworked sand and gravel. The record also notes a brick wall on eastern side of the trial pit. Given the position of the trial pit (see Figure 4), this could be associated with the former railway station identified at the site. A Copy of the investigation point records and investigation point plan are presented in Appendix D3. The position of the investigation points are also shown on Figure 4.

2.7.3 Available BGS Borehole Records

Reference to the digital mapping and records available on the British Geological Survey (BGS) website (BGS, 2019), indicates no pertinent borehole records at the site.

2.7.4 Geological Overview

Based on the review of the previous investigation information, we consider that Site B will be underlain by a variable covering of coarse grained Made Ground (however generally less than 2m thick), followed by areas of Blown Sand deposits (more likely in the north/north east). In some areas, the Blown Sands may be absent and the Made Ground will directly underlain by bedrock, weathered in some areas.

2.8 Hydrogeology

2.8.1 Aquifer Classification

Reference to the aquifer maps published on the environmental data report (Appendix C2) indicates that the localised superficial deposits beneath the site (Blown Sands) are classed as a Secondary A aquifer, whilst the bedrock (Oxwich Head Limestone) is classed as Principal Aquifer.

Principal Aquifers generally correspond with the previously classified major aquifers and are described by the Environment Agency as 'rock or drift deposits that have high intergranular and/or fracture permeability'. They may support water supply and/or river base flow on a strategic scale. Principal Aquifers are particularly sensitive to pollution.

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.

2.8.2 Anticipated Groundwater Bodies

No Groundwater was encountered in the previous investigations within the superficial deposits on site. This includes monitoring undertaken during the Dela Simmons investigation (DS, 2011).

Based on previous borehole investigation information to the east of the site (NH, 1979), water strikes within boreholes constructed in the infilled dock (30m east) were identified between 5.75m and 6.5m. Standing levels observed ranged between 6.0m and 6.5m BGL.

Previous groundwater monitoring (JPB, 1999) was undertaken within 5no. standpipes installed in boreholes positioned within the infilled dock. These indicate groundwater levels to be generally between 4.2m and 5.6m, although shallower and deeper levels were identified at around 2.8m and 6.8m below surface level respectively.

Previous monitoring undertaken by Quantum Geotechnical (QG, 2013), indicates levels across Salt Lake car park to the east of the site to be between 2.6m and 6.2m BGL.

Based on the above, we consider groundwater is likely within the Oxwich Head Limestone bedrock at a depth of around 6.0m below ground level.

2.8.3 Groundwater Movement

Groundwater movement within the Blown Sand will be controlled by intergranular flow whilst, in the bedrock, fracture flow is likely to be dominant.

The ESP monitoring regime for the food store site included measurements of the groundwater levels at the site at times of low, high and slack tides. No significant differences in the groundwater levels have been identified at varying tide levels and it was concluded that the tidal influence of Sandy Bay would not likely significantly affect the groundwater levels at the site.

Based on this, we consider that there is unlikely to be any tidal influence on the groundwater levels beneath Site B.

The water within Sandy Bay located some 130m to the south and east of the site and the groundwater within the bedrock beneath the site are likely in hydraulic continuity.

The JPB investigation (JPB, 1999) looked at variations in groundwater levels over a 12-hour period within the infilled dock only. They concluded that the results of their monitoring indicated fluctuations of the groundwater levels (between 0.06m and 2.33m) within the confines of the infilled dock with changes in tidal levels, however the changes in levels were not uniform across the monitored boreholes. The only significant change in water level was observed in the standpipe located closest to the former harbour lock gates in the south end of the former dock, located some 70m south of the site. The influence of the tide was noted to significantly reduce in the north east of the former dock, as observed within BH10.

2.8.4 Abstractions and Groundwater Vulnerability

The environmental data report indicates that there are no groundwater abstractions or Source Protection Zones (SPZ's) within 1km of the site. The groundwater vulnerability is shown in the environmental data report to be 'Major Aquifer/High Leaching Potential'.

2.8.5 Aquifer Contamination Status

Considering the proximity of the site to the sea, the quality of the groundwater bodies beneath the site may have been naturally degraded by the intrusion of saline waters and therefore are unlikely to be as sensitive as their designation suggests (Section 2.8.1). Additionally, the former land use as dockland and railway land will have degraded the groundwater to a certain extent.

2.9 Environmental Setting

2.9.1 Summary of Environmental Data

The site exists in a historically industrial, and now an-semi-urban setting. An environmental data report has been provided by the Client from a previous investigation of a wider site area (Appendix C1). ESP have also obtained a site-specific data report for the site and is presented in Appendix C2. The data from both reports has been reviewed and is summarised in Table 4 below and, where salient, discussed in Section 2.9.2.

Table 4: Summary of Environmental Data

Item	On the Site	In the Immediate Vicinity
Environmentally Sensitive Sites [1,2]	None identified.	None recorded within 500m of the site.
Potentially Contaminative Land Use	See Section 2.9.2.1.	See Section 2.9.2.1.
Historical Tanks, PFS, Garages, Energy Facilities	Substation in north west	4no. recorded between 90m and 250m of the site (see Table 2).
Potentially Infilled Land	See Section 2.9.2.2.	See Section 2.9.2.2.
IPPC Authorisations	None identified.	None recorded within 500m of the site.
Discharge Consents	None identified.	None recorded within 500m of the site.
List 1 and 2 Dangerous Substances Sites	None identified.	None recorded within 500m of the site.
Radioactive Substance Sites	None identified.	None recorded within 500m of the site.
Enforcements	None identified.	None recorded within 250m of the site.
Pollution Incidents	None identified.	4no. recorded between 50m and 250m of the site.
Contaminated Land under Part 2A EPA 1990.	None identified.	None recorded within 500m of the site.
Waste Management Facilities	None identified.	None recorded within 250m of the site. Previous ESP investigation for food store identified NRW landfill some 300m north.
Current Industrial/Commercial Sites	Electrical substation on site in north west.	None recorded within 250m of the site.
Radon	See Section 2.9.2.3.	

Notes
1. Sensitive land uses include Sites of Special Scientific Interest, Nature Reserves, National Parks, Special Areas of Conservation, Special Protection Areas, Ramsar sites, World Heritage sites and Ancient Woodland.
2. Nitrate vulnerable areas relate to the agricultural use of fertilizers and are not considered further in this assessment.

2.9.2 Further Discussion on Salient Environmental Features

2.9.2.1 Potentially Contaminative Land Use

Following a review of the historical mapping (Table 2) and the Environmental Data Report, (Appendix C), the following potentially contaminative land uses have been identified on site and within 250m of the site boundary, as summarised in Table 5 below. A plan identifying the location and source of potentially relevant contaminative land uses is presented as Figure 2.

Table 5: Summary of Potentially Contaminative Land Uses

On Site	Within 250m of the Site
Railway land, railway sidings, railway station, dock/dockland, electrical substation, car park.	Dock, unspecified pit, railway buildings, railway land, railway lines, cuttings, lifeboat station, unspecified tank, smithy, police station, unspecified tank, garage.

2.9.2.2 Potentially Infilled Land

A number of areas of potentially infilled land are identified in the Environmental Data Report (Appendix C2), including dockland, unspecified pit, cuttings and ground workings. The previous investigations have also identified a covering of Made Ground on site.

2.9.2.3 Waste Management Facilities (Historical Registered Landfills)

No current permitted sites are identified within 250m of the site.

The data report previously supplied by the Client (appendix C1) indicates that Salt Lake car park is a landfill and we consider that this is associated with the infilling of the former dock. Previous investigations have identified slag, colliery spoil and other rubble across Salt Lake car park within the former dock footprint. No other details for the Salt Lake car park landfill are listed.

2.10 Preliminary Geotechnical Risk Register

2.10.1 Summary of Potential Geotechnical and Geomorphological Hazards

The potential for various geotechnical and geomorphological hazards at the site is provided in the environmental data and geological data report (Appendix C2). The potential hazards, as reported in these reports are listed in Table 3 below, along with any salient further information on the potential hazard identified by ESP in the preparation of this report. Where a potential hazard has been identified, it is discussed further in subsequent sections.

Table 6: Preliminary Geotechnical Risk Register

Ground Stability Hazard	Potential[1]	ESP Comment
Coal Mining	-	Site is not underlain by coal measures bedrock. No further consideration required.
Mining (non-coal)	-	See Section 2.10.2.
Shrinking or Swelling Clays	Negligible	See Section 2.10.3.
Landslides	Low	No further information identified to contradict data report.
Ground Dissolution (Soluble Rocks)	Low	See Section 2.10.4
Compressible Ground	Moderate	See Section 2.10.5
Collapsible Ground	Very Low	No further information identified to contradict data report.
Running Sand	Low	See Section 2.10.6
Volumetrically Unstable Slag	Not reported.	See Section 2.10.7
Sulphate/Pyritic Ground	Not reported.	See Section 2.10.8
Unexploded Ordnance	Not reported.	See Section 2.11
Radon	See Section 2.12	
Underground Structures	Not reported.	See Section 2.13

Notes
1. Potential as reported in environmental data report (Appendix C2)
2. Salient hazards discussed in following sections.
3. An updated Geotechnical Risk Register, following intrusive investigation of salient hazards, is presented as Table 18 in Section 8.2.1.

2.10.2 Mining (non-coal)

The Oxwich Head Limestone underlying the site can contain mineral veins, however no evidence of mining has been identified (with the exclusion of the dock excavation) and considering the practicalities of extracting it the potential is considered very low.

2.10.3 Shrinkable and Swelling Soils

The previous investigation at the site identified a firm clay to between depths of 1.8m and 2.2m in WS01. No geotechnical testing was undertaken. No other previous investigation points have identified clay at the site. If fine grained soils are encountered at the site, they are likely to be limited and of no great thickness.

There are no significant trees at the site and only an area of rough vegetation is located in the west (likely to be removed during development). Vegetation as part of any future development is likely to be limited.

Notwithstanding this, we consider that the Negligible potential for shrinkable/swelling soils at the site reported in the geological data report should be increased to low/moderate, pending further investigation.

2.10.4 Ground Dissolution

The Oxwich Head Carboniferous Limestone bedrock underlying the site is susceptible to chemical weathering, producing natural solution cavities in both the horizontal and vertical direction. Such features can cause uncontrolled subsidence at the surface in the right conditions.

The geological data report (Appendix C3) does not indicate any natural cavities on site, with the closest being more than 1km to the north (sinkhole and solution pipe).

Previous investigations on-site and in neighbouring areas have not identified any obvious evidence of limestone solution (e.g. significant variations in bedrock depth, cavities etc.)

Therefore, pending further investigation, we consider that the potential for ground dissolution impacting on the development should be advanced from that reported in the geological data report (Very Low) to low/moderate.

2.10.5 Compressible Ground

The Made Ground soils anticipated beneath the site are potentially compressible, particularly where containing organic materials and therefore there is a potential for significant differential settlement at the surface if loaded. The Blown Sand is also potentially compressible/prone to settlement with loose to very dense deposits being identified in the area.

Therefore, we consider that the potential for compressible ground at the site should be advanced from that reported in the geological data report (Moderate) to moderate /high.

2.10.6 Running Sand

Where groundwater is present there is a potential for running sands within excavations within the natural soils (Wind Blown Sands). Groundwater is not generally anticipated above 4m bgl based on limited available data and is likely to be within the bedrock. However, its presence cannot be totally discounted at this stage.

Therefore, we consider that the potential for running sands beneath the site should be advanced from that reported in the environmental data report Low) to Moderate.

2.10.7 Volumetrically Unstable Slag Materials

The potential for volumetrically unstable slag material to be present on the site is not considered in the environmental data report.

In our experience, on former industrial/railway land sites such as this, there is the potential for slag materials to be present within the Made Ground, although the previous investigations on site have not identified/named an slag materials on their records. Investigations of adjacent areas have identified slag materials within the Made Ground, more likely associated with the infilling of the dock and surrounding areas.

There are a number of chemically different types of slag found on brownfield sites across the UK. Some forms of slags are volumetrically stable but, depending on their chemistry, some can be

extremely unstable when hydrated, which can lead to significant heave at the surface and damage to buildings and hard surfaces.

Given the currently available information, the presence of slag within the shallow Made Ground is expected, and the risk from volumetrically unstable slag is considered low/moderate.

2.10.8 Pyritic Ground

The natural soils underlying the site are not anticipated to contain elevated levels of pyrite, which could oxidise to sulphates.

The Made Ground could contain elevated levels of sulphate and potentially pyrite. Given this, we consider that the potential for sulphate/pyrite attack on buried concrete within the Made Ground is moderate/high.

2.11 Unexploded Ordnance (UXO)

A Preliminary UXO Desk Study assessment of risk has been completed by a specialist Ordnance consultant in accordance with CIRIA guidelines (Stone et al, 2009) and is presented in Appendix F (Zetica, 2019). The preliminary assessment states *"a detailed desk study, whilst always prudent, is not considered essential in this instance".*

No further assessment is considered necessary at this stage.

2.12 Radon Hazard

Radon is a colourless, odourless, radioactive gas, which can pose a risk to human health. It originates in the bedrock beneath the site, where uranium and radium rich minerals are naturally present, and can move through fractures in the bedrock, and overlying superficial deposits, to collect in spaces within/beneath structures.

The environmental data report (Appendix C) indicates that the site is in a Radon Affected Area, as between 5 and 10% of properties are above the Action Level. Given the currently available information, the risk from radon is considered moderate and basic protection measures will be required.

2.13 Underground Structures/Obstructions

Review of historical data (see Section 2.2) indicates railway lines across the centre of the site (north to south) and a station in the east of the site. The previous investigation identified a brick wall and reinforcement bar within a shallow excavation, likely associated with the former station. Given this, further structures associated with the former railway and station may be present beneath the site surface.

A rising main is present trending west to east across the approximate centre of the site (see Figures 3 and 5) and we understand that this will remain in its current location.

Obstructions/structures will require consideration as part of the development design (in particular foundations), and where shallow, they may require removal (possibly with large excavators), diversion or protection as part of the site preparation works.

3 Preliminary Geo-Environmental Risk Assessment

3.1 Phase One Conceptual Site Model

3.1.1 Background

The Phase One Conceptual Site Model lists the potential sources of geo-environmental risk, the receptors at risk and the pathways between the two. These are discussed in the following sections.

3.1.2 Potential Contamination Sources

From the available information, we consider that the following features on site could prove sources of diffuse and point source contamination that could impact on the development, environment or site users:

- Made Ground – general diffuse contamination;
- Former railway land and station;
- Former dock land;
- Usage as car park;
- Existing Electricity sub-station;
- Made Ground – potentially contain pyrite.

The remnants of a disused building in poor repair is located in the north west portion of the site. This may have contained asbestos containing materials and an asbestos specialist should be contacted to assess the building prior to demolition. The demolished former railway station and other buildings on-site may have contained asbestos.

3.1.3 Potential Contaminants Present

A review of the former investigations which have included Site B (BCBC, 2008, DS, 2011 and QG, 2013), has identified limited geochemical testing/data for the site. Testing as part of the Delta Simmons investigation (DS, 2011) identified generally low levels of metals (for commercial developments) from the three windowless sample drill holes on-site and one sample tested for PAH's and TPH's indicated levels below laboratory testing detection.

No asbestos was identified in the two samples tested at Site B (DS, 2011 and QG, 2013). Investigations of adjacent areas have identified asbestos within the Made Ground soils and therefore it cannot be discounted that the Made Ground soils at the site may contain asbestos.

