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CISM, Swansea University Bay Campus, Swansea

Geoenvironmental risk assessment

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RSK GENERAL NOTES

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1 INTRODUCTION

RSK Environment Limited (RSK) was commissioned by AECOM Ltd (the Client) to carry out a geo-environmental risk assessment (PRA) of the proposed Centre for Integrative Semiconductor Materials (CISM), Swansea University Bay Campus, Swansea.

This report is subject to the RSK service constraints given in Appendix A. A summary of legislation and policy relating to contaminated land is given in Appendix B.

1.1 Objective

AECOM Ground Investigation Specification Project No: 60605215 October 2019 sets out the requirements for a Preliminary Risk Assessment and a Phase 2 intrusive Ground Investigation. In summary, these are as follows:

- Phase 1 desk study,
- Site works. To include (but not limited to) the following:
 - Window sample boreholes
 - Cable percussion boreholes
 - Machine dug trial pits
 - Plate bearing tests
 - Hand dug inspection pits
 - Gas & groundwater monitoring boreholes & monitoring
 - In situ testing –SPET, UT100, PID, hand vane tests, hand penetrometer tests
 - In situ permeability –Soakaway tests
- Laboratory testing.
- Full and complete factual report detailing the works undertaken.

1.2 Interpretative reporting. Scope

The scope of the investigation and layout of this report has been designed with consideration of CLR11 (Environment Agency, 2004); BS 10175: 2013 (BSI, 2013); and guidance on land contamination reports issued by the Environment Agency (EA) (2010a). The project was carried out to an agreed brief as set out in RSK's proposal (ref: 314617 T01 (00)), dated 14th November 2019.

1.3 Existing reports

No site-specific reports have been provided. However the following reports pertaining to the wider area have been provided:

- WSP - Phase II Geo-Environmental and Geotechnical Assessment Report, Project No. 37221, August 2013
- WYG - Ground Investigation Factual Report, A096196, issued September 2016
- AECOM - Geotechnical and Geo-environmental Interpretive Report. Project No. 60476794, October 2016

The pertinent information from within has been provided where applicable.

1.4 Limitations

The comments given in this report and the opinions expressed are based on the site walkover and published third party information. However, there may be conditions pertaining to the site that have not been disclosed by the walkover or published third party information and therefore could not be taken into account in the preparation of this report.

2 THE SITE

2.1 Site location and description

The site is located approximately 4.35 km to the east of Swansea city centre and is situated on the Swansea University Bay campus, Skewen, Swansea, SA1 8QB (nearest postcode) which comprises multiple buildings with soft and hard landscaping. The site is immediately bound by buildings to all sides, discussed further in Table 1. There is currently no vehicular access, however hardstanding and footpaths lead to Crymlyn Way road to the east and a service road leading to the A483 (Fabian Way) to the north.

The site occupies an area of circa 0.24ha. The site is currently occupied by 2no. structures along with soft and hard landscaping. One of the structures occupying the site is referred to as 'ORACLE II' and is the 'Outdoor Research and Community Learning Environment' building. It is described as a '8m x 6m outdoor classroom / pavilion' and was constructed by a company called 'Down to Earth' using ecologically low impact locally sourced materials utilising skills such as dry-stone walling and timber frame forming'. The other structure is the Green Roof Bike Shelter and was constructed opposite ORACLE II at the same time by Down to Earth using the same methods and materials (Swansea University Bay Campus Grounds Management Plan 2018-2019). The site is generally flat with the broader area sloping gently southward toward the Severn Estuary; neighbouring buildings are at a similar elevation.

Table 1: Site setting

To the north:	The site is bound by a foot pathway leading to the Energy Safety Research Institute (ESRI) building, beyond which lies car parking, a service road for the university campus and the A483 with further commercial premises.
To the east:	The site is bound by an area of hard landscaping with a foot pathway leading to the 'Active Office / Classroom' (SPECIFIC) building, beyond which lies Crymlyn Way road and the Crymlyn Burrows SSSI.
To the south:	The site is bound by an irregular shaped hedge leading to an area of hardstanding, presumed to be used as a goods / delivery loading area, beyond which lies the 'Engineering EAST' building and soft landscaping down to the Severn Estuary.
To the west:	The site is bound by a foot pathway leading to the ISM building, beyond which lies further buildings of the Swansea University Bay Campus.

2.2 Proposed development

It is understood that the site is proposed to be developed for the Centre for Integrative Semiconductor Materials (CISM), which will be a multiple storey building of traditional construction.

3 PRELIMINARY RISK ASSESSMENT (PRA)

3.1 Site walkover

The site walkover was undertaken on 21st January 2020. Photographs are provided in Appendix C. A description of the site along with any potentially significant environmental and/ or geotechnical issues are summarised below.