Although no significantly elevated levels of contaminants have been identified previously, given the variable nature of the Made Ground anticipated and the historical presence of railway lines and railway land at the site, the potential for contaminants to be present at unacceptable levels remains.

The potential contaminants associated with the above potential sources have been identified from various guidelines published by DEFRA, the Environment Agency and others. Based on this guidance and our experience, we consider that the following contaminants could be present on the site:

- heavy metals and semi-metals (arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, vanadium, zinc);
- cyanide, sulphate, sulphide;
- polyaromatic hydrocarbon (PAH) compounds;
- petroleum hydrocarbons;
- VOC's and SVOC's;
- phenols;
- polychlorinated biphenyls (PCBs) –around the substation;
- asbestos.

No evidence has been identified from the desk study to suggest that radioactive substances may be present on the site. The potential presence of radon in discussed in Section 3.1.4.

3.1.4 Potential Sources of Hazardous Ground Gas and Radon

Salt Lake Car Park some 30m east of the site is underlain by the former, infilled Porthcawl Dock and is recorded as a landfill.

Based on the available information, the following potential sources of hazardous ground gas have been identified on, or in close vicinity of, the site:

On Site

- General Made Ground associated with former railway land and station – organic and other materials could generate combustible and noxious gases;
- Petroleum hydrocarbons within Made Ground from former railway land and use as car park – un-weathered hydrocarbons can generate hazardous volatile organic vapours and as they degrade, the hydrocarbons can generate combustible and noxious gases;

Off-Site

- Infilled dock 30m east of the site (also recorded as landfill) which extends south and north below Salt Lake car park (see Section 2.9.2.3) - combustible and noxious gases will be generated in any putrescible waste;
- Petroleum hydrocarbons within Made Ground from former railway land, tanks and car parking in the vicinity of the site– un-weathered hydrocarbons can generate hazardous volatile organic vapours and as they degrade, the hydrocarbons can generate combustible and noxious gases.

We are not aware of any previous gas monitoring undertaken within the site boundary, however ESP has completed monitoring for the food store site some 220m north east of the site. Elevated levels of ground gas were identified and gas protection measures will be required for the development. Monitoring of potentially hazardous ground gas will be required at Site B to determine the risk to the site end user and the development.

Based on the guidelines presented by O'Riordan and Milloy (1995) and revised by Wilson et al (2009), the above potential gas sources would generally be classified as of low to moderate gas generation potential considering their age.

As discussed in Section 2.11, the risk from radon is moderate and basic radon protection measures are required for development (see Section 7.3.2).

3.1.5 Potential Receptors

As discussed in Section 1.1, the proposed site development will comprise a hotel and commercial leisure facilities (such as a restaurant or café).

The nearest major surface water feature to the site is the seawater within the harbour some 75m to the south and the seawater within Sandy Bay (to the east) and Porthcawl Point (to the south), with the mean high-water mark approximately 130m to the south and east at its closest point.

The superficial deposits (if present) beneath the site (Blown Sands) are classed as a Secondary A aquifer, whilst the bedrock (Oxwich Head Limestone) is classed as Principal Aquifer (although it is not within a source protection zone). However, as discussed in Section 2.8.5, the quality of the groundwater bodies beneath the site have likely been naturally degraded by the intrusion of saline waters and therefore they are unlikely to be as sensitive as their designation suggests. This is likely the reason that no groundwater abstractions or SPZ's are noted within 1km of the site and the groundwater beneath the site is not suitable for use as drinking water. Degradation through contamination associated with the former dockland and railway land has also been considered.

Given the above, we consider that the most vulnerable receptors with regards to any contamination or hazardous ground gas present are likely to be as follows.

- Future employees and site visitors (e.g. shoppers), the critical receptors being employees outside during their break periods and any maintenance/groundworkers working.
- Construction and maintenance workers.
- Buried concrete (foundations, drainage etc.).
- The water quality in Sandy Bay and the harbour to the south.
- The groundwater within the Oxwich Head Limestone bedrock (Principal Aquifer).
- The groundwater within the Blown Sands (if present) strata (Secondary A aquifer).

3.1.6 Potential Migration Pathways

Based on the Conceptual Site Model discussed in the previous sections, the following are considered the most likely migration pathways with regard to any contamination or hazardous ground gas present beneath the site.

Considering the proposed development as a hotel and commercial leisure facility (restaurant/café), we assume that the majority of the site surface will be occupied by hardstanding and therefore exposure risks to end users will be further mitigated and the leaching potential will be reduced.

Site Users:

- Ingestion of soils and inhalation of dust in landscaping areas.
- Dermal contact with contaminated soils.
- Exposure to asbestos containing materials within the shallow soils.
- Potential explosive risk from flammable ground gas/vapours from on-site sources.
- Potential risk from toxic ground gas/vapours from on-site sources.
- Potential exposure to flammable or toxic ground gas/vapours originating from off-site sources – the near surface coarse soils and Made Ground anticipated are likely to allow free migration of any gas/vapours present.
- Chronic (long term) exposure to unacceptable levels of radon.

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 on-site sources.
- Potential explosive risk from flammable or toxic ground gas/vapours from off-site sources.

Groundwater:

- Leaching of mobile contaminants into the water-bearing strata within the Blown Sand and bedrock.

Sandy Bay

- Leaching of mobile contaminants to the groundwater beneath the site, and then on to the nearby Sandy Bay and the harbour to the south. Previous investigation information indicates they are in hydraulic continuity.
- Surface run-off of contaminated leachate to adjacent drainage and in to any outfalls to Sandy Bay.

Buildings:

- Sulphate attack on buried concrete (foundations, drainage etc.).
- Potential explosive risk from flammable ground gas/vapours from on-site sources.
- Potential explosive risk from flammable ground gas/vapours from off-site sources.

Although the majority of the site is to be hard-surfaced, any soakaways constructed for the development have the potential to leach contaminants from the infiltration strata, which could then impact on the groundwater beneath the site.

3.2 Preliminary Risk Evaluation & Plausible Pollutant Linkages

The land use history of the site and surrounding area, as established from the desk study and walkover, has identified a number of potential contamination linkages due to ground conditions or former operations either on, adjacent to, or in the vicinity of the site. Note that these potential linkages will need to be later assessed and re-established using actual site data obtained from an exploratory investigation.

3.2.1 Introduction to Risk Evaluation Methodology

The methodology set out in CIRIA C552 *Contaminated Land Risk Assessment – A Guide to Good Practice* (Rudland et al, 2001), has been used to assess whether or not risks are acceptable, and to determine the need for collating further information or remedial action.

Whilst at a later stage, this methodology may be informed by quantitative data (such as laboratory test results) the assessment is a qualitative method of interpreting findings to date and evaluating risk. The methodology requires the classification of:

- The magnitude of the potential consequence (severity) of risk occurring (Table A1 in Appendix A):
- The magnitude of the probability (likelihood) of risk occurring (Table A2 in Appendix A).

The classifications defined above are then compared to indicate the risk presented by each pollutant linkage, allowing evaluation of a risk category (Tables A3 and A4 in Appendix A). These

tables have been revised slightly from those presented in CIRIA C552, to allow for the circumstances where no plausible linkage has been identified and, therefore, no risk would exist.

The methodology described above has been used to establish Plausible Pollutant Linkages (PPL) based on the Conceptual Site Model generated for the site and proposed development, and to evaluate the risks posed by those linkages, using information known about the site, at this desk study stage. This is presented as Table 7 in Section 3.2.2 below.

3.2.2 Tabulated Preliminary Risk Evaluation & Plausible Pollutant Linkages

***Table 7**: Preliminary Risk Evaluation & Plausible Pollutant Linkages (PPL)*

Source	Pathway	Receptor	Classification of Consequence	Classification of Probability	Risk Category	Further Investigation or Remedial Action to be Taken
Potential contaminants in shallow soils (General Made Ground from former dock land and railway land)	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Site Users (employees)	Medium – potential for chronic levels.	Low likelihood[3]	Moderate/Low Risk	Sampling of near-surface soils to confirm levels of total contamination present.
	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Construction/ Maintenance Workers	Minor – standard PPE likely to be sufficient	High Likelihood[3]	Moderate/Low Risk	
	Leaching of soil contaminants	Impact on Groundwater /Potable Water	Severe - site lies on Principal & Secondary A Aquifers	Likely[2]	High Risk	Sampling of near-surface soils to confirm levels of leachable contamination and sampling of the groundwater to confirm levels of contamination present
	Leaching of soil contaminants	Impact on Sandy Bay/Harbour	Medium – site lies 70m from Harbour	Likely[2]	**Moderate Risk**	
Asbestos in derelict building in north west	Ingestion of fibres	Demolition Workers/ Ground Workers	Medium – potential for chronic levels	Likely[3]	**Moderate Risk**	Inspection of building by asbestos specialist.
Asbestos in shallow soils	Ingestion of fibres	Construction/ Maintenance Workers	Medium – potential for chronic levels	Likely[4]	**Moderate Risk**	Sampling of shallow soils for asbestos.
Soil sulphate and pyrite	Aggressive groundwater	Buried Concrete	Mild – damage to structures	High likelihood[5]	**Moderate Risk**	Sampling of soils and groundwater to further confirm levels of sulphate, pH.
Hazardous ground gas/vapours	Asphyxiation/poisoning. Injury due to explosion.	Site Users/Visitors.	Severe – acute risk.	High likelihood[6]	**Very High Risk**	Install and monitor gas wells.
	Damage through explosion.	Building/Property	Severe – acute risk.		**Very High Risk**	
	Asphyxiation/poisoning. Injury due to explosion.	Construction and Maintenance Workers.	Severe – acute risk.		**Very High Risk**	
Radon gas	Migration into Buildings	Site Users (employees)	Medium – potential for chronic levels	Likely[7]	**Moderate Risk**	See Section 5.12

Notes:

1. Methodology and details of risk consequence, probability and category based on CIRIA C552 (2001) and presented in Section 3.2.1.
2. Made Ground is likely to be present across the majority of the site, associated with the railway land, dock land and historical development directly adjacent. An electrical substation is located in the north west. There is a potential for localised deeper Made Ground, especially in the area of the former railway station. Previous investigation information indicates the potential for contamination at the site (Section 3.1.2).
3. The remnants of a disused building in poor repair is also located in the north west portion of the site. This may have contained asbestos or asbestos containing materials and an asbestos specialist should be contacted to assess the building and the potential risk to the site. (Section 3.1.3).
4. Previous investigation information indicates the potential for asbestos within the Made Ground at the site and in the vicinity, therefore there is the potential for asbestos to be present in the Made Ground at the site. (Section 3.1.2).
5. No previous investigation data contains any laboratory data for sulphate levels. The Made Ground anticipated has the potential to contain elevated levels of pyrite (Section 2.10.8).
6. A number of potential sources of on-site and off-site hazardous ground gas/vapours have been identified (Section 3.1.4).
7. Radon risk identified in environmental data report. Basic protection measures will be required for the development. (Section 5.12).
8. The above risk evaluation is updated following the intrusive investigation and testing in Table 17, Section 6.2.

4 Exploratory Investigation

4.1 Investigation Points

4.1.1 Introduction

The intrusive investigation was undertaken between 28th November and 6th December 2018, in general accordance with BS5930:2015 and BS10175:2013, and was designed to investigate both geo-environmental and geotechnical hazards identified in the desk study (Section 2). It comprised windowless sample drill holes, cable percussion boreholes, rotary coring, gas and groundwater monitoring and sampling of groundwater.

Following the main investigation, the Client commissioned additional works to undertake supplementary gas monitoring at the site, which was undertaken between November 2019 and February 2020. No other supplementary works were undertaken.

The exploratory holes were supervised and logged by an engineering geologist in general accordance with BS5930:2015, BS EN ISO14688-1: 2018 and BS EN ISO 14689: 2018, along with published weathering schemes.

Descriptions and depths of the strata encountered are presented on the various drill hole records presented in appendices G to I. The results of the monitoring are presented in appendices J and K. The investigation point positions are shown on Figure 5.

The ground levels and coordinates of the investigation points were surveyed by Davies Surveys on completion and are shown on the various hole records.

4.1.2 Investigation Strategy

The investigation strategy was generally designed in accordance with BS10175:2013, taking into account the previous investigation information and the potential for geotechnical hazards to be present. When considering the previous and current investigation points a general spacing of around 10 -25m was achieved, which is in accordance with the spacing for a 'detailed investigation'. Access was reduced in some areas due to parked cars and services, however sufficient access was available to achieve a good coverage.

The desk study identified a number of potential contaminant sources/geotechnical hazards at the site (see Section 3.1 and Figures 2 and 3 respectively). The investigation points were selected to maximise the information obtained on these hazards, as well as obtaining a general overview of the general ground conditions present. In this regard, a number of the investigation points were targeted at the above sources, as summarised in Table 8 below.

Table 8: Placement Rationale for Investigation Points

Point ID	Location	Placement Rationale
WSA, WSB, WSC, BH09, BH10, RC09	Across Site B	To investigate general ground model across the site including areas of former railway and dock land and car parking to confirm the extent and contamination status of any Made Ground. Obtain groundwater samples and monitor ground gasses within the area.
RC09	North west	To obtain information on the bedrock type and its condition beneath the proposed food store to inform pile design. Obtain groundwater samples and monitor ground gasses within the area.
BH11	North east	To investigate the depth and nature of the Made Ground in the area of the former railway station and to investigate any remaining structures associated. Obtain groundwater samples and monitor ground gasses within the area.
WSD/RC09	North west	To investigate any potential contamination from the electrical sub-station in the north west.
Key to Investigation Points: WS: Windowless Sample boreholes. BH: Cable percussion boreholes. RC: Rotary Cored (and open hole) drill hole.		

4.2 Windowless Sampling

4no. windowless sample drill holes (WSA to WSD were constructed on 28th November 2018 to a maximum depth of 5.45m. A hydraulically powered rig was used to drive plastic lined sampling tubes into the ground, with the soil recovered within the tubes, which are then split to allow sampling and logging. Disturbed samples were obtained throughout the boreholes for identification and laboratory testing purposes. The windowless sampling provided generally good recovery to the depth of refusal and the borehole records are presented in Appendix H.

Where investigation points were positioned within an area of hardstanding (WSA and WSB), the surface tarmacadam was broken out using a hydraulic breaker, and a service inspection pit excavated by hand. In areas of landscaping (WSC and WSD), a service inspection pit was excavated by hand from the surface. The inspection pits were excavated to a depth of 1.2m or refusal (where no further excavation could be achieved due to the density of the ground).

Standard Penetration Tests (SPT) were carried out using a split spoon/solid cone in the boreholes in accordance with BS EN ISO 22476-3 (2005) and BS5930 (2015) to assess the relative density of the coarse-grained soils encountered in the borehole using relationships published by Stroud (1975). As required in BS5930:2015, the SPT N-values shown on the borehole records are the direct, uncorrected results obtained in the field. Given only two SPT tests were undertaken within the Blown Sand (WSA), they have not been corrected.

On completion, the drill holes were backfilled with arisings/gravel, with the concrete/tarmacadam reinstated at the surface in WSA and WSB.

4.3 Cable Percussion Boreholes

3no. 200mm diameter cable percussion boreholes (BH09 to BH11) were constructed to a maximum depth of 5.0m between 3rd and 5th December 2018. The borehole records are presented as Appendix G.

At the commencement of each borehole, the surface tarmacadam was broken out using a hydraulic breaker a service inspection pit excavated by hand to a depth of 1.2m.

Standard Penetration Tests (SPT) were carried out using a split spoon/solid cone in the boreholes in accordance with BS EN ISO 22476-3 (2005) and BS5930 (2015) to assess the relative density of the coarse-grained soils encountered in the borehole using relationships published by Stroud (1975). As required in BS5930:2015, the SPT N-values shown on the borehole records are the direct, uncorrected results obtained in the field. Given only two SPT tests were undertaken within the Blown Sand (WSA), they have not been corrected.

On completion, monitoring instrumentation was installed in the boreholes as detailed in Section 4.5.1. Below the instrumentation, the borehole was backfilled with arisings/gravel. BH09 was made safe and secured with fencing to await rotary coring follow on drilling, as detailed in Section 4.4 below.

4.4 Rotary Cored Drillholes

1no. rotary cored drill hole was constructed (RC09) to a depth of 12.9m on 6th December 2018. The ODEX 115 system of casing was used in the Made Ground (drilled previously by cable percussion method) and the drill hole records are presented as Appendix I.

Cores of nominal 100mm diameter were recovered in plastic liners using a triple tube barrel system, over runs of nominal 1.5m length. Compressed air and water was used as a flushing medium to keep the drill bits cool and aid the coring process. The percentage recovery of the samples was good and therefore a reduction in the length of core run (to improve recovery), was not required. The recovered cores were sealed in the plastic liners and placed in solid core boxes to prevent disturbance and swelling before logging. The plastic liners were only cut immediately prior to logging and sampling. In addition to the nature of the rock material, the identified fractures within the rock mass were also logged in accordance with BS5930:2015. The Rock Quality Designation (RQD) recorded was for rock core 100mm or greater in length. The fracture state of the recovered cores is presented on the drill hole records, which are presented in Appendix I.

On completion, instrumentation was installed in boreholes as detailed in Section 4.5.1. Below the instrumentation, the borehole was backfilled with bentonite and arisings.

4.5 Instrumentation

4.5.1 Gas Well Installations

Single or dual 50mm diameter monitoring well was installed in selected boreholes in accordance with BS8576:2013 in order to allow monitoring of hazardous ground gases and monitoring and sampling of groundwater. The wells, comprising slotted plastic pipe with a gravel surround (the response zone), bentonite seals above the response zone, and a lockable vandal proof cover, were installed as detailed on the borehole records and summarised in Table 9 below.

Table 9: Gas Well Installations

Well ID	Date of Installation	Response Zone depth	Response Zone Stratum
RC09(s)	06/12/2018	0.5 – 2.0m	Made Ground
RC09(d)	06/12/2018	6.0 – 12.9m	Oxwich Head Limestone
BH10	04/12/2018	0.5 – 4.5m	Made Ground/Oxwich Head Limestone
BH11	05/12/2018	0.5 – 5.0m	Made Ground/Oxwich Head Limestone

Notes:
1. Details of each monitoring well are presented on the individual borehole records (Appendices G and I).
2. RC09 installed with a dual monitoring well comprising a shallow (s) and deeper (d) well as detailed above.

4.5.2 Gas Monitoring

Monitoring of the installed gas wells has been undertaken on a 'spot' monitoring basis (periodic visits to monitor gas levels at the time of the visit). CIRIA C665 (Wilson et al, 2007) provides guidance on the number and frequency of monitoring visits required for installed gas wells. These depend on the gas generation potential of the source and the sensitivity of the development to gas risk and are designed as a typical minimum only.

As discussed in Section 3.1.4, the most significant source in the vicinity of the site in terms of gas risk is the Made Ground on-site (former dock/railway land and railway station) and associated volatile contamination. The infilled dock some 30m from the site is also a potential off-site source of hazardous ground gas. The identified sources are classified as being of low to moderate gas generation potential. The proposed development of a hotel and associated commercial developments (café/restaurant) would be classified as being low sensitivity in terms of gas risk. Therefore, based on the guidelines in CIRIA C665, a minimum of six monitoring visits are required over a three month period.

The installed wells have been monitored for levels of groundwater and ground gas on six occasions between 19th December 2018 and 4th March 2019, with a further 6no. visits completed between 28th November 2019 and 20th February 2020 (12no. visits in total). The results of the gas and groundwater monitoring are presented in Appendix J and K. The results of the monitoring are discussed further in Section 5.12.

During each visit, Gas Data LMSxi G3.18e portable monitoring equipment was used to measures levels of the following ground gases within the airspace in the wells and the flow rates from the wells:

- Methane - total and percentage of Lower Explosive limit (LEL);
- Carbon dioxide;
- Oxygen; and
- Hydrogen sulphide.

The percentage of nitrogen is also calculated by difference. The equipment uses infra-red methane (CH4) and carbon dioxide (CO2) detectors, coupled with pressure (barometric and well), temperature and flow sensors. A photo-ionisation detector (PID) was used during the monitoring to measure the levels of volatile organic compounds present in the well. Following measurement of gas levels and flow rates, the well cap was removed and groundwater levels were measured using a dip-meter from the site surface. During each visit, an interface probe was used to measure the presence of any phase-separated hydrocarbons in the groundwater.

Monitoring was also undertaken during different tidal conditions (e.g. rising, falling etc.) to assess the potential for any variation due to the piston effect.

4.6 Sampling Strategy

4.6.1 Soil Sampling

Soil samples were collected from the exploratory holes as discussed in the previous sections. The sampling procedures were selected on the basis of the suitability for the laboratory testing proposed.

Sampling for soil contaminants was undertaken on a targeted strategy, focused on the contaminant sources identified in Section 3.1.2. Further soil samples were also taken randomly from non-targeted areas to provide a general indication of the variability in concentrations of possible diffuse source contamination across the site as a whole.

Environmental samples (denoted as ES on the exploratory holes records) were collected for possible geo-environmental laboratory testing and generally comprised a plastic tub, an amber glass jar and an amber glass vial. The sample containers provided clean by the testing laboratory appropriate for the proposed testing to be scheduled. Immediately after collection the samples were placed in sealed cool boxes with ice packs where they remained during storage and transport to the laboratory.

Samples for logging and geotechnical laboratory testing purposes were collected at regular intervals within the exploratory holes.

4.6.2 Soil Sample Quality

Samples of soil recovered from investigations are classified as Classes 1 to 5 in terms of quality and depend on the investigation and sampling method, the particle size of the strata sampled, and the presence of groundwater. Class 1 and 2 samples are those in which there has been no or only slight disturbance of the soil structure, with moisture contents and void ratios being similar to the in-situ soil. Class 3 and 4 samples contain all the constituents of the in-situ soil in their original proportions, and the soil has retained its original moisture content, but the structure of the soil has been disturbed. In Class 5 samples, the soil structure and original layering cannot be identified and the water content may have changed from that in-situ. The category and class of samples are discussed further in BS EN ISO 22476:2006, EN 1997-2:2007 and BS5930:2015.

During cable percussion drilling, the split spoon sample from a Standard Penetration Test (SPT) is usually considered a Class 5 sample however, it can be deemed Class 4 in homogeneous fine-grained soils. Disturbed sampling (bulk bags and small tubs) from boreholes is considered Class 3 (if dry), Class 4 (fine soil below the water table) or Class 5 (coarse soils from beneath the water table).

The samples recovered within the liner in windowless sampling are generally Class 3 in fine-grained soils with good recovery, becoming Class 2 in favourable circumstances, but Class 3 or 4 in coarse-grained soils.

Provided recovery is good, rock cores collected using rotary techniques are classified as Class 2 samples, provided that the plastic liners are sealed and only opened immediately prior to logging. The chippings recovered during open-holes drilling are considered Class 5 samples.

4.6.3 Groundwater Sampling

Prior to sampling and to attempt to collect the most representative water samples the wells were developed by purging, with the removal of three well volumes before sampling during the first monitoring visit.

In order to establish the groundwater quality beneath the site, samples of groundwater were collected from the installed wells on 19th December 2018 and 14th January 2019 in general accordance with BS ISO 5667-11 (2009) using a low flow pump. The use of the low flow pump during water sampling eliminates the need to purge the wells prior to sampling.

All groundwater samples taken for possible laboratory chemical analysis were collected in suitable clean containers provided by the testing laboratory for (e.g. clean polyethylene jars/bottles with fitted lids for routine soil testing, clear or amber glass bottles with screw on air-tight caps for organic contaminants, glass vials for volatile contaminants, etc.). Immediately after collection the samples were placed in sealed cool boxes with an ice pack where they remained during storage and transport to the laboratory.

4.7 Evidence of Site Hazards Found During Site Works

With regard to potential hazards identified in the desk study and Preliminary Risk Assessment, the following observations were made.

4.7.1 Site Stability

Some spalling of the Made Ground soils was noted during the construction of the hand excavated service pits, which was generally identified as loose to medium dense. No casing was required during the construction of the windowless sample drilling and the holes remained open until backfilled.

No obvious evidence of the of the former railway infrastructure of the former railway station were encountered during the investigation, however some timber was identified in BH09 (in the area of a former railway line) and crushed bricks and stone were identified in BH11 (in the area of the former station).

No evidence of limestone solution was identified during the investigation. The increase in depth to bedrock in the east portion is considered to be natural.

4.7.2 Site Evidence of Contamination

The Made Ground was generally identified to be around 1 - 2m across the site, with deeper Made Ground identified in the west portion WSB, BH10 and BH11, within an area of a former railway line and the railway platform respectively. The Made Ground identified was relatively the same across all investigation points, comprising largely sandy gravels with man-made materials such as brick, crushed stone and occasional slag. Ash was also noted within the Made Ground. Details of the strata's encountered are presented in Section 5.1.

No significant direct visual or olfactory evidence of contamination was noted during the works and the PID readings did not identify any volatile gases during the investigation.

4.8 Geotechnical Laboratory Testing

Geotechnical laboratory testing was undertaken on samples from the suitable quality classes recovered from the exploratory holes in order to obtain information on the geotechnical properties on the soils beneath the site.

The following tests were undertaken by a UKAS accredited laboratory on samples selected by ESP in accordance with the methodologies presented in BS1377:1990. The results are presented in Appendix L3.

- Particle size analysis;
- Point Load Value of rock; and
- Uniaxial Compressive Strength (UCS) of rock.

Selected samples were also analysed for soil sulphate and pH value in accordance with the analytical methods specified in BRE Special Digest SD1 (BRE, 2005). Due to the potential presence of pyrite in the soils (see Section 2.9.13), these samples were also analysed to determine the levels of total sulphur, acid soluble sulphate in accordance with the analytical methods specified in BRE Special Digest SD1 (BRE, 2005).

Samples of groundwater recovered from the exploratory holes/installed wells were also analysed for the levels of sulphate and pH value in accordance with the analytical methods specified in BRE Special Digest SD1 (BRE, 2005).

The results of the sulphate testing are included with the geo-environmental test results in Appendix M3 (soils) and O (groundwater)

4.9 Geo-environmental Laboratory Testing

Laboratory testing has been undertaken to identify the levels of selected contaminants within samples of soil, leachate generated from shallow soils, groundwater.

The geo-environmental analyses were carried out by a UKAS accredited testing laboratory with detection limits being generally compatible with the relevant guideline values adopted in the assessment (see Section 4.1.1).

4.9.1 Soil Samples

To allow an assessment of the potential chronic risks posed to human health, a total of seven selected samples of the Made Ground and two samples of the natural Blown Sand deposits have been analysed for the contaminants identified in Section 3.1.2, plus other determinands typically present on brownfield sites in the UK.

The general suite of geo-environmental laboratory testing undertaken comprised:

- Arsenic, barium, beryllium, boron, cadmium, total chromium, chromium VI, copper, lead, mercury, nickel, selenium, vanadium, zinc;
- US EPA 16 polyaromatic hydrocarbon (PAH) compounds;
- Total monohydric phenols;
- Total cyanide, asbestos qualitative screen (presence or absence);
- Soil organic content, pH value;
- Petroleum hydrocarbons (CWG ali/aro carbon banded C_5 to C_{35});
- Volatile organic compounds (including chlorinated solvents);

- Polychlorinated biphenyls (PCBs) – WSD only near the sub-station;
- Asbestos quantification analysis.

The geo-environmental soil test results are presented in Appendix M3.

4.9.2 Leachate Samples

In order to allow an assessment of the potential pollution risks to controlled waters, samples of leachate have been generated from three samples of Made Ground soil recovered from the exploratory holes. The leachate preparation was carried out in accordance with the guidance given in BS EN 12475 at 10:1 elluate ratio.

The resulting leachate was analysed for the following determinants:

- Arsenic, barium, beryllium, boron, cadmium, total chromium, copper, iron, lead, mercury, nickel, selenium, vanadium, zinc;
- Aluminium, antimony, cobalt, molybdenum manganese, silver, sodium, tin;
- US EPA 16 polyaromatic hydrocarbon (PAH) compounds;
- Total monohydric phenols;
- Cyanide, soluble sulphate, pH value;
- Petroleum hydrocarbons (CWG ali/aro carbon banded C_5 to C_{35});
- Volatile organic compounds (including chlorinated solvents);
- Semi-volatile organic compounds (SVOCs).
- Polychlorinated biphenyls (PCBs) – WSD only;

The results of the leachate tests are presented in Appendix N2.

4.9.3 Groundwater Samples

In order to allow an assessment of the potential pollution risks to controlled waters, samples of groundwater recovered from selected wells have been analysed for the following determinands:

- Arsenic, barium, beryllium, boron, cadmium, total chromium, copper, iron, lead, mercury, nickel, selenium, vanadium, zinc;
- US EPA 16 polyaromatic hydrocarbon (PAH) compounds;
- Total monohydric phenols;
- Cyanide, soluble sulphate, pH value;
- Petroleum hydrocarbons (CWG ali/aro carbon banded C_5 to C_{35});
- Volatile organic compounds (including chlorinated solvents);
- Semi-volatile organic compounds (SVOCs).

Groundwater was only able to be sampled from BH09d within the bedrock, with the remainder of the installations (BH10 and BH11) being dry or only wet at the base.

5 Development of the Revised Conceptual Model

5.1 Geology

The exploratory holes have identified the site to be generally underlain by covering of Made Ground followed by limited areas of Blown Sand deposits overlying weathered and competent Oxwich Head Limestone bedrock.

Previous investigations (BCBC, 2008, DS, 2011 and QG, 2013) identified a ground model comprising Made Ground overlying sand to a depth of approximately 4.0m. A 0.4m band of clay was also noted in one previous investigation point (DS, 2011), between 1.8m and 2.2m depth, overlying probable limestone bedrock.

These strata identified are discussed in more detail in the following sections and the geological succession identified is presented on a Conceptual Ground Model in Figure 6.

Made Ground: encountered to a maximum depth of 4.6m below ground level (BGL) comprising largely sandy gravels and occasional gravelly sands, with man-made materials such as brick and crushed stone with occasional slag and clinker. Timber and metal were also noted, with ashy soils also noted within cable percussion boreholes.

Particle size analyses (ESP and previous) have indicated the Made Ground to comprise between up to 23% cobbles, between 43% and 71% gravel, 21% to 39% sand and between 1% to 18% silt/clay. Based on our observations on site, these proportions would appear representative of the in-situ soils.

Field SPT N-values within the Made Ground varied between 4 and 41, with an average of 15, indicating the Made Ground to be in a generally medium dense state.

No previous SPT data is available within Site B from historical investigations.

Blown Sand Deposits: encountered beneath the Made Ground in TP4 (BCBC, 2008), WS02 (DS, 2011) WSA and WSD (ESP, 2018) only, from between depths of between 0.95m and 2.8m BGL and was identified to be between 0.25m and 2.2m in thickness.