The site is approximately square in shape and comprises a central foot pathway (intersecting the site in a north-south orientation), soft landscaping and the 'ORACLE 2' and 'Green Roof Bike Shelter' structures previously discussed in Section 2.1.

The site is bound by foot pathways, hard landscaping and buildings of the Swansea Bay University Campus previously discussed in Section 2.1.

Access to the site is pedestrianised from any of the foot pathways and hard landscaping surrounding the adjacent buildings, which lead to the adjacent road network previously discussed in Section 2.1.

Soft landscaping comprised grass verges and mounded grass areas. Japanese knotweed or other invasive species were not observed to be present on site, however this does not exclude its absence or that of other invasive species, as the walkover was not undertaken by a qualified ecologist.

The site was noted to be relatively flat with the exception of the mounded areas. The broader area slopes gently southward toward the Severn Estuary.

A number of manhole covers and live services have been identified throughout the site.

No visible sources of potential land contamination were observed during the site walkover on or near to the site.

3.2 Ground conditions

3.2.1 Geology

Published records (British Geological Survey (BGS), 1:50,000 series, (Sheet No 247, 'Swansea 2011) and 1:10,000 for the area indicate the geology of the site to be characterised by the succession recorded in Table 2.

Table 2: Geology at the site

Geological unit	Description	Estimated thickness (m)
Made Ground	The supplied documents suggest that site wide levels have been previously raised during the enabling earthworks for the campus. Therefore, it is assumed that approximately 2.5m depth of made ground (albeit likely to be engineered fill) is located below the topsoil.	Up to depths >2.5m
Superficial Deposits Aeolian deposits (blown sands) and potentially fluvio-glacial till.	Sand and Diamicton.	Unknown.
Bedrock geology South Wales Middle Coal Measures Formation	Grey coal bearing mudstones/siltstones (BGS Lexicon).	Up to 240m in the Swansea area (BGS Lexicon).
Source: http://mapapps.bgs.ac.uk/geologyofbritain/home.html ? http://www.bgs.ac.uk/lexicon/lexicon		

There are no BGS boreholes recorded on the site. The nearest recorded BGS borehole is located circa 500m north-west of site and is illegible. The other recorded BGS boreholes are considered to be located too far away to be a reliable indication of the underlying stratigraphical succession of the site.

3.2.2 Ground stability

Evidence has been sought to identify the maximum hazard rating of natural subsidence within the site boundary based on six natural ground stability hazards as presented within the environmental database report. The following hazard ratings have been given:

- Shrink swell clays – negligible
- Landslides – very low
- Ground dissolution of soluble rocks – negligible
- Compressible deposits – negligible
- Collapsible deposits – negligible
- Running sands – negligible

As suggested in Section 3.2.1, there is likely a considerable amount of Made Ground to depths of >2.5m below ground level which could significantly affect the ground stability.

3.2.3 Radon

The environmental database report states that the site is not located in a Radon Affected Area, therefore radon protective measures would not be necessary.

3.2.4 Mining, quarrying and ground workings

Evidence has been sought to identify any ground workings, mining and quarrying operations, past and present, which have taken place within a radius of 1 km of the site. The sources of information referenced in this element of the desk study include:

- The environmental database report
- Historical Ordnance Survey maps and plans
- Geological mapping.

With reference to the above data, ground workings were undertaken between 1964 and 1979, with the construction of the former oil storage depot that occupied the site. Prior to this the site appeared to be sand (beach) with rough grass vegetation (as indicated in historical mapping) and on or close to the high-tide mark. The surrounding area has undergone considerable ground working with the construction of docks, railways, roads and residential, commercial and industrial buildings. Following demolition of the former oil depot, the new Swansea University Bay Campus has been constructed with associated ground level alterations.

There are no records of historical mining within 1000m of the site boundary.

The site lies in or in close proximity to a coal mining reporting area as defined by the Coal Authority.

There are two potential records of non-coal mining activity within 1000m of the site boundary which include 'localised small-scale underground mining' for Iron Ore (Bedded) located 253m south and 342m south-west of the site. In addition, a record for a quarry exists for the 'Halfway House Sand Pit' located 795m north-west of the site (Enviroinsight Report). There are no other records of non-coal related mining and quarrying.

3.2.5 Landfilling and land reclamation

Evidence has been sought to identify any landfilling or land reclamation operations, past and present, which have taken place in the vicinity of the site. The sources of information referenced in this element of the desk study include:

- Environmental database report
- Historical Ordnance Survey maps and plans

There are no records of Environment Agency (EA) / Natural Resources Wales (NRW) landfill data, historical landfill sites or licenced waste sites within 250m of the site.