Field SPT N-values within the Blown Sands were only obtained from WSA at depths of 3m and 4m, with both results identifying an N-Value of 4. This indicates a generally loose state. When corrected, the N-values still indicate the sands are generally in a loose state.

No previous SPT data is available within Site B from historical investigations.

Grade B Oxwich Head Limestone Bedrock: encountered at the base of all of the windowless sample and cable percussion drill holes (except WSA) and proven in the cored drill hole RC09 from a depth of 2.2m to 12.9m below surface level as a light grey thinly to medium bedded calcitic limestone. Fractures within the bedrock were generally very closely to closely spaced with localised weathering and fine-medium gravel infilling. A band of limestone conglomerate was identified between 4.45m and 5.65m depth.

The depth to bedrock generally increases to the east and this likely due to natural erosional processes.

The limestone was estimated to be generally weak to medium strong in terms of strength.

5.2 Hydrogeology

5.2.1 Groundwater Bodies

The groundwater conditions identified in the investigation are summarised in Table 10 below:

Table 10: *Summary of Groundwater Ingress in the Investigation*

Hole ID	Stratum	Comment on groundwater encountered
RC09	Oxwich Head Limestone	Water strike identified at 10.5m depth during drilling
		BH09(s) shallow well (2.0m depth) dry throughout monitoring. Monitored levels in BH09(d) identified between 4.22m and 7.78m BGL.
BH10	Made Ground/ Oxwich Head Limestone	Standing water (likely perched) measured at 2.55m and 4.15m depth during drilling.
		Well was 'wet at base' on4no. visits (visits 2, 3, 4 and 10). Monitored levels identified between 4.10m and 4.39m BGL.
BH11	Made Ground	Standing water (likely perched) measured at 3.3m depth during drilling.
		Largely dry (8 out of 12 visits) Monitored levels identified between 4.51m and 4.80m BGL (likely perched water).

Previous investigation works (BCBC, 2008 and DS, 2011), indicated the investigation points to be dry to a maximum depth of 4.0m.

Based on the above findings and the Conceptual Ground Model, we consider that the main groundwater body beneath the site is within the Oxwich Head Limestone bedrock at a depth of around 4-7m BGL. The above standing water levels were likely perched water bodies within the Made Ground, as monitoring indicates that there is no water body within the Made Ground at the site. Deeper water bodies also likely exist within the Oxwich Head Limestone bedrock.

5.2.2 Hydraulic Gradient

Based on the site setting and available information, we consider that the hydraulic gradient beneath the site is likely to be slightly towards Sandy Bay to the south and south east and the groundwater within the bedrock beneath the site is likely in hydraulic continuity with the waters in Sandy Bay.

5.3 Site Instability

5.3.1 Global Site Stability

No evidence was identified of potential landslides or unstable ground in the Preliminary Geotechnical Risk Register (Table 6) and we identified no evidence of any global instability issues on the site.

5.3.2 Excavation Stability

Some spalling of the Made Ground soils was noted during the construction of the hand excavated service pits and the Made Ground was generally loose to medium dense. No casing was required during the construction of the windowless sample drilling and the holes remained open until backfilled.

5.4 Limestone Solution

No evidence of limestone solution was identified in the investigation.

5.5 Chronic Risks to Human Health – Generic Assessment of Risks

5.5.1 Assessment Methodology

The long term risks to health have been assessed using methodologies and frameworks determined by the Environment Agency within documents SR2, SR3, SR4 and the CLEA Technical Review published to support the Contaminated Land Exposure Assessment Model (CLEA). Where applicable, reference has been made to the supporting toxicological reports (TOX Series) and the Soil Guideline Value reports (SGV Series). It is assumed that the reader is familiar with the above documents and it is not intended to repeat these described methodologies in detail, for further information, please refer directly to the specific documents.

In order to provide an initial 'screen' to identify elevated levels of contaminants, a Generic Quantitative Risk Assessment (GQRA) has been undertaken using the most appropriate Generic Assessment Criteria (GAC) determined by assessment of exposure frequency/duration relevant to the critical receptor.

5.5.2 Assessment Criteria

In 2014, DEFRA published the Category 4 Screening Levels (C4SL) for use in Part 2A determinations. The C4SL are designed to be more pragmatic, but still strongly precautionary, assessment criteria compared to the previous assessment criteria (SGV – see below) used to assess chronic human health risks. They are designed for use in deciding whether land is suitable for use and definitely not contaminated, and DEFRA and the Welsh Government have recommended that they be used in assessing human health risks during the planning regime (i.e. as part of standard development investigations). However, the C4SL have been calculated for a limited number of contaminants at this stage, and range of land uses including residential, commercial and public open space, but are based on a 'low level' of risk rather than the 'minimal level' of risk adopted by the Environment Agency in preparing their Soil Guideline Values (SGV). At the time of writing, the use of the C4SL in planning has not yet been accepted by many parties, including some regulators. The C4SL have also only been published for a limited number of contaminants. The C4SL have not been generally adopted in this assessment.

In this assessment, where available, the Soil Guideline Values (SGV) published by the Environment Agency have been adopted as the Generic Assessment Criteria (GAC) in the first instance. However, the SGV are only available for a limited number of contaminants for three proposed land uses (residential, commercial and allotments - not public open space). Where no SGV is available, the Suitable For Use Levels (S4ULs) published in January 2015 by the Chartered Institute of Environmental Health (CIEH) and Land Quality Management (LQM) have been adopted (Nathanail et al, 2015). These assessment criteria adopt updated toxicological data and exposure models, but the same 'minimal level' of risk as the SGV (i.e. unlike the C4SL). The S4ULs have been published for a large number of contaminants typically found on brownfield sites in the UK, and for the same range of land uses as the C4SL, i.e. including public open space scenarios.

For more exotic, predominantly organic, compounds no SGV, S4UL or C4SL assessment criteria have been published. In this instance, GAC published by CL:AIRE and the Environmental Industries Commission (CL:AIRE/EIC, 2010) have been adopted. These GAC have also been developed using the CLEA UK software based on a 'minimal level' of risk and for the same land use scenarios as the SGVs (i.e. not public open space).

At the time of writing there is no published SGV, S4UL or CL:AIRE/EIC assessment criteria for lead. For the purposes of this assessment, and in the absence of any other current authoritative guidance, the Category 4 Screening Level (C4SL) value published by DEFRA has been adopted.

Details of the source of the GAC adopted for each contaminant are presented on the assessment table below. The proposed development comprises a hotel and commercial leisure facilities (such as a restaurant or café),with external hardstanding and landscaping. Therefore, the GAC appropriate for the commercial land use have been adopted in this assessment. The GAC for most organic compounds are dependent on the organic content of the soil. Analysis has shown that the soil organic content in the soils analysed ranged from 0.7% to 14%. Therefore, for the purposes of this assessment, GAC for a soil organic content of 1% has been adopted. This again is considered a conservative approach for the majority of the soils at the site.

5.5.3 Generic Quantitative Risk Assessment

The samples analysed for soil contaminants comprised seven samples of Made Ground and two of natural Blown Sand soils. Three samples from the Delta Simmons investigation (DS, 2011) and one sample from the Quantum Geotechnical (QG, 2013) investigations have also been included in the analysis.

At this stage, all samples have been considered across the site as one averaging area. If any exceedances are identified, a statistical analysis based on particular averaging areas may be undertaken to further assess the risks. The risks from asbestos are considered further in Section 7.1.1. The results of the Generic Quantitative Risk Assessment are presented in Table 11 below.

Table 11: Summary of Geo-environmental Soil Results

Determinand	Range Recorded	GAC	Source of GAC	Exceedances
Metals and Semi-metals				
Arsenic	6 - 35mg/kg	640mg/kg	SGV[2]	None
Barium	150 - 530mg/kg	22,000mg/kg	CL:AIRE[4]	None
Beryllium	0.3 – 2.4mg/kg	12mg/kg	S4UL[3]	None
Boron	0.8 – 1.3mg/kg	240,000mg/kg	S4UL[3]	None
Cadmium	0.1 – 3.1mg/kg	230mg/kg	SGV[2]	None
Chromium (total)[6]	6.9 - 36mg/kg	8,600mg/kg	S4UL[3]	None
Chromium (hexavalent)	<1.0mg/kg	33mg/kg	S4UL[3]	None
Copper	9.3 – 160mg/kg	68,000mg/kg	S4UL[3]	None
Lead	15 - 530mg/kg	2,330mg/kg	C4SL[5]	None
Mercury[7]	<0.05 – 0.61mg/kg	1,100mg/kg	S4UL[3]	None
Nickel	7.5 - 21mg/kg	980mg/kg	S4UL[3]	None
Selenium	<0.2 – 1.8mg/kg	13,000mg/kg	SGV[2]	None
Vanadium	17 - 50mg/kg	9,000mg/kg	S4UL[3]	None
Zinc	32 - 350mg/kg	730,000mg/kg	S4UL[3]	None
Polyaromatic Hydrocarbons (PAH)				
Acenaphthene	<0.03 – 2.7mg/kg	84,000mg/kg*	S4UL[3,8]	None
Acenaphthylene	<0.03 – 0.32mg/kg	83,000mg/kg*		None
Anthracene	<0.03 – 6.7mg/kg	520,000mg/kg		None
Benzo(a)anthracene	0.13 – 12mg/kg	170mg/kg		None
Benzo(a)pyrene	0.08 – 8.9mg/kg	35mg/kg		None
Benzo(b)fluoranthene	0.18 – 12mg/kg	44mg/kg		None
Benzo(ghi)perylene	0.05 – 5.0mg/kg	3,900mg/kg		None
Benzo(k)fluoranthene	0.06 – 5.8mg/kg	1,200mg/kg		None
Chrysene	0.15 – 9.6mg/kg	350mg/kg		None
Dibenzo(a,h)anthracene	<0.03 – 1.1mg/kg	3.5mg/kg		None
Fluoranthene	0.17 - 26mg/kg	23,000mg/kg		None
Fluorene	<0.03 – 4.9mg/kg	63,000mg/kg*		None
Indeno(123-cd)pyrene	0.06 – 4.3mg/kg	500mg/kg		None
Naphthalene	<0.03 – 3.4mg/kg	190mg/kg*		None
Phenanthrene	0.08 - 21mg/kg	22,000mg/kg		None
Pyrene	0.21 - 15mg/kg	54,000mg/kg		None
BTEX Compounds				
Benzene	<0.01mg/kg	27mg/kg	S4UL[3,8]	None
Toluene	<0.01mg/kg	56,000mg/kg*		None
Ethyl benzene	<0.01mg/kg	5,700mg/kg*		None
Xylene[9]	<0.01mg/kg	5,900mg/kg*		None
Aliphatic Petroleum Hydrocarbons (Equivalent Carbon Number)				
Ali EC 5-6	<0.01mg/kg	3,200mg/kg*	S4UL[3,8]	None
Ali EC 6-8	<0.01mg/kg	7,800mg/kg		None
Ali EC 8-10	<0.01mg/kg	2,000mg/kg		None
Ali EC 10-12	<1.5mg/kg	9,700mg/kg*		None
Ali EC 12-16	<1.2mg/kg	59,000mg/kg*		None
Ali EC 16-35	<3.5mg/kg	1,600,000mg/kg		None
Aromatic Petroleum Hydrocarbons (Equivalent Carbon Number)				
Aro EC 5-7	<0.01mg/kg	26,000mg/kg*	S4UL[3,8]	None
Aro EC 7-8	<0.01mg/kg	56,000mg/kg*		None
Aro EC 8-10	<0.01mg/kg	3,500mg/kg*		None
Aro EC 10-12	<0.9 – 4.8mg/kg	16,000mg/kg*		None
Aro EC 12-16	<0.5 - 31mg/kg	36,000mg/kg*		None
Aro EC 16-21	<0.6 - 96mg/kg	28,000mg/kg		None
Aro EC 21-35	<1.4 - 280mg/kg	28,000mg/kg		None

Continued over.

Table 11 (continued): Summary of Geo-environmental Soil Results

Determinand	Range Recorded	GAC	Source of GAC	Exceedances
Other Organic Compounds				
Phenol	<0.3 – 0.5mg/kg	760mg/kg	S4UL[3,8]	None

Notes
1. Assessment for commercial land use.
2. CLR SGV: Soil Guideline Value published by Environment Agency.
3. S4ULs Suitable 4 Use Levels. Copyright Land Quality Management Limited, reproduced with permission; Publication No. S4UL3156. All Rights Reserved.
4. CL:AIRE/EIC GAC published by CL:AIRE and Environment Industries Commission.
5. C4SL: Category 4 Screening Level. No current SGV, S4UL or CLAIRE/EIC assessment criteria for lead. Category 4 Screening Level adopted in assessment.
6. In the absence of Chromium VI, all chromium present likely to be Chromium III. GAC for Chromium III adopted.
7. GAC for inorganic mercury adopted.
8. GAC for organic compounds based on 1% soil organic content.
9. GAC for xylene based on p-xylene (lowest S4UL).
10. Exceedances highlighted in red and bold.
11. Laboratory results presented in Appendix M3.

One sample (WSD, 0.6m) was also selected to be tested for PCB's, which can be an indication of contamination arising from electrical substations. WSD, was positioned as close to the sub-station as was feasible. The testing identified no elevated levels of PCB's and all levels were below laboratory detection limits.

Two samples (WSD, 0.6m and BH10, 0.5m) were selected for testing for VOC's and SVOC's from the area of the electrical substation and within railway land respectively. All VOC's and SVOC's tested were below detectable limits with the exception of Bis(2-ethylhexyl)phthalate (0.3mg/kg) in the sample from WSD (0.6m) and 3&4-Methylphenol (0.2mg/kg), 2-Methylnaphthalene (0.8mg/kg), 4-Nitrophenol (2.3mg/kg), Dibenzofuran (2.6mg/kg) and Carbazole (1.7mg/kg). No general acceptance criteria are available for these compounds, however we consider them to be generally low levels. All VOC's and SVOC's from previous investigation works (DS, 2011), were below the laboratory detection limits.

No further statistical analysis is warranted for a commercial land end-use at this stage.

5.5.4 Asbestos

Previous investigations did not identify any evidence of asbestos within the soils within the Site B boundary, however asbestos containing materials (ACM) were identified in the Made Ground in the vicinity.

A qualitative analysis has identified chrysotile asbestos present as bundles of fibres in the Made Ground in the north east of the site in the area of the former railway station (BH11, 0.5m). Further quantitative testing has been undertaken and identified that the level of this asbestos to be less than 0.001%. Asbestos was not identified in the remainder of the samples. This is discussed further in Section 7.1.1.

Existing buildings on-site to be demolished as part of future development may contain ACM.

5.6 Risk to Controlled Waters – Level Two Assessment

5.6.1 Methodology

The potential impact of contamination originating at the site on controlled waters in the area of the site (i.e. groundwater and surface water) has been initially evaluated in line with the Environment Agency guidance (Carey et al, 2006).

Levels of contaminants within leachates and the groundwater beneath the site have been analysed, which represents a 'Level Two' risk assessment (Carey et al, 2006).

5.6.2 Assessment Criteria

As for the assessment of human health risks above, the results of the contamination testing have been compared to assessment criteria appropriate to the controlled water receptors in the area.

As for the assessment of human health risks above, the results of the contamination testing have been compared to assessment criteria appropriate to the controlled water receptors in the area.

The Preliminary Risk Assessment has identified that the following controlled water receptors are potentially at risk from contamination originating at the site:

- The groundwater within the Carboniferous Limestone bedrock which is classified as a Principal Aquifer. The site is not within a source protection zone (SPZ).
- The groundwater within the Blown Sand deposits, classified as a Secondary A aquifer, where the groundwater could be abstracted for potable use in the future.
- The water within Sandy Bay located some 130m to the south and east of the site. The groundwater within the shallow soils beneath the site are likely in hydraulic continuity with the water in Sandy Bay.

The investigation identified limited Blown Sand deposits across the site, with only WSA identifying any significant thickness of Blown Sands. Given the available information, we consider that the most vulnerable receptor with regards to leachable and mobile contamination would be the groundwater within the Oxwich Head Limestone bedrock, monitored at levels of around 7.5m BGL. It is likely that the groundwater is in hydraulic continuity with the water within Sandy Bay and this is therefore also considered in our assessment.

Given the likely saline intrusion historically and at present beneath the site and the likely hydraulic continuity between the groundwater and the waters within Sandy Bay, in order to assess the potential impact on the waters beneath the site and within Sandy Bay, the levels of contaminants have been compared to the Environmental Quality Standards (EQS) for salt water. For the purposes of this assessment, the Annual Average (AA) EQS have been adopted which represent the acceptable levels of a contaminant over an annual period. No annual average EQS has been published for mercury compounds, so the Maximum Allowable Concentration (MAC) EQS has been adopted for this metal.

There are currently no EU or UK guidelines for ethylbenzene and the World Health Organisation criteria (WHO, 2011) has been adopted for this compound. Similarly, there are no published assessment criteria for the higher chain petroleum hydrocarbons within controlled waters. The Environment Agency have previously stipulated an assessment criteria of 10µg/l for all bands of petroleum hydrocarbons, and this has been used tentatively as the assessment criteria. However, it should be appreciated that this only represents a preliminary, broad-brush appraisal

of the levels of contamination present and an exceedance does not necessarily define an unacceptable risk.

Despite being Secondary A and Principal Aquifers, the groundwater is not considered a potable resource due to natural saline intrusion degrading its quality. However, to generally assess their quality, the results of the testing have also been compared to the Threshold Values (TV) published in the Water Framework Directive (WFD, 2015). It is appreciated that these threshold values are designed to be protective of the general groundwater body and not for use on a site specific basis, however, in the absence of other published guidelines, we consider that they may be adopted to provide an indication of the groundwater quality beneath the site.

The actual assessment criteria adopted are shown in the following table(s), and further details on them can be found in the respective published documents.

Contaminants within controlled waters have been classed as Priority or non-Priority Substances by the European Union. Priority Substances are those toxic substances whose emissions are to be reduced progressively over time. Whilst the Non-Priority Substances comprise the remaining contaminants analysed in this assessment. The classification of each substance analysed is presented in Table 12 and 13 in the following sections.

5.6.3 Assessment of Leachate & Groundwater Test Results

The leachate assessment considers contaminant levels based on three leachates of the general Made Ground from the ESP investigation (ESP, 2018). The assessment also considers one sample from a previous investigation at the site (TP1 at 0.4m - QG, 2013).

The groundwater assessment considers contaminant levels based on two samples of the groundwater from the Oxwich Head Limestone bedrock (BH09(d)) from the ESP investigation (ESP, 2018). No previous groundwater test results have been identified for the site.

The results of the leachate and groundwater testing and their comparison to the relevant assessment criteria is presented in Table 12 and 13 below, based on the groundwater beneath the site and the waters in Sandy Bay as the most vulnerable receptor.

Table 12: Controlled Waters Risk Assessment – Leachate Results

Compound	Range Recorded	TV (WFD 2015)	2015 EQS Value (WFD) *Saltwater*	Exceedances
Metals and Semi-metals:				
Arsenic[1]	0.86 – 10µg/l	7.5µg/l	25ug/l[1]	1 of 4 (EQS)
Boron[2]	<100 - 190µg/l	750µg/l	1000ug/l[1]	None
Cadmium[1,6,]	<0.03µg/l	3.75µg/l	0.2 ug/l[1]	None
Chromium VI[2]	0.34 – 7.0µg/l	37.5µg/l	0.6 ug/l[1]	2 of 4 (EQS)
Copper[2,3]	0.9 – 5.5µg/l	1,500µg/l	3.76 ug/l [1,10]	1 of 4 (EQS)
Iron[2]	12 - 160µg/l	1,000µg/l	1000 ug/l[1]	None
Lead[1]	<0.09 – 67µg/l	7.5µg/l	1.3 ug/l[1]	1 of 4 (EQS & TV)
Mercury[1,5]	<0.01µg/l	0.75µg/l	0.07 ug/l[2]	None
Nickel[1]	<0.5 – 3.6µg/l	15µg/l	8.6 ug/l[1]	None
Zinc[2,4]	<1.3 – 21µg/l	-	7.9 ug/l[1]	1 of 4 (EQS)
Polyaromatic Hydrocarbon Compounds				
Anthracene[1]	<0.01 – 0.78µg/l	-	0.1µg/l	3 of 4 (EQS)
Benzo[a]pyrene[1]	<0.01 – 8.4µg/l	0.075µg/l	0.00017µg/l	3 of 4 (EQS)
Fluoranthene[1]	<0.01 – 6.6µg/l	0.075µg/l	0.0063µg/l	3 of 4 (EQS)
Naphthalene[1]	<0.01 – 0.90µg/l	0.075µg/l	2.0µg/l	3 of 4 (EQS)
Petroleum Hydrocarbon Compounds				
Benzene[3]	<1.0µg/l	5.16µg/l	8µg/l	None
Toluene[4]	<1.0µg/l	38.2µg/l	8µg/l	None
Ethylbenzene[4]	<1.0µg/l	300µg/l	300ug/l[5]	None
Xylene[4]	<1.0µg/l	15.5µg/l	30ug/l[1]	None
Miscellaneous				
Cyanide[4]	<40µg/l	1µg/l	50µg/l (PCV)	None
Phenol[4]	<1.5 – 2.0µg/l	7.7µg/l	15.2µg/l (TV)	None
pH	6.9 – 9.0	-	6.5 – 9.5 (PCV)	None

Key to Table 12:
TV – Threshold Value, for general quality of groundwater body (from Schedule 5, Table 1, WFD, Directions 2015). TV for drinking water used where general quality TV was available.
EQS – Environmental Quality Standard (saltwater/other surface waters) - Annual Average (AA, from Part 2, Table 1 and Part 3, Table 1, WFD Directions, 2015).

Notes:
1. Priority substance. EQS taken from Part 3, Table 1, WFD Directions (2015).
2. Non-priority substance (i.e. not listed in Part 3, WFD Directions (2015).
3. Most stringent value. No monitoring for dissolved oxygen undertaken, however if detailed assessment is required, dissolved oxygen measurements should be taken to determine EQS value.
4. No EQS-AA for mercury. Value adopted is maximum allowable concentration (MAC).
5. World Health Organisation, Guidelines for Drinking Water. Fourth Edition. (WHO, 2011)
6. *Cadmium = lowest published EQS.
7. Test results presented in Appendix N2.
8. Caution should be applied when considering the results of QG, 2013 – LOD's for some compounds may differ.

No elevated levels of TPH, or PCB's were identified for the samples tested from Site B and all of the volatile and semi-volatile organic compounds tested for during the ESP investigation were below laboratory detection limits.

One marginally elevated level of chromium was identified in the ESP investigation (ESP, 2018) and elevated levels of arsenic, chromium, copper, lead and zinc have been identified in the sample from the previous Quantum Geotechnical investigation (QG, 2013).

Elevated levels of leachable PAH compounds against the EQS assessment criteria have been identified from three samples tested from the Made Ground (WSB, WSD and BH11), during the recent ESP investigation (ESP, 2018).

These criteria are considered to be extremely stringent and the levels identified do not necessarily pose a high risk to the groundwater beneath the site. See Section 7.2 for further discussion.

Table 13: Controlled Waters Risk Assessment – Groundwater Results

Compound	Range Recorded	TV (WFD 2015)	2015 EQS Value (WFD) *Saltwater*	Exceedances
Metals and Semi-metals:				
Arsenic[1]	2.4 – 3.3µg/l	7.5µg/l	25ug/l[1]	None
Boron[2]	<100 - 260µg/l	750µg/l	1000ug/l[1]	None
Cadmium[1,6,]	0.17 – 0.38µg/l	3.75µg/l	0.2 ug/l[1]	1 of 2 (EQS)
Chromium VI[2]	0.84 – 0.93µg/l	37.5µg/l	0.6 ug/l[1]	2 of 2 (EQS)
Copper[2,3]	3.8 – 6.4µg/l	1,500µg/l	3.76 ug/l [1,10]	2 of 2 (EQS)
Iron[2]	28 - 82µg/l	1,000µg/l	1000 ug/l[1]	None
Lead[1]	4.7 - 28µg/l	7.5µg/l	1.3 ug/l[1]	2 of 2 (EQS) 1 of 2 (TV)
Mercury[1,5]	<0.01µg/l	0.75µg/l	0.07 ug/l[2]	None
Nickel[1]	1.8 – 3.3µg/l	15µg/l	8.6 ug/l[1]	None
Zinc[2,4]	46 - 55µg/l	-	7.9 ug/l[1]	2 of 2 (EQS)
Polyaromatic Hydrocarbon Compounds				
Anthracene[1]	<0.01µg/l	-	0.1µg/l	None
Benzo[a]pyrene[1]	<0.01µg/l	0.075µg/l	0.00017µg/l	None
Fluoranthene[1]	<0.01µg/l	0.075µg/l	0.0063µg/l	None
Naphthalene[1]	<0.01µg/l	0.075µg/l	2.0µg/l	None
Miscellaneous				
Cyanide[4]	<40µg/l	1µg/l	50µg/l (PCV)	None
Phenol[4]	<1.5 – 2.0µg/l	7.7µg/l	15.2µg/l (TV)	None
Sulphate	52	-	250mg (PCV)	None
pH	6.9 – 9.0	-	6.5 – 9.5 (PCV)	None

Key to Table 12:
TV – Threshold Value, for general quality of groundwater body (from Schedule 5, Table 1, WFD, Directions 2015). TV for drinking water used where general quality TV was available.
EQS – Environmental Quality Standard (saltwater/other surface waters) - Annual Average (AA, from Part 2, Table 1 and Part 3, Table 1, WFD Directions, 2015).

Notes:
1. Priority substance. EQS taken from Part 3, Table 1, WFD Directions (2015).
2. Non-priority substance (i.e. not listed in Part 3, WFD Directions (2015).
3. Most stringent value. No monitoring for dissolved oxygen undertaken, however if detailed assessment is required, dissolved oxygen measurements should be taken to determine EQS value.
4. No EQS-AA for mercury. Value adopted is maximum allowable concentration (MAC).
5. World Health Organisation, Guidelines for Drinking Water. Fourth Edition. (WHO, 2011)
6. *Cadmium = lowest published EQS.
7. Test results presented in Appendix O.
8. Caution should be applied when considering the results of QG, 2013 – LOD's for some compounds may differ.

As shown in Table 13 above, five elevated levels of metal compounds have been identified when compared against the EQS (and one against the TV) assessment criteria from two groundwater samples tested during the recent ESP investigation (RC09). No elevated levels of PAH were identified. All of the volatile and semi-volatile organic compounds tested for during the ESP investigation were below laboratory detection limits.

The assessment criteria are considered to be extremely stringent and the levels identified do not necessarily pose a high risk to the groundwater beneath the site. See Section 7.2 for further discussion.

5.7 New Planting

Soil contamination can have a deleterious impact on the health of new plants. Such 'phytotoxic' effects can include inhibited growth, nutrient deficiencies and discolouration of vegetation. However, the potential impact on planting is difficult to quantify partly due to differing abilities of various plants to tolerate different soil conditions.

Contaminants are taken up by plants in a number of ways, the principal mechanism being via root uptake, but also including adsorption to roots. The impact on contaminants on plant growth depends on a number of factors, including the plant species, the soil type, the soil pH, the availability of the contaminant, and the impact of other external stresses on the plant such as drought.

The British Standard for the provision of Topsoil (BS3882:2007) provides guidance on acceptable levels of copper, nickel and zinc within a growing medium, which vary with soil pH value. ICRCL 70/90 (1990) discussing the restoration of metalliferous mining sites also provides 'threshold trigger levels' for a number of metals and fluoride, below which there should be no impact on plant growth. Finally MAFF (1998) provides assessment criteria for the assessment of the impact of a number of metals on the growth of plants. For the purposes of this assessment, we have adopted the BS3882 guidance values in the first instance, followed by the MAFF published guidelines, and finally the ICRCL 'trigger values'.

The assessment along with the assessment criteria adopted are presented in Table 25 below:

Table 14: Summary of Assessment Criteria for Planting

Determinand	Range Recorded	GAC	Source of GAC	Exceedances
Metals and Semi-metals				
Arsenic	6 - 35mg/kg	250mg/kg	MAFF[1]	None
Cadmium	0.1 – 3.1mg/kg	3mg/kg	ICRCL[2]	None
Chromium (total)[6]	6.9 - 36mg/kg	400mg/kg	MAFF[1]	None
Copper	9.3 – 160mg/kg	200mg/kg	BS3882[3]	None
Lead	15 - 530mg/kg	300mg/kg	MAFF[1]	None
Mercury	<0.05 – 0.61mg/kg	1mg/kg	MAFF[1]	None
Nickel	7.5 - 21mg/kg	110mg/kg (pH>7)	BS3882[3]	None
Zinc	32 - 350mg/kg	300mg/kg (pH>7)	BS3882[3]	1 of 9

Notes
1. MAFF: Ministry of Agriculture, Fisheries and Food guideline for maximum permissible concentrations in agricultural soils.
2. ICRCL: ICRCL 70/90.
3. BS3882:2007 – values dependent on soil pH values.
4. Laboratory test results presented in Appendix M3.

The testing has indicated levels of zinc in one sample to be present at a concentration which could be potentially phytotoxic to new planting. If any landscaping is proposed as part of the future development, this should be considered in designing the planting regime for the development.

5.8 Ground Gas

5.8.1 Degradation of Organic Materials

The likelihood and severity of a gassing event is considered as part of the risk assessment process in accordance with C665 (Wilson et al, 2007).

The gas wells have been installed and monitored for hazardous gases on 12no. occasions, equating to monitoring over a 6-month period and the monitoring regime is therefore complete. The monitoring results are presented in Appendix J and are summarised in Table 15 below:

Table 15: *Summary of Gas Monitoring Data (Visits 1 to 6)*

Well	Response Zone Depth[1] (m)	No visits	Methane (%)	Carbon dioxide (%)	Oxygen (%)	Gas Flow (L/hr)	Water depth (m)	Atmospheric pressure
RC09(s)	0.5 – 2.0	12	nd - 0.6	nd – 1.8	19.9 – 21.7	-0.6 – 1.1	Dry	999 - 1026
RC09(d)	6.0 – 12.9	12	nd - 0.6	nd - 0.4	20.7 – 21.8	-1.8 – 2.1	4.22 – 7.78	999 - 1026
BH10	0.5 – 4.5	12	nd – 0.3	nd – 2.0	16.4 – 21.7	0 – 1.4	4.10 – 4.39	999 - 1026
BH11	0.5 – 5.0	12	nd – 0.1	nd – 2.4	19.7 – 21.6	-3.9 – 1.3	4.51 – 4.80	999 - 1026

Notes:
1. nd – none detected with instrument (<0.2% for methane, <0.1% for carbon dioxide).
2. BH9(s) – shallow well. BH9(d) – deep well.