3.3 Hydrogeology

3.3.1 Aquifer characteristics

The hydrogeology of the site is likely to be characterised by the presence of an unconfined shallow aquifer within the superficial deposits (wind-blown sands) and bedrock (South Wales Middle Coal Measures Formation).

Given the site use, it is anticipated that considerable made ground is present beneath the site placed during construction of the previous oil terminal and existing Swansea University Bay Campus. Depending upon the composition of this made ground, localised areas of perched groundwater may be present beneath the site in the near-surface.

Given the anticipated low transmissivity of the South Wales Middle Coal Measures Formation, groundwater flow is likely to be slow to negligible. Any gradual flow present is anticipated to flow in a general southerly direction across the site, towards the River Severn Estuary.

3.3.2 Vulnerability of groundwater resources

The site has been classified to overlie a 'Secondary A' Aquifer (Superficial Deposits and Bedrock geology). These aquifers comprise permeable layers capable of supporting water supplies at local rather than strategic scale, and in some cases forming an important source of base flow to rivers.

3.3.3 Licensed groundwater abstraction

The environmental database report indicates that there is no currently licensed groundwater abstraction within a 2 km radius of the site.

Information available on the Natural Resources Wales website (Lle Geo-Portal Map browser) indicates that the site does not lie within a currently designated groundwater Source Protection Zone (SPZ).

3.4 Hydrology

3.4.1 Surface watercourses

The River Severn Estuary lies approximately 250m south of the site, however due to the variable tidal range, the tide level varies considerably.

There are a several records of licensed discharge consents within 500m of the site that apply to two sites and discharge to either groundwater or 'sea outfall', detailed below:

- **Swansea Bay Innovation Campus**, Site Office, Elba Crescent, Crymlyn Burrows (Trade Discharges – Site Drainage to groundwater – permit number 'EPRMB3897TQ') located 72m and 301m south-west of site.

- **Neath Port Talbot, Wales** (Sewer Storm Overflow to sea outfall – Water Company – permit number 'BE0010502') located 384m south-west of site.

There are no records of Water Industry Referrals (potentially harmful discharges to the public sewer) within 500m of the site.

There are no recorded contamination incidents originating from the site, however several pollution incidents have occurred within proximity to the site. The nearest of these records is located 22m south-east of the site, with the pollutant unidentified and no impact on either water, land or air. The other records mainly refer to atmospheric pollutants and have had no impact or a minor impact on water.

3.4.2 Surface water abstractions

The environmental database report indicates that there are three currently licensed surface water abstractions within a 2 km radius of the site. A licence is held 1720m north of site by Hawk Plant hire Ltd (license number WA/059/0001/001). Water is abstracted from Pond no.29, Lower end of Freemans Bund Stream, Neath.

A second license is held 1762m north of site by St Mowden Properties PLC (license number 22/59/5/0007) for abstraction from Freemans Bund.

A third license is held 1792m north of site by an unnamed party (license number 22/59/5/0007) for unknown abstraction.

3.4.3 Preliminary flood risk data

The indicative floodplain map for the area, published by the EA, shows that the site lies within a Zone 2 floodplain (Fluvial /Tidal Models) and Zone 3 floodplain (Fluvial Models). Zone 2 floodplains, according to the EA, have an annual probability of flooding from rivers of between 1 in 1000 (0.1%) and 1 in 100 (1%). Zone 3 floodplains, according to the EA, have an annual probability of flooding from rivers of 1 in 100 (1%) or greater.

The Risk of Flooding from Rivers and the Sea (RoFRaS) flood rating, as determined by the EA, is noted in the environment database as 'low' for the site. This is defined as the chance of flooding from rivers or the sea is considered to be less than 1 in 100 (1%) but greater than or equal to 1 in 1000 (0.1%) in any given year.

In addition, the area is not considered to be prone to groundwater flooding based on rock type.

Please note that this report is not intended to replace a full hydrological study.

3.5 History of site and surrounding area

The history of the land-use and development of the site and surrounding area has been assessed based on the following sources:

- Historical maps within the environmental database from 1882 to 2019

- Internet search
- Publicly available aerial photography
- Anecdotal evidence from site walkover

Copies of OS and County Series maps are included in the environmental database report in Appendix E. Reference to historical maps provides invaluable information regarding the land use history of the site, but historical evidence may be incomplete for the period pre-dating the first edition and between successive maps.

The development history of the site and surrounding area from the above sources is detailed in Table 3 and summarised below.