The monitoring to date has indicated levels of methane between below the detection limit and 0.6% and carbon dioxide levels between below detection and 2.4%. Oxygen was depleted where the levels of methane and carbon dioxide were elevated. Maximum gas flow rates of 2.1l/hr were recorded. Levels of volatile organic compounds were recorded as below detection.

The results of monitoring undertaken to date (six visits) have been used to calculate Gas Screening Values (GSV) appropriate for the site using the methodology published in CIRIA C665 (Wilson et al, 2007). The calculated GSV for the site are presented in Table 28:

Table 16*: Gas Screening Values (based on six visits)*

	Maximum Recorded Level (%)	Maximum Gas Flow Rate (L/hr)	GSV (L/hr)
Methane	0.6	2.1	0.0126
Carbon dioxide	2.4	2.1	0.0504

Notes:
1. GSV calculated using method derived in CIRIA 665 (2007).

On the basis of the above calculated GSV, we consider that the site would be classified as Characteristic Situation CS-1 for a commercial development (CIRIA C665:2007), however given the extent of the Made Ground and historical land uses at the site and in the neighbouring areas, we recommend that the site should be upgraded to CS2 to ensure the safety of the future development and the site end users. This is discussed further in Section 7.3.

5.8.2 Radon

As discussed in Section 2.11, the risk from radon is moderate and basic radon protection measures are required for development (see Section 7.3.2).

5.9 Sulphate Attack

The assessment of the concrete protection against sulphate attack has been undertaken in accordance with BRE SD1 (2005).

5.9.1 Classification of Site:

Due to the presence of Made Ground on the site, we consider that it should be considered as 'brownfield' in terms of concrete classification.

5.9.2 Groundwater Setting:

Groundwater was encountered in the installed wells at a minimum depth of 7.44m and a probable perched water body has also been identified at shallower depth, although this is not consistent across the site. These groundwater bodies are likely to be close to the depth to which buried concrete will be placed. Therefore, groundwater has been considered as mobile in this assessment.

5.9.3 Sulphate Levels:

Laboratory test results indicate the levels of water soluble sulphate (as SO_4) in the Made Ground and Blown Sands soils to be between 18mg/l and 81mg/l. As levels of water soluble sulphate are less than 3,000mg/l, there is no need to consider the levels of magnesium present in the soils. Levels of acid soluble sulphate varied between 0.04% and 0.13% and total sulphur between 0.02% and 0.18%. From these results, the calculated levels of total potential sulphate are between 0.06 and 0.54%, and oxidisable sulphides are between 0.02 and 0.41%. The level of oxidisable sulphides exceeds 0.3% in two samples of the Made Ground (WSC, 0.3m and WSD, 0.6m), therefore pyrite is likely to be present parts of the Made Ground soils at the site.

pH values in the Made Ground and Blown Sands varied between 7.8 and 10.9, indicating near neutral to alkaline soil conditions to exist. As the pH levels all exceed 5.5, there is no need to further assess the soils for the types of acids present (e.g. hydrochloric and nitric acids).

Analysis of one sample of groundwater collected from RC09, from within the Oxwich Head Limestone bedrock indicates a level of dissolved sulphate (as SO_4) of 52mg/l. pH values varied between 7.0 and 7.2, indicating near neutral water to be present.

5.9.4 Foundation Concrete Design:

Using the above results, we consider that the following characteristic values are applicable for the shallow soils at the site (all as SO_4):

Water soluble sulphate:	48.5mg/l;
Groundwater sulphate:	52mg/l;
Total potential sulphate:	0.44%
pH value:	7.9

6 Phase Two Geo-Environmental Risk Assessment

6.1 Discussion on Occurrence of Contamination and Distribution

The site history has indicated several potentially contaminative historical land uses (see Table 5), including railway land, railway sidings, railway station and a dock/dockland. The site is currently used as a car park and an electrical sub-station is present.

Investigation information (historic and current) has identified a general ground model comprising a covering of Made Ground followed by localised areas of superficial deposits (Blown Sand and occasional fine grained soils of possible glacial origin or weathered bedrock), overlying Oxwich Head Limestone bedrock. Deeper Made Ground has been identified to a depth of around 4.5m below ground level in the east of the site, which includes the area of the former railway station. No obvious visual or olfactory evidence of significant contamination was identified across the site.

Laboratory chemical testing of the Made Ground soils from across the site has identified generally low levels of soil contaminants with regards to the GAC's for a commercial end use. A qualitative analysis has identified chrysotile asbestos present as bundles of fibres in the general Made Ground in the area of the former station (north west) in BH11 at 0.5m depth. Further quantitative testing has been undertaken and identified that the levels of this asbestos is <0.001%. No asbestos was identified in the remainder of the samples tested.

The existing buildings on-site may contain ACMs and further consideration is required pre-demolition (see Section 7.1.1.).

Leachate testing has identified elevated levels of leachable PAH compounds from three samples tested from the Made Ground (WSB, WSD and BH11) across the site. The criteria used are considered to be extremely stringent and the levels identified do not necessarily pose a high risk to the groundwater beneath the site. One marginally elevated level of chromium was identified in the ESP investigation (ESP, 2018) and elevated levels of arsenic, chromium, copper, lead and zinc have been identified in the sample from the previous Quantum Geotechnical investigation (QG, 2013). No elevated levels of TPH, or PCB's were identified for the samples tested from Site B and all of the volatile and semi-volatile organic compounds tested for during the ESP investigation were below laboratory detection limits.

Groundwater testing from BH09 (ESP, 2018) has identified marginally elevated levels of leachable metal compounds against the EQS (and one against the TV) from two samples tested from the groundwater within the Oxwich Head Limestone bedrock strata. No elevated levels of PAH from leachates were identified. Given the absence of sources and the low levels of VOC's and SVOC's recorded in the soils and leachates, testing for these within the groundwater was not undertaken. See Section 7.2 for further discussion.

6.2 Revised Risk Evaluation & Relevant Pollutant Linkages

As discussed in detail within Section 3.2.1, the methodology set out in CIRIA C552 (2001) has been used to assess whether or not risks are acceptable, and to determine the need for collating further information or remedial action. The risks evaluated at the desk study stage of this report (Table 6, Section 3.2.2) have been updated and revised in Table 17 following information learned from the exploratory works and results of monitoring and laboratory testing.

Table 17: *Revised Risk Evaluation & Relevant Pollutant Linkages (RPL)*

Source	Pathway	Receptor	Classification of Consequence	Classification of Probability	Risk Category	Further Investigation or Remedial Action to be Taken
Potential contaminants in shallow soils (General Made Ground from former dock land and railway land)	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Site Users (employees)	Medium – potential for chronic levels.	Unlikely[2]	Low Risk	See Section 7.1.2.
	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Construction/ Maintenance Workers	Minor – standard PPE likely to be sufficient	Likely[3]	Low Risk	See Section 7.1.4.
	Leaching of soil contaminants	Impact on Groundwater /Potable Water	Severe - site lies on Principal & Secondary A Aquifers	Low Likelihood[2]	**Moderate Risk**	See Section 7.2.
	Leaching of soil contaminants	Impact on Sandy Bay/Harbour	Medium – site lies 130m from Sandy Bay (in continuity with groundwater)	Low Likelihood[2]	Moderate/Low Risk	
Asbestos in derelict building in north west	Ingestion of fibres	Demolition Workers/ Ground Workers	Medium – potential for chronic levels	Likely[4]	**Moderate Risk**	See Section 7.1.1.
Asbestos in shallow soils	Ingestion of fibres	Construction/ Maintenance Workers	Medium – potential for chronic levels	Likely[4]	**Moderate Risk**	
Soil sulphate and pyrite	Aggressive groundwater	Buried Concrete	Mild – damage to structures	Likely[5]	**Moderate Risk**	See Section 7.4.2.
Hazardous ground gas/vapours	Asphyxiation/poisoning. Injury due to explosion.	Site Users/Visitors.	Severe – acute risk.	Low likelihood[6]	Moderate/Low Risk	See Section 7.3.1 & 7.3.3.
	Damage through explosion.	Building/Property	Severe – acute risk.		Moderate/Low Risk	
	Asphyxiation/poisoning. Injury due to explosion.	Construction and Maintenance Workers.	Severe – acute risk.		Moderate/Low Risk	
Radon gas	Migration into Buildings	Site Users (employees)	Medium – potential for chronic levels	Low likelihood[7]	Moderate/Low Risk	See Section 7.3.2.

Notes:

1. Methodology and details of risk consequence, probability and category based on CIRIA C552 (2001) and presented in Section 3.2.1.
2. Laboratory chemical testing of the Made Ground soils from across the site has identified generally low levels of soil contaminants with regards to the GAC's for a commercial end use. Considering the proposed development as a hotel and commercial leisure facility (restaurant/café), we assume that the majority of the site surface will be occupied by hardstanding and therefore exposure risks to end users will be further mitigated and the leaching potential will be reduced. See Section 7.1.2.
3. Due to the presence of contaminants within the Made Ground soils across the site (including asbestos – see Section 7.1.1), in accordance with best practice, we recommend prevention of exposure to the soils to mitigate any potential health risks. See Section 7.1.1 and 7.1.4.
4. A qualitative analysis has identified chrysotile asbestos present as bundles of fibres in the general Made Ground in the area of the former station (north west) in BH11 at 0.5m depth. Further quantitative testing has been undertaken and identified that the levels of this asbestos is <0.001%. See Section 7.1.1.
5. Elevated levels of total potential sulphates recorded therefore increased concrete classification likely to be required. See Section 7.4.2.
6. On the basis of the calculated GSV, we consider that the site would be classified as Characteristic Situation CS-1 for a commercial development (CIRIA C665:2007), however given the extent of the Made Ground and historical land uses at the site, we recommend that the site should be upgraded to CS2 to ensure the safety of the future development and the site end users. This is discussed further in Section 7.3.
7. The risk from radon is moderate and basic radon protection measures are required for development.
8. The above risk evaluation is updated following the intrusive investigation and testing in Table 7, Section 3.2.2.

7 Remedial Strategy for Contamination Risks

The objective of the investigation was to obtain sufficient information to allow an initial assessment of the ground conditions and potential geo-environmental risks and constraints on the proposed hotel and commercial leisure (restaurant/café) development. Once detailed development proposals are known and regulatory/planning conditions have been prescribed, some additional investigation and assessment may be required to further assess the risks preliminary assessed in the following section.

The following recommendations are based on interpretations made from the relatively limited site investigation data obtained to-date, and do not form the full Options Appraisal stage of CLR11. If at any stage of the construction works, contamination or a potential for such contamination is identified that is different to that presented within this report, all of the following should be reviewed and the advice of a geo-environmental specialist sought immediately.

7.1 Risks to Health

7.1.1 Asbestos

As indicated in Section 5.5.4, a qualitative analysis has identified chrysotile asbestos present as bundles of fibres in the general Made Ground in the north east of the site in the area of the former railway station (BH11, 0.5m). Further quantitative testing has been undertaken and identified that the levels of this asbestos is <0.001%. Previous testing off-site, has also identified asbestos within the general Made Ground soils.

The remnants of a disused building in poor repair is located in the north west portion of the site. This may contain asbestos containing materials and an asbestos specialist should be contacted to survey the building pre-demolition.

There is no clear UK guidance on what would constitute an acceptable concentration of asbestos in soil. Working with asbestos (even within soils) is governed by the Control of Asbestos Regulations (2012). This requires that the excavation and removal of the asbestos contaminated soils musty be undertaken by a licensed contractor. One mitigating option could be to remove all asbestos contaminated soils from site prior to development, however given there is a covering of Made Ground across the whole site and widespread asbestos has not been identified, this would unlikely be suitable or practical.

To provide an initial analysis of the potential risk from asbestos, we have undertaken a preliminary risk assessment in line with the Joint Industry Working Group (JIWG) 'Decision Support Tools for the Qualitative Risk Ranking of Work Activities and Receptors Involved in or Exposed to Asbestos in Soil or Construction & Demolition Materials'. This tool is designed to provide a consistent decision making format to further assess the potential risk from asbestos. Based on the currently available information, a generally low risk is anticipated for the site end users, however the risk to the groundworkers during construction is likely to be at a low to medium level (based on a commercial development).

Considering the proposed development as a hotel and commercial leisure facilities, we assume that the majority of the site surface will be occupied by hardstanding and therefore exposure risks to end users will be mitigated across the majority of the site. Once the development proposal are known, we recommend some additional testing for asbestos is undertaken in proposed landscaped areas to confirm the risk where there is an exposure potential.

Additional testing could also be undertaken to further assess risks to construction workers or alternatively suitable mitigation measures and PPE could be used as a precautionary measure in accordance with current health and safety requirements.

We recommend that an asbestos specialist should be employed to undertake further assessment of the risk posed by asbestos present in the soils to construction and maintenance workers and the general public prior to any development. Input may also be required for human health risks dependent on the results of the additional testing in landscaped areas.

The following sections presume that any risks from asbestos materials at the site are mitigated.

7.1.2 Site End Users

Laboratory chemical testing of the Made Ground soils from across the site has identified generally low levels of soil contaminants with regards to the GAC's for a commercial end use. Considering the proposed development as a food store, we assume that the majority of the site surface will be occupied by hardstanding and therefore exposure risks to end users will be further mitigated.

Assuming an end use as a hotel and leisure facilities (commercial) development, the identified levels of soil contamination at the site as part of this initial assessment are not considered to pose a significant risk to future site users.

Wide scale remedial measures are not considered necessary, however considering the past significant industrial history there is a potential for un-identified contamination across the site. This includes the area of the existing sub-station which may be moved as part of future development. Upon its removal, we recommend further testing beneath its footprint (including PCBs) to confirm the absence of any contamination that may warrant further consideration.

Once the development proposal are known, we recommend additional testing is undertaken in proposed landscaped areas to confirm the low risk initially identified.

7.1.3 New Service Connections

The current water industry guidance for the suitability of pipe materials on potentially contaminated sites (Blackmore et al, 2010) has onerous requirements and it is likely/possible, based on this guidance, that the levels of contaminants on site may prevent the use of plastic pipework. We recommend that enquiries are made to the local water authority to confirm their requirements for underground service materials for this development.

7.1.4 Risk to Construction and Maintenance Workers

Short term (acute) risks to construction and maintenance workers are generally poorly understood within the industry, certainly when compared to the volume of research undertaken on long term risks.

The recommendations contained within the Health and Safety Executive Document: *Protection of Workers and the General Public During the Development of Contaminated Land* (HSE, 1991) should be considered and applied where appropriate. Notwithstanding the above, we recommend that construction workers adopt careful handling of the potential contaminants and good standards of personal hygiene should be adopted to reduce the risk of possible ingestion and skin contact should any hotspots be encountered. The contractor should comply with the appropriate current Health and Safety at work legislation.

Due to the presence of contaminants within the Made Ground soils across the site (including asbestos – see Section 7.1.1), in accordance with best practice, we recommend prevention of exposure to the soils to mitigate any potential health risks. This will comprise, as a minimum, the use of overalls, boots, gloves etc. to prevent dermal exposure and washing facilities to prevent ingestion (i.e. at lunch-times). These controls must be strictly implemented at this site and should be reviewed throughout the works during excavations and earthworks etc. (see Section 7.1.5)

The above precautions would be required for both construction workers during development and maintenance workers following development. A copy of this report and these recommendations should be included in the Health and Safety File for the development and provided to all future ground workers, including utility companies so that they may undertake their own assessment of risks to their operatives.

7.1.5 General Public/Neighbouring Properties

The site lies adjacent to a busy pedestrian thoroughfare, restaurant and main road (The Portway), which are often very busy, especially during the summer months. Visitors to the beach and the surrounding areas (especially children) would be particularly sensitive to any dust created during development. We recommend strict dust control measures during development in the drier summer months where required, and particular care would be required when excavating any Made Ground soils (where localised asbestos has been identified – see Section 7.1.1).

7.2 Risks to Controlled Waters

Investigation information (historic and current) has identified a general ground model comprising a covering of Made Ground followed by localised areas of superficial deposits (Blown Sand and occasional fine grained soils of possible glacial origin or weathered bedrock), overlying Oxwich Head Limestone bedrock, which is classed as Principal Aquifer.

We consider that the bedrock groundwater body is likely in in hydraulic continuity with the waters in Sandy Bay and the quality of the aquifer has been naturally degraded by the intrusion of saline waters and the historical land use and therefore they are unlikely to be as sensitive as their designation suggests. Saline intrusion is the likely reason that no groundwater abstractions or SPZ's are noted within 1km of the site as the groundwater is not suitable as a potable supply.

Historical industry, including railway land, railway sidings, railway station and a dock/dockland will have also degraded the overall quality of the soils and groundwater beneath site over time.

No significant or olfactory evidence of contamination was identified during the investigation.

Significantly elevated total soil concentrations of metals have not been recorded, with low levels of PAHs and generally non-detectable levels of TPH, SVOC and VOC contamination. Current and historical leachate testing has recorded slightly elevated levels of some metals and PAHs above the stringent current guidelines, with all others below the acceptance criteria. Groundwater testing has identified marginally elevated levels of metal compounds against the EQS (and one against the TV). No elevated levels of PAH from leachates were identified.

Current levels from further testing across the Site A area within Salt Lake car park indicate levels of contamination are consistent across the site and no significant levels have been identified.

Considering the proposed development as a hotel and leisure facilities (commercial), we assume that the majority of the site surface will be occupied by hardstanding and therefore further leaching from the shallow soils will be reduced.

Given the results of this Level 2 assessment, we consider that the overall risk to controlled waters from the development of the site is likely to be low. Discussion with NRW will be required to confirm their opinion on the sensitivity of the aquifers to confirm the risk. If considered lower than classified due to saline intrusion, it is possible that limited further testing and assessment may be required.

We cannot discount that as part of future planning submissions, additional testing and assessment may be requested in accordance with specific local authority and NRW requirements which are currently unknown. This could include a Level 3 controlled waters risk assessment.

Some risk mitigation is likely to be required if soakaways are used to dispose of surface water run-off.

If a piled foundation is the chosen option for the proposed development a standalone risk assessment may be requested by the regulatory authorities to demonstrate that the foundation construction will not create additional contamination pathways that could detriment underlying aquifers. Considering the conceptual model (see Figure 6), we consider that the shallow and deep aquifers are in hydraulic continuity generally across the site and within the infilled dock area, therefore there the risk of additional contaminant loading as a result of piling is likely to be low.

7.3 Risks from Ground Gas

7.3.1 Risk to the Development – Degradation of Organic Material

As discussed in Section 5.8.1, the gas wells have been installed and monitored for hazardous gases on 12no. occasions, which equates to monitoring over a 6-month period and the monitoring is complete. The monitoring undertaken is in accordance with current guidance based on the potential risk and source potential. The monitoring results are presented in Appendix J.

The levels of hazardous gas measured to date ranged between:

- methane: below detection to 0.6%;
- carbon dioxide: below detection to 2.4%; and
- Maximum gas flow rate of 2.1L/hr.

The monitoring has attempted to capture worst case conditions and has been undertaken at varying tidal states and varying atmospheric pressures in an attempt to capture a range of varied conditions, as well as the worst case scenario (i.e. rising tide, falling pressure).

Based on the monitoring undertaken to date, we consider that the site would be classified as Characteristic Situation CS-1 for a commercial development (CIRIA C665:2007), however given the extent of the Made Ground and historical land uses on and off-site, we recommend that the site should be upgraded to CS2 to ensure the safety of the future development and the site end users.

The requirements for gas protection have been assessed in accordance with BS8485:2015, which considers gas protection in terms of a ranking ‘score’ for various types of property.

Considering the proposed development as a hotel and commercial leisure facilities and anticipated to have a degree of central building management control of the use and maintenance of the building. We consider this to be classified as a Type B building of BS8485:2015.

Based on Characteristic Situation CS-2, and a Type B Building, (Table 3 of BS 8485+A1:2019), which requires a minimum gas protection score of 3.5 (Table 4 of BS 8485+A1:2019). To achieve the minimum gas protection score of '3.5' a combination of two or more of the following three types of protection measures should be used:

1. Structural barrier i.e. floor slab or basement slab and wall if present;
2. Ventilation measures; and
3. Gas resistant membrane.

In accordance with Tables 5, 6 and 7 of BS8485+A1:2019, there are several variations of protective measures which could be used to achieve the score required. One possible combination would be to use the following protection measures to achieve the required 3.5 points and would be dependent on proposed construction and foundation type:

1. Cast in situ monolithic well reinforced suspended floor slab with minimal penetrations (1.0 point or 1.5 point - conservative, as no option for precast slab);
2. Good performance passive subfloor dispersal layer in accordance with Annex B (1.5 points) with the criteria for void formers presented in Table 6 adhered to.
3. Taped and sealed membrane gas resistant membrane meeting all criteria outlined in Table 7 of BS8485:2019 (2 points).

If the design cannot incorporate the reinforcement required or the level of membrane installation required, then alternative protection measures such as vented void spaces will be required.

We are not aware of any proposed basements as part of the development works. However, if basements are proposed, it will be necessary to suitably incorporate the recommended ground gas protection measures into the basement construction.

Further advice can be provided by this office once the design of the buildings has been finalised.

7.3.2 Risk to the Development – Radon

The risk from radon is moderate and basic radon protection measures are required for development.

7.3.3 Risk to Construction and Maintenance Workers

Carbon dioxide is a particular risk in Made Ground materials as it is commonly present and as it is heavier than air, it can displace it at the base of excavations, which can then lead to workers being at risk from asphyxiation. The presence of elevated levels of methane, carbon dioxide and depleted oxygen in the Made Ground could pose a risk to construction workers, and lead to asphyxiation in confined spaces. All excavations should be treated as confined spaces and suitable precautions taken prior to man entry.

If during construction any organic materials are encountered, they should be excavated and replaced.

7.4 Risks to Property

7.4.1 Spontaneous Combustion

No evidence of combustible materials has been identified in the shallow soils. Therefore, the risk from spontaneous combustion is considered to be low.

7.4.2 Sulphate Attack on Buried Concrete

Shallow and deep foundations will likely come into contact with both the Made Ground and underlying natural soils/rock in different areas across the site. This assessment has considered the potential risk to buried concrete from all strata.

From Section 5.9.4, the following characteristic values are applicable for the shallow soils at the site (all as SO_4):

Water soluble sulphate:	48.5mg/l;
Groundwater sulphate:	52mg/l;
Total potential sulphate:	0.44%
pH value:	7.9

Based on these characteristic values, we consider that the site would be classified as Design Sulphate Class DS-2 and Aggressive Chemical Environment for Concrete Class AC-2, allowing for mobile groundwater.

7.5 Risks to New Planting

As discussed in Section 5.7, the testing has indicated a level of zinc to be present at a concentration which could be potentially phytotoxic to new planting. If any landscaping is proposed as part of the future development, this should be considered in designing the planting regime for the development.

7.6 Re-Use of Materials/Disposal of Excess Arisings

7.6.1 General Comments on Re-use/Disposal

All soils or other materials excavated from any site are generally classified as waste under the Waste Framework Directive (European Union, 2008) and their re-use is controlled by this legislation.

If the soils are to be re-used on site (e.g. within the red-line planning boundary), provided that they are 'uncontaminated' or other naturally occurring deposits and they are certain to be used for the purposes of construction in their natural state on the site from which they are excavated, they may be excluded from waste regulation (Duckworth, 2011). A Materials Management Plan (MMP) may be required – further guidance can be provided by this office once proposals have been finalised. However, if they are man-made or contaminated materials, their use on the site may be limited.

If the soils are to be removed from site, they are automatically classified as waste, and they may only be:

- Disposed at a licensed landfill;
- Disposed at a licensed, permitted soil treatment centre; or

- Removed to a Receiver Site for beneficial re-use.

In Scenarios 1 and 2, the materials must be transferred by a licensed waste carrier and the waste producer (the developer) must ensure that the destination landfill or treatment centre is a legitimate operation (e.g. by requesting a copy of the Environmental Permit before releasing the soils).

Prior to removal from site, the excavated arisings would need to be classified as either 'hazardous' or 'non-hazardous' waste based on the hazard that they pose– a WM3 assessment (note that this is a different assessment to the risk assessments reported on in earlier sections of this report). This can commonly be undertaken on the results of soils testing undertaken during the investigation, although further sampling and testing may be required. A preliminary WM3 assessment is presented in the following section (Section 7.6.2).

Only once the soils have been classified under the WM3 assessment, would Waste Acceptability Criteria (WAC) testing then be required to determine the type of landfill in which the arisings could be disposed in Scenario 1. Further testing and assessment may also be required by the soil treatment centre in Scenario 2.

In Scenario 3, management of soils could be undertaken via an Environmental Permit or Exemption. However, these can take time and are costly to arrange. Therefore, in certain circumstances, it is permissible to use the protocols laid down in the CL:AIRE Definition of Waste, Development Industry Code of Practice (DoWCoP, Duckworth, 2011) to classify the arisings and put a management plan in place to control the use. This involves approval of the proposals by a Qualified Person and is generally more efficient (in terms of time and cost) to implement.

For information, a material re-use flowchart in included as Appendix T of this report. Further guidance on the legislative requirements of the re-use/disposal of materials generated by the development can be provided by this office once the development proposals have been finalised.

7.6.2 WM3 Assessment

An initial WM3 assessment has been undertaken on samples of shallow Made Ground soils across the site and is presented in Appendix P. To determine the hazardous nature of waste soils, the current legislation requires that they are classified under the European Waste Catalogue 2000/532/EC (EWC), part of the Waste Framework Directive 2008/98/EC (WFD). The EWC contains 846, six-digit waste codes arranged in twenty chapters, where each chapter is based on a generic industry or process that generated the waste or upon the type of waste. The EWC is based on a hazard assessment, rather than an assessment of risk, i.e. a different approach to when evaluating the impact on human health or controlled waters.

The EWC differentiates between hazardous and non-hazardous by identifying hazardous waste entries with an asterisk.

Soils excavated from development sites would normally be classified as one of two 'mirror' entries:

- 17-05-03*: soil and stones containing dangerous substances - hazardous waste (note the asterisk).
- 17-05-04: soils and stones other than those mentioned in 17 05 03 - non-hazardous waste.

The class into which soils fall depends on the levels of contaminants, and the likely form of the compound present. The available test data has been assessed for Made Ground and and the output from the WM3 model is summarised in Table 18 below and presented Enclosure P.

Table 18: Summary of WM3 Assessment

Soils	Waste Classification	EWC Code
Made Ground (ESP, 2018)	Non-Hazardous Waste	17 05 04
Made Ground (DS, 2011 & QG, 2013)	Hazardous Waste	17 05 03

As shown above and in Appendix P, samples from the resent ESP investigation (ESP, 2018) indicate that the Made Ground soils are non-hazardous waste. One sample of the Made Ground (WS01A, 0.5m) from the previous Delta Simmons investigation (DS, 2011) and one sample from the previous Quantum Geotechnical investigation (TP1, 0.4m) indicate the Made Ground to be classified as hazardous waste. No analysis has been undertaken on the shallow natural Wind Blown Sands, however these are likely to be classed as 'non-hazardous' waste.

Further testing may be warranted once arisings have been generated to confirm their classification and refine disposal options/costs.

7.6.3 Imported Materials

Any soils or materials to be imported to site (including Topsoil) should be certified clean and inert, and suitable for use. An appropriate number of samples (depending on the volume of soils imported) should be analysed for an appropriate suite of contaminants, and verification certificates should be provided. Further guidance can be provided by this office if required.

8 Geotechnical Comments

The objective of the investigation was to obtain sufficient information on the geotechnical character and properties of the ground beneath the site to allow an initial assessment of the ground conditions with particular reference to the potential impact and constraints on the proposed developments.

The development layout and design has yet to be finalised and therefore once known some addition work to inform detailed design cannot be discounted.

8.1 Site Preparation and Earthworks

8.1.1 Invasive Plants

No evidence of invasive plants such as Japanese Knotweed or Himalayan Balsam was identified on the site during the site works. Notwithstanding this, the works were undertaken during the winter months and invasive species may not have been visible. A survey across the site should be undertaken during the summer months to check for any invasive species.

8.1.2 Existing Underground Structures and Services

As detailed in Section 2.2, the site is shown to be within the area of former railway land associated with the adjacent infilled dock, with lines trending north to south across the site. The north east portion was also occupied by a railway station. All of the infrastructure associated with the former railway land (tracks, station etc), were shown to have been demolished/removed by the late 1960's, associated with the closure of the dock a few years previously.

It is likely that some underground structures and/or obstructions associated with the above may remain, especially in the area of the former station. No significant obstructions were identified during the current investigation; however, timber was identified in BH09 (in the area of a former railway line) and crushed bricks and stone were identified in BH11 (in the area of the former station), which may be associated with their former uses. Investigation points constructed previously were terminated due to shallow obstructions.

Site observations and the available plans indicate the following services to be present at the site:

- Underground rising foul sewer main, trending west to east across the north area of the site. The main extends east beneath Dock Street and follows a straight line across Site B, before extending north to the east of The Portway;
- Underground BT cables, which enter the site in the north west and terminate just inside the access road from Dock Street; and
- An electrical substation is located in the north west area of the site, with all cables trending west away from the site.
- No gas pipes are indicated on site, but are noted to be present beneath Dock street adjacent to the site to the west.

8.1.3 New Services

For new services, flexible pipework and connections should be provided as a safeguard against potential settlements. Consideration could be given to increasing the gradients on sewage connections to mitigate against possible settlements.

8.1.4 Earthworks

We have not been advised that the development requires any significant earthworks. The site is relatively flat and, therefore, no such earthworks are anticipated. If any significant changes in ground level are proposed, further geotechnical advice should be sought from this office.

A review of the risks to construction workers with regards to contamination (including the potential for asbestos in the soils) should be undertaken for any earthworks (see Section 7.1.4).

In line with the published Manual of Contract Documents For Highway Works, Volume 1 Specification For Highway Works Series 600 Earthworks document, preliminary testing of the general Made Ground soils (based on two samples only) indicate that the Made Ground would be classified (in terms of material re-use) as either general granular (Class 1) or cohesive fill (Class 2). The soils may also conform to some selected fill categories, however as the material is Made Ground and highly variable, further testing of the soil mass would be required if detailed categorising of the soils is required.

Testing of the Wind Blown Sand from previous investigations off-site, indicate it would be generally be classed as General Granular Fill.

It should be noted that this is an initial assessment only and further sampling will be required to formally assess material reuse.