Table 3: Summary of historical development

Date	Land use/features on site	Land use/features in vicinity of site
1880's	The site is indicated below high water mark for ordinary tides.	Crymlyn Burrows is indicated in the surrounding area, north of the site The Great Western Railway is present approximately 600 m from the northern site boundary. Burrows chemical works is indicated some 700m northwest.
1897-1900	The site is indicated above high water mark for ordinary tides.	Some expansion of the railway has taken place with a carriage and wagon repair shop and associated sidings present some 720m north west. A sand pit is indicated near the chemical works some 720m north-northwest.
1914s	No significant changes	The railway has expanded further south with the development of the Kings Dock Tin Plate works some 250m north-northwest of the site, with associated roadways and tanks. Baldwin Crescent (presumed residential dwellings) have also been developed in the north west some 490m of the site.
1920's	No significant changes.	No significant changes.
1930's	No significant changes.	Development of Elba Crescent has taken place some 150m north the site. Elba Tin Plate works has been developed some 450m north.
1940's	No significant changes.	A rifle range is indicated some 250m north-northeast.
1960's	Trees are indicated across the site. By 1969 an oil storage depot is indicated on site. Large tanks are encroaching into southwest and	Development of the A483 roadway and associated drainage has occurred some 90m north of the site. A filling station is indicated some 139m

Date	Land use/features on site	Land use/features in vicinity of site
	northeast portions of the site. The trees are no longer indicated. A trackway associated with depot runs through the central portion of the site trending east west.	northeast. A large circular object (1:1250, 1963-64 only) a presumed oil storage tank, is located some 170m west of the site. By 1969 a large oil storage depot is indicated. 12no storage tanks are located within 500m of the site boundary.
1980's	No significant changes.	The railway north of the site is now indicated as dismantled. No other significant changes.
1990's	No significant changes.	No significant changes.
2000's	Tanks are no longer indicated within the site boundary.	The tanks and storage depot are no longer indicated post 2003.
2010's	Construction of the Swansea University Bay Campus has occurred. The 2019 map indicates that the site layout is the same as present day.	Construction of the Swansea University Bay Campus has occurred around the site.

It is our understanding that the tanks were decommissioned and demolished by 2003. During the period of product storage, tank leaks occurred. Anecdotal evidence of leaks involving Tanks 840, 853 and 856 (Benzene) for the period 1988 – 1997.

Further to this, it is our understanding that site levels have been raised significantly over its history.

3.6 Sensitive land uses

Crymlyn Burrows, which is within 50 m to the east of the site, is designated as a Site of Special Scientific Interest (SSSI). The area contains sand dunes, a salt marsh and carr woodland. The burrows also contain a rare orchid- the Fen Orchid.

Please note that a comprehensive evaluation of ecological receptors is outside the scope of this report.

3.7 Potentially polluting industries

A number of potentially polluting industrial premises and features have been located within 250 m of the site including:

- Tanks on and off site
- Petrol filling station some 139m northeast.

3.8 Unexploded ordnance

Based upon the documents provided, it is our understanding that an Explosive Ordinance Threat Survey was undertaken by BACTEC (2009) for the wider Swansea

area, the results of which showed that the threat levels varied across the area. The online Zetica UXO risk map (accessed Nov 2019) indicates that the site is at low risk from unexploded ordnance. Furthermore as the site has been through various phases of development post war (e.g. past buildings, infilling etc), it is considered that the risk from UXO would be very low, therefore no further assessment is required..

4 INITIAL CONCEPTUAL SITE MODEL

In the UK land contamination is assessed using a risk-based approach taking account of the magnitude (severity of the hazard) and likelihood (probability) of occurrence. A 'receptor' is something that could be adversely affected by contamination (e.g. people, an ecological system, property or a water body). A 'pathway' is a route or means by which a receptor is or could be exposed to or affected by a contaminant. A 'contaminant source' is a hazard but it can only pose a risk to a receptor where a pathway is present. The relationship between sources, pathways and receptors are referred to as a conceptual site model. A risk can only be released where a contaminant source, pathway and receptor are all in place, referred to as a 'pollutant linkage'.

In line with CLR11 (Environment Agency, 2004) and BS 10175: 2011 + A2 2017 (BSI, 2017), RSK has used information in the preceding sections to identify sources of contaminants, receptors that may be impacted and plausible linking pathways. Where all three are present this is termed a potentially complete contaminant linkage and a qualitative risk estimation is made.

The proposed development is considered indicative of a Commercial end use.

4.1 Potential soil, soil vapour and groundwater linkages

4.1.1 Potential sources of contamination

Potential sources of soil and groundwater contamination identified from current activities and the history of the site and surrounding area are presented in Table 4. Ground gas sources are addressed in the next section.

Table 4: Potential sources of soil and groundwater contamination

Potential sources	Contaminants of concern	Current or historical?
On-site		
Made ground (i.e. fill material used to raise site levels)	Unknown fill material but potentially including brick, ash and clinker and containing toxic and phytotoxic metals, inorganics, polycyclic aromatic hydrocarbons (PAHs), asbestos	Historical
Above ground storage tanks and associated pipework	Petroleum hydrocarbons (petrol/diesel*)	Historical
Off-site		
Petrol filling station, from 139m north-east	Petroleum hydrocarbons, fuel additives, PAHs, chlorinated solvents, asbestos	Current/historical*

Potential sources	Contaminants of concern	Current or historical?
Above ground storage tanks and associated pipework	Petroleum hydrocarbons (petrol/diesel*)	Historical
Made ground (i.e. fill material)	Unknown fill material but potentially including brick, ash and clinker and containing toxic and phytotoxic metals, inorganics, polycyclic aromatic hydrocarbons (PAHs), asbestos	Historical

It would be reasonable to assume that the historical potential sources on site would have undergone a degree of remediation given that the tanks were decommissioned in the early 2000s, followed by construction of the university buildings in the 2010s. However, for completeness the historical potential sources have been included.

The tanks and made ground identified off site will unlikely be a major contributor to onsite contamination via migration, as the fill material is likely to be of similar composition to that found onsite.

The offsite source with regards to the petrol filling station has not been carried forward due to its distance from the site boundary and the development history of the site.

4.1.2 Sensitive receptors and linking exposure/migration pathways

Sensitive receptors identified at or in the vicinity of the site that could be affected by the potential sources identified above comprise:

- current/ future site users – public open space users, commercial workers [oral, dermal and inhalation exposure with impacted soil, soil vapour and dust]
- current adjacent site users – public open space users, commercial [migration of contamination via dust/fibre deposition, vapour or groundwater migration combined with inhalation]
- current/ future buildings and services [direct contact with contaminated soils or groundwater and chemical attack]
- existing/ future vegetation [direct contact with contaminated soils or groundwater and root uptake leading to phytotoxicity]
- groundwater in secondary A aquifer within superficial deposits [leaching from soils/ percolation to aquifer/ lateral migration of dissolved phase/ NAPL etc]
- groundwater in secondary A aquifer within bedrock deposits [percolation through permeable strata to aquifer/ lateral migration of dissolved phase/ NAPL etc.]
- surface water course (Severn Estuary) situated 250 m south [lateral migration / drainage]
- ecological receptors - SSSI etc. [lateral migration / site run-off].

Potential linking pathways are show in brackets for each item above.

Please note that construction workers and future maintenance workers have not been identified in the conceptual model as receptors because risks are considered to be managed through health and safety procedures according to the CDM Regulations.

Ecological receptors are only considered within the conceptual model in the context of statutory protected sites.

4.2 Potential ground gas linkages

4.2.1 Ground gas generation potential

Potential ground gas sources identified for the site and surrounding are shown in Table 5.

Table 5: Potential ground gas sources

Potential sources	Indicative ground gas generation potential (CIEH, 2008)	Additional information
On-site		
Natural soil strata with a low degradable organic content	Very low	-
Made ground with low degradable organic content (e.g. up to 5% organic material and no easily degradable waste).	Very low	Unknow fill materials used to raise site levels but likely to have comprised engineered fill in the most recent iteration.
Natural soil with a high degradable organic content	Low	-
Made ground with TOC up to 6% (e.g. dock silt, no food or other easily degradable waste)	Low	Unknow fill materials used to raise site levels but likely to have comprised engineered fill in the most recent iteration.
Above ground storage tanks	Low	Potential for VOC's and SVOC's
Off-site		
Above ground storage tanks	Low	Potential for VOC's and SVOC's
Marsh land associated with Crymlyn Burrows	Low	-

Given the anticipated ground conditions set out above, no significant potential sources of ground gas generation have been identified. This should be confirmed through monitoring.

4.2.2 Preferential pathways for ground gas migration

Credible preferential pathways potentially connecting the source and receptor through vertical and lateral migration are:

- geology of the Blown Sand formation which is likely to be permeable.
- building foundations, piled foundations and vibro-stone columns
- construction joints and cracks within building structure
- utility routes and service penetrations into buildings.

4.2.3 Sensitive receptors and linking pathways

Sensitive receptors identified at or in the vicinity of the site that could be affected by the potential ground gas sources identified above comprise:

- future site users –commercial [migration and ingress of ground gases into buildings, build-up in confined spaces and explosion/ asphyxiation]
- current/ adjacent site users –commercial [migration and ingress of ground gases into buildings, build-up in confined spaces and explosion/ asphyxiation]
- current/ future buildings and services [migration and ingress of ground gases into buildings, build-up in confined spaces and explosion].

The assessment has identified receptors to include building structures and current/ proposed end-users.

Construction workers have not been identified as receptors for the purposes of this assessment. Risks may still be present to construction workers especially where works include the entry into excavations within the ground. Construction workers should undertake appropriate risk assessments and risks should be managed through health and safety procedures and the use of PPE.

4.3 Preliminary risk assessment

The preliminary risk assessment findings and potentially complete contaminant linkages are shown in Table 6 overleaf. The risk classification based on the combination of hazard consequence and probability using a risk matrix from CIRIA C552 (Rudland et al., 2001), a summary of which is included in Appendix D.

Table 6: Risk estimation for potentially complete pollutant linkages

Potential source	Potential receptor	Possible pathway	Likelihood	Severity	Risk and justification
Onsite					
Made Ground (e.g. fill material etc) associated with former/current development at the site.	Future site occupants and adjacent site users	Direct contact (soil, dust and vegetable ingestion, dermal contact, dust and fibre inhalation) and inhalation pathways.	Low likelihood	Medium	Low to moderate risk The majority of the site is covered in hard standing with only limited soft landscaping areas, reducing the likelihood of site users coming into contact with any existing made ground present beneath the site. Pathways may exist for areas of current/future soft landscaping. The site exists as a commercial operation. Therefore, it is unlikely that site users will spend significant quantities of time in direct contact with any made ground present. Site development history suggests that significant quantities of made ground may be present beneath the site although the composition and thickness are unknown.
	Vegetation	Plant uptake	Low likelihood	Mild	Low risk Potential for impact within soil at the site. Site development history suggests the potential for the presence of made ground of unknown composition. Vegetation including mature and semi-mature trees is present on site. No visible vegetation stress was observed during the site walkover.
	Potable water supply pipes	Direct contact	Low likelihood	Medium	Low to moderate risk Organic contaminants may subsequently come into contact and permeate potable water supply pipes.

Potential source	Potential receptor	Possible pathway	Likelihood	Severity	Risk and justification
	Buildings and infrastructure (foundations)	Direct contact	Low likelihood	Mild	Low risk Potential for significant impact within soil at the site is considered low, however if present, it is possible that buried concrete may be affected.
	Groundwater (Secondary A)	Vertical migration	Low likelihood	Medium	Low to moderate risk Site development history suggests the potential for the presence of made ground of unknown composition. The majority of the site is covered in hardstanding, with runoff leading to drainage systems. Spills and leakages historically could have made their way to ground through either cracks in the site surface or following entry into the drainage via defects in that system. Given the anticipated geology of the site (the granular Blown Sands), it is considered likely that groundwater, if present, may have been impacted through vertical and lateral migration.
Former above (and Potential Underground) fuel storage tanks and dispensers.	Future site occupants and adjacent site users	Direct contact (soil, dust and vegetable ingestion, dermal contact, dust and fibre inhalation) and inhalation pathways.	Low likelihood	Medium	Low to moderate risk Potential for significant impact within soil at the site is considered low given the relatively recent demolition and construction. However if present, it is possible that future site users may come into contact through areas of soft landscaping.
	Vegetation	Plant uptake	Low likelihood	Mild	Low risk Potential for significant impact within shallow soil at the site is considered low given the relatively recent demolition and construction.

Potential source	Potential receptor	Possible pathway	Likelihood	Severity	Risk and justification
	Potable water supply pipes	Direct contact	Low likelihood	Medium	Low to moderate risk Potential for significant impact within shallow soil at the site is considered low given the relatively recent demolition and construction.
	Buildings and infrastructure (foundations)	Direct contact	Low likelihood	Mild	Low risk Potential for significant impact within shallow soil at the site is considered low given the relatively recent demolition and construction.
	Groundwater (Secondary A)	Vertical migration	Low likelihood	Medium	Low to moderate risk Potential for significant impact within soil at the site is considered low. Based on the sensitive nature of the underlying aquifers there is considered to be a moderate to low risk.
Potential ground gases associated with Made Ground.	Future residents	Inhalation in indoor and outdoor air	Low likelihood	Medium	Low to moderate risk Potential for quantities of degradable Made Ground at the site is considered low due to the likely engineered fill used. However, the composition of the material is unknown and any gas risk can therefore not be discounted.,
	Buildings and infrastructure (foundations)	Migration and accumulation of gas within on-site buildings and services	Low likelihood	Mild	Low risk Potential for quantities of degradable Made Ground at the site is considered low due to the likely engineered fill used. However, the composition of the material is unknown and any gas risk can therefore not be discounted.

Potential source	Potential receptor	Possible pathway	Likelihood	Severity	Risk and justification
Former above (and Potential Underground) fuel storage tanks with regards to ground gas and vapour.	Future residents	Inhalation in indoor and outdoor air	Low likelihood	Medium	Low to moderate risk Potential for quantities of degradable Made Ground at the site is considered low due to the likely engineered fill used. However, the composition of the material is unknown and any gas risk can therefore not be discounted.
	Buildings and infrastructure (foundations)	Migration and accumulation of gas within on-site buildings and services	Low likelihood	Mild	Low risk Potential for quantities of degradable Made Ground at the site is considered low due to the likely engineered fill used. However, the composition of the material is unknown and any gas risk can therefore not be discounted.
Offsite					
Made Ground associated with ground level alterations and developments.	Future residents	Inhalation in indoor and outdoor air	Low likelihood	Mild	Low risk Potential for quantities of degradable Made Ground is considered low due to the likely engineered fill used. However, the composition of the material is unknown and any gas risk can therefore not be discounted.
	Buildings and infrastructure (foundations)	Migration and accumulation of gas within on-site buildings and services	Low likelihood	Mild	Low risk Potential for quantities of degradable Made Ground is considered low due to the likely engineered fill used. However, the composition of the material is unknown and any gas risk can therefore not be discounted.

Potential source	Potential receptor	Possible pathway	Likelihood	Severity	Risk and justification
Former above (and Potential Underground) fuel storage tanks with regards to ground gas and vapour.	Future residents	Inhalation in indoor and outdoor air	Low likelihood	Mild	Low Risk Potential for quantities of degradable Made Ground is considered low due to the likely engineered fill used. However, the composition of the material is unknown and any gas risk can therefore not be discounted
	Buildings and infrastructure (foundations)	Migration and accumulation of gas within on-site buildings and services	Low likelihood	Mild	Low risk Potential for quantities of degradable Made Ground is considered low due to the likely engineered fill used. However, the composition of the material is unknown and any gas risk can therefore not be discounted

Risk matrix		Consequences			
		Severe	Medium	Mild	Minor
Probability	Highly likely	Very high	High	Moderate	Moderate/low
	Likely	High	Moderate	Moderate/low	Low
	Low likelihood	Moderate	Moderate/low	Low	Very low
	Unlikely	Moderate/low	Low	Very low	Very low

Potentially complete contaminant linkages with a potential risk of moderate to low or higher identified in in Table 6 comprise:

- current/ future site users – public open space users, commercial [oral, dermal and inhalation exposure with impacted soil, soil vapour and dust]
- current adjacent site users –commercial, public open space users [migration of contamination via dust/fibre deposition, vapour or groundwater migration combined with inhalation]
- current/ future buildings and services [direct contact with contaminated soils or groundwater and chemical attack]
- existing/ future vegetation [direct contact with contaminated soils or groundwater and root uptake leading to phytotoxicity]
- groundwater in secondary A aquifer within superficial deposits [leaching from soils/ percolation to aquifer/ lateral migration etc]
- groundwater in secondary A aquifer within bedrock deposits [percolation through permeable strata to aquifer/ lateral migration etc.]
- surface water course (Severn Estuary) situated some 250 m south [lateral migration / drainage]

These potentially complete contaminant linkages need to be assessed further through appropriate site investigation to target the identified sources of potential contamination and assess the feasibility of identified pathways.

4.4 Data gaps and uncertainties

Key data gaps and uncertainties identified in the CSM at desk study stage include:

- Underground services exist sporadically across the site which will restrict areas of investigation
- there are no previous investigations available for the site, therefore no information on actual concentrations of contaminants in soil and groundwater or ground gas at this stage
- groundwater depth and flow direction are conceptual at this stage
- site levels have been raised however, documentation pertaining to the decommissioning and demolition process and origins of made ground has not been made available

5 SITE INVESTIGATION STRATEGY & METHODOLOGY

5.1 Introduction

RSK carried out intrusive investigation works and subsequent monitoring of boreholes between January and February 2020.

5.2 Objectives

The specific objectives of the investigation were as follows:

- to establish the ground conditions underlying the site including the extent and thickness of any made ground
- to investigate specific potential sources of contamination identified in initial CSM
- to determine groundwater depth
- to determine the ground gas regime underlying the site
- to assess geotechnical properties of soils (reported under a separate cover)

5.3 Selection of investigation methods

The techniques adopted for the investigation were chosen with consideration of the objectives and site constraints, which are described below.

Cable percussion drilling was chosen based on the targeted drill depth, requirement for in-situ geotechnical data, the opportunity to collect both disturbed and undisturbed samples and install monitoring wells. This was supplemented by mechanically excavated trial pitting to obtain a number of investigation locations and achieve greater visibility of the Made Ground.

Prior to conducting intrusive works, utility service plans were provided by the client, with further CAT scanning undertaken by RSK, in line with RSK's health and safety procedures.

5.4 Investigation strategy

The ground investigation was carried out using intrusive ground investigation techniques in general accordance with the recommendations of BS5930: 2015 Code of practice for ground investigations, which maintains compliance with BS EN 1997-1 and 1997-2 and their related standards. Whilst every attempt was made to record full details of the strata encountered in the boreholes, techniques of hole formation and sampling will inevitably lead to disturbance, mixing or loss of material in some soils and rocks.

The investigation strategy involved targeted boreholes and trial pits as outlined in the provided scope and where possible due to limitations imposed by buried services and areas of hard landscaping.

The constraints to the investigation were as follows:

- Numerous live underground services throughout the site area;
- Hard standing/paved walkways, under constant use;
- Mounded soil areas within central portion, one with numerous pipes/pipework and potential ecological constraints;
- Bike shed and maintenance shed;
- Planted areas with specialised plants and potential ecological constraints

Buried concrete was encountered at various depths across the site.

Details of the investigation locations, installations and rationale are presented in Table 7 and are summarised below.

3no. machine excavated trial pits were dug to a maximum depth of 2.70 m bgl before being backfilled with arising.

2no. cable percussive boreholes were drilled to a maximum depth of 21.1m bgl, each was installed with a combined gas and groundwater monitoring well.

4no Dynamic sampling holes were drilled to a maximum depth of 4.2m bgl, two of which were installed with a combined gas and groundwater monitoring well.

Table 7: Exploratory hole and monitoring well location rationale

Investigation type	Number	Designation	Monitoring well installation	Rationale
Boreholes by cable percussive methods	2	BH1 to BH2	Gas/ groundwater*	Located within areas of site accessible for the drilling rig and in areas that would have minimal impact on risks to current site users. To prove the geological succession beneath the site and obtain geotechnical data and to install combined gas and groundwater monitoring wells.
Boreholes by dynamic/ windowless sampling methods	4	WS1 to WS4c	Gas/ groundwater*	Located within areas of site accessible for the drilling rig and in areas that would have minimal impact on risks to current site users.

Investigation type	Number	Designation	Monitoring well installation	Rationale
				To determine the contamination status of the ground beneath the site and to install additional dual purpose groundwater and gas monitoring wells.
Trial-pits excavated by hand/mechanical excavator	3	TP1 to TP3.	n/a	To accurately log the upper strata in targeted and non-targeted locations beneath the site. Collect samples from the shallow made ground soils. To undertake infiltration testing.

5.4.1 Implementation of investigation works

The exploratory holes were logged by an engineer in general accordance with the recommendations of BS 5930:2015 (which incorporates the requirements of BS EN ISO 14688-1, 14688-2 and 14689-1).

The monitoring well construction and associated response zones are detailed on the exploratory hole records in Appendix F. The response zones were installed to target identified gas generation sources or migration pathways detailed in the initial preliminary CSM and to provide groundwater level readings.

The soil sampling and analysis strategy was designed to characterise each encountered soil strata, permit an assessment of the potential contaminant linkages identified and investigate the geotechnical characteristics. In addition, samples were taken to allow for geo-environmental and geotechnical testing to be undertaken.

Soils collected for laboratory analysis were placed in a variety of containers appropriate to the anticipated testing suite required. They were dispatched to the laboratory in cool boxes under chain of custody documentation. Samples were stored in accordance with the RSK quality procedures to maintain sample integrity and preservation and to minimise the chance of cross contamination.

Selected samples were placed in polythene bags for headspace screening with a photo-ionisation detector (PID) fitted with a 10.6 eV bulb. The PID screening results are presented on the exploratory hole records.

5.5 Monitoring programme

5.5.1 Ground gas monitoring

In line with the initial CSM, response zones were installed to target the sources or pathways as detailed in Table 6.

The 3no monitoring rounds scheduled have been undertaken to provide data to support refining of the CSM.

An infrared gas meter was used to measure gas flow, concentrations of carbon dioxide (CO₂), methane (CH₄) and oxygen (O₂) in percentage by volume, while hydrogen sulphide (H₂S) and carbon monoxide (CO) were recorded in parts per million.

The atmospheric pressure before and during monitoring, together with the weather conditions, were recorded.

All ground gas monitoring results obtained thus far, together with the temporal conditions are contained within Appendix G. Equipment calibration certificates are available on request.

5.5.2 Groundwater monitoring and sampling

An initial round of groundwater monitoring was carried out with boreholes sampled for metals and TPH with a subsequent round of monitoring carried