8.2 Geotechnical Risk Register

The desk study (Section 2) identified the following potential geotechnical hazards at the site:

- Shrinkable and swelling soils;
- Ground Dissolution;
- Compressible Ground;
- Running Sand;
- Volumetrically Unstable Slag Materials;
- Pyritic Ground (include in all reports);
- Historic Underground Structures/Obstructions;

This has been updated in Table 18 with additional information on these and other potential geotechnical/construction risks identified by the intrusive investigation.

Table 18: Updated Geotechnical Risk Register

Hazard	Risk	Comments
Shrinking or Swelling soils	Negligible	See Section 8.2.1
Ground Dissolution (Soluble Rocks)	Low	See Section 8.2.2
Compressible Ground/ Settlement of Foundations	Moderate	See Section 8.2.3
Running Sand	High	See Section 8.2.4
Volumetrically Unstable Slag	Not reported.	See Section 8.2.5
Sulphate Attack	High	See Section 7.4.2
Underground Structures	Not reported.	See Section 8.2.6

Notes
1. This table updates Table 6 in Section 2.9.1 using the results of the intrusive investigation.
2. Further discussion is presented in the following sections.

8.2.1 Shrinking or Swelling Clays

With the exception of a thin localised layer in one previous investigation point, no significant shallow fine-grained soils have been encountered. Coarse grained soils are not susceptible to changes in moisture content therefore no further consideration is warranted at this stage.

If fine grained soils are encountered as part of any future investigation this may require re-consideration by a geotechnical engineer.

8.2.2 Ground Dissolution (Limestone Solution)

As discussed in Section 2.10.4, the site lies in an area susceptible to limestone solution, however no evidence has been identified by the desk study or during previous or current investigation of solution features on the site.

The bedrock is located at depths of approximately 2 - 5m across the site and generally becomes deeper to the west. D

We cannot discount that solution features exist beneath the site, particularly due to its coastal location. Dependent on the development design, evidence of potential features could be encountered during the construction works where shallow excavations encounter bedrock.

Solution features may affect foundations due to variations in rockhead depth or the possible presence of natural cavities. Further investigation which may include geophysical surveying could be considered by the purchaser to reduce the uncertainty of potential risks from un-recorded solution features beneath the site.

If any anomalous conditions are encountered, they should be subject to further investigation by an experienced geological engineer.

8.2.3 Compressible Ground

The Made Ground across the site comprises a generally coarse-grained stratum of sand, gravel and cobbles. The general Made Ground was visually estimated to be loose to medium dense.

Field SPT N-values within the coarse infilled dock Made Ground varied between 4 and 41, with an average of 15, indicating the Made Ground to be in a generally medium dense state, although it is highly variable (very loose to medium dense).

Generally limited Blown Sand deposits were identified across most of the site, with the only notable thickness identified in the north of the site (WSA and WS02), where the superficial deposits were proven to a depth between 2.8m and 5.0m below surface level. Field SPT N-values within the Blown Sands were only obtained from WSA at depths of 3m and 4m, with both results identifying an N-Value of 4. This indicates a generally very loose to loose state.

The proposed hotel development will be underlain by varying thicknesses of Made Ground and Blown Sands. As a result differential settlement is likely if a shallow foundation solution was intended to be used. A deeper piled solution is likely to be the favoured foundation option to avoid potential structural effects. The competent Oxwich Head Limestone bedrock is likely to be of low compressibility and therefore the likely founding strata for a piled foundation solution.

The potential risk from compressible soils should be further assessed following finalisation of the proposed development layout and design. Consideration of compressible ground with regards to foundation design is presented in Section 8.3.

8.2.4 Running Sand

Generally limited Blown Sand deposits were identified across most of the site, with the only notable thickness identified in the north the site. Based on our understanding of the proposed development, no significant groundwater ingress is anticipated above 5m depth. However, the presence of perched water bodies cannot be discounted.

No large excavations (e.g. trial pits) have been undertaken within the north portion where Blown Sands are present to assess the potential occurrence of running sands and the temporary stability of any excavation.

Where groundwater ingress occurs within the Blown Sand deposits, the potential for running sands is considered high. The design of all excavations or bored foundation solutions (drainage, foundations etc) should consider this hazard where Blown Sand deposits are present. Tidal influence on groundwater levels is not considered to be significant.

8.2.5 Volumetrically Unstable Slag

The general Made Ground was noted to contain minor constituents of slag gravels across the site, however the overall content is not considered to be of significant risk. If any areas of high quantities of slag gravels are identified during the works, they should be removed and replaced with clean inert fill.

8.2.6 Underground Structures/Obstructions

It is likely that some underground structures and/or obstructions associated with the historical rail infrastructure remains, especially in the area of the former station.

A rising main is present trending west to east across the approximate centre of the site (see Figures 3 and 5) and we understand that this will remain in its current location.

Obstructions/structures will require consideration as part of the development design (in particular foundations), and where shallow, they may require removal (possibly with large excavators), diversion or protection as part of the site preparation works.

8.3 Foundation Design and Construction

At this time, we understand that the development will likely be large multi storey hotel structure with additional commercial leisure facilities (such as a restaurant or café), with associated variably sized structures and areas of hardstanding.

The following recommendations assume that any foundation solution would likely be located in the bedrock, however due to its varying depth across the site (see Figure 6) both shallow and deeper foundations could be utilised to achieve this. It is possible that a combination of the two foundations solutions may be utilised for large buildings which span the entire site.

The choice of optimum foundations for the main new structure (hotel) will depend on the nature of the structure, layout, foundation loads, and its tolerance to ground movements. The selected foundation design will need to consider/protect the continued presence of the rising main beneath the approximate centre of the site (see Figure 5).

The following is preliminary only to provide an initial indication of potential foundation solutions. It should be reviewed by a geotechnical engineer following finalisation of the development design and any future investigation.

8.3.1 Shallow Bedrock

For buildings located in the west portion of the site where the bedrock is shallower, traditional strip foundations may be suitable located in the competent Oxwich Head Limestone bedrock. However, the bedrock depth does varies across the site and therefore their feasibility and cost effectiveness (which will be dependent on their depth) would need to be confirmed once the building location is known.

For small lightly loaded minor structures located in areas where bedrock is at greater depth (e.g. east portion), spread foundations or raft foundations could be a potential option, constructed within the Made Ground, following ground improvement. Should any such structures be included in the proposed development, this office can assist in the design of suitable foundations.

As discussed in Section 8.2.2, the site lies in an area susceptible to limestone solution. Therefore, following excavation, the formation should be very carefully inspected and any anomalous feature investigated further.

8.3.2 Deeper Bedrock

In areas where bedrock is at greater depth and compressible and variable strength soils are present at shallow depth (see Section 8.2.3), the likely high loads for the proposed development could lead to significant and unacceptable settlements for significant structures constructed on shallow footings of any form. Therefore, we consider that piled foundations are likely to be required for the anticipated high structural loadings.

We consider that the piled foundations should be taken down to the competent Oxwich Head Limestone bedrock at depths of between approximately 2m and 5m below ground level (rock head is variable across the site). The following criteria should be considered for pile design:

- The magnitude and resulting effect of different structural loadings, including any machine vibration effects (e.g. liquefaction within saturated sands);
- Possible impacts on neighbouring structures and underground services;
- Pile/soil/structure interaction effects;
- The potential presence of obstructions (see Section 8.2.6) and the potential for buckling.

The final safe working load on the pile will be dependent on the pile type, diameter and length of the piles, the penetration into the bearing stratum, and the settlement tolerances required.

Based on the available information, and given the site constraints, it is likely that the most appropriate system is likely to be a driven, displacement pile system, which may prove most efficient for the particular ground conditions, particularly as the quantity of arisings will be limited. The use of driven piles should only be considered if vibrations and environmental constraints can be maintained within acceptable limits, with regard to the proximity of existing buildings and services.

Alternatively, a non-displacement vibration-less technique such as bored piles or continuous flight auger piles, however, this technique will generate arisings at the surface which will need to be re-used or disposed of under a materials management plan. Running sands within the Blown Sand deposits when groundwater is encountered may also create difficulties with this technique.

Discussions should be held with specialist piling contractors to obtain specific piling proposals based on their particular proprietary system and to evaluate costs. The piling contractor should be asked to provide a performance specification and in particular the magnitude of total and differential settlements which could be guaranteed. Test loading will be required on a proportion of the piles to confirm that they are adequate to carry the design working loads, and the contractor should monitor closely the pile installations to satisfy himself that the ground conditions encountered are as good as, or better than, those assumed in his design. Care should be taken to ensure that piles are not stopped short on obstructions and that all are taken down to bedrock. Consideration should also be given to the variable depths to rock head across the site.

If required, further guidance on design criteria can be given by this office when structural loadings, design, layout and cost implications have been finalised.

8.4 Floor Slab Foundations

Due to over 600mm of Made Ground across the site and given the likely size of the floor areas and internal loadings associated with the proposed hotel and commercial leisure facilities, we consider that ground bearing floor slabs would not be feasible without treatment of the ground prior to construction, for example through excavation and replacement. Shrinkage and swelling will not require consideration unless fine grained soils are encountered.

Alternatively, the floor slab could be incorporated into a piled foundation design if this is the preferred option. Further advice can be provided by this office once the floor slab designs have been finalised.

8.5 Retaining Wall Design

We are not aware of any retaining structures being required in the development.

8.6 Pavement Design

We understand that vehicle access roads and areas of hardstanding are proposed at the site.

8.6.1 Design CBR Value

California Bearing Ratio (CBR) tests have not been carried out at the site, but based on experience and published guidelines, a CBR value of <2.5% is considered appropriate for preliminary design purposes, for the near surface Made Ground. Considering their coarse grained nature, improvement works could be undertaken on the Made Ground to improve design values.

Actual design values should be determined for designated areas as required.

8.6.2 Susceptibility to Frost Action

The near surface coarse grained soils are considered to be non-frost susceptible.

8.7 Excavation and Dewatering

It is anticipated that excavation throughout most of the site will be within the capabilities of conventional mechanical excavators. Old structures/obstructions may require higher capacity machines for their removal (e.g. in the area of the former railway station).

Support of excavations sides may be necessary for shallow excavations in the Made Ground soils and is likely within areas where Wind Blown Sands are present. As part of future re-development, careful temporary works design will be needed which should include management of surface water run-off.

Based on our understanding of the proposed development, no significant groundwater ingress is anticipated above 5m depth, however some short term ingress from perched water within the Made Ground may occur. Where water ingress occurs it is likely that pumping from screened sumps within shallow excavations will be adequate.

8.8 Soakaway Drainage

8.8.1 Soakaway Design

No soakaway infiltration testing has been undertaken at the site however, based on the findings of the investigation, some preliminary comments can be made.

Soakaways would not be suitable in the Made Ground soils without detailed risk assessment to demonstrate they would not pose a contamination risk to the identified controlled waters.

Where locally present, the Blown Sands are predominantly coarse-grained in composition and may have sufficiently good infiltration characteristics to make the use of soakaway drainage. Soakaway infiltration testing in accordance with BRE 365 should be undertaken at the proposed positions and depths of soakaways to confirm the likely infiltration rates.

The infiltration stratum at the site would be the Blown Sand deposits, which is in hydraulic continuity with the underlying Oxwich Head Limestone bedrock, which is classed as a Principal aquifer and the groundwater within is vulnerable to pollution. The Environment Agency has a general policy that no direct discharge of surface run-off would be accepted in vulnerable

groundwater aquifers, however as indicated in this report saline intrusion has degraded its quality. We recommend that enquiries are made to Natural Resources Wales (who have taken over the role of the Environment Agency) to identify whether they would allow such discharge at the site, if soakaways are required. As a minimum, risk mitigation measures such as oil interceptors are likely to be required.

Soakaways should be positioned a minimum of 5m from all foundations. Considering the size of the site and the nature of the development, there may be insufficient space to achieve this.

Consideration of the dissolution risks associated with the underlying limestone bedrock would also be required. Any additional works undertaken to determine the potential risk from solution features would likely inform this.

9 Recommendations

The objective of the investigation was to obtain information on the character and properties of the ground beneath the site, to allow an initial assessment of potential geotechnical and geo-environmental risks and constraints, to enable prospective bidders to make decisions regarding scheme layout and costings associated with construction and site remediation.

Using previous investigation information and current findings we consider this has largely been achieved for Site B. However, certain aspects require more clarity.

Once detailed development design layouts and proposals are known and the site specific regulatory requirements (local authority and NRW) are confirmed as part of the associated planning conditions, some additional investigation, monitoring and assessment is recommended/may be required to further assess contamination risks initially assessed or to robustly finalise the geotechnical design advice provided in this report.

We recommend further work should include the following geo-environmental and geotechnical investigation.

9.1 Geo-Environmental

1. Once the development proposals are known, we recommend some additional testing for asbestos is undertaken in proposed landscaped areas to confirm the risk where there is an exposure potential to long term end users. Additional testing could also be undertaken to further assess risks to construction workers.
2. We recommend that an asbestos specialist should be employed to undertake a survey of the existing building and further assessment of the risk posed by asbestos present in the soils to construction and maintenance workers and the general public prior to any development. Input may also be required for human health risks dependent on the results of the additional testing in landscaped areas.
3. Wide scale remedial measures are not considered necessary, however considering the past significant industrial history there is a potential for un-identified contamination across the site. This includes the area of the existing sub-station which may be moved as part of future development. Upon removal, we recommend further testing beneath its footprint (including PCBs) to confirm the absence of any contamination, that may warrant further consideration.
4. We consider that the overall risk to controlled waters from the development of the site is likely to be low. Discussion with NRW will be required to confirm their opinion on the sensitivity of the aquifers to confirm the risk. Additional testing and assessment may be requested in accordance with specific local authority and NRW requirements, which are currently unknown.
5. Gas protection measures in accordance with BS8485 are required to be incorporated into the development design in accordance with a CS-2 classification. If during construction any organic materials are encountered, they should be excavated and replaced.
6. Testing indicates that there is a potential risk from elevated levels of sulphate within the Made Ground. If a reduction of the classification would be cost beneficial, further testing would be required to confirm the required design class.
7. Once waste streams have been considered, we recommend some further testing is undertaken to confirm waste classifications (non-hazardous/hazardous), which has been initially assessed as part of this report. WAC testing may also be required.
8. A landscaping specialist should be consulted with regards to future planting across the site.

9.2 Geotechnical

1. Once the development location, proposed loadings and settlement tolerances are known, the available information should be reviewed to confirm the potential foundation options that have been presented within this report.
2. Obstructions remain present beneath the site and include old foundations associated with the former station and existing services. Obstructions/structures will require consideration as part of the development design (in particular foundations), and where shallow, they may require removal (possibly with large excavators), diversion or protection as part of the site preparation works.
3. Support of excavations sides is likely to be necessary for shallow excavations as part of future re-development and careful temporary works design will be needed which should include management of surface water run-off.
4. We cannot discount that solution features exist beneath the site. These may affect foundations due to variations in rockhead depth or the possible presence of natural cavities. Further investigation which may include geophysical surveying should be considered by the purchaser to reduce the uncertainty of potential risks from un-recorded solution features beneath the site.
5. If soakaway drainage is desired, we recommend that enquiries are made to Natural Resources Wales to identify whether they would allow such discharge at the site considering the designation of the underlying aquifers. The localised Blown Sand may be a suitable infiltration stratum, however soakaway infiltration testing in accordance with BRE 365 should be undertaken at the proposed positions and depths of soakaways to confirm the likely infiltration rates.

Proposals for the above can be provided by ESP once development proposals have been formalised.

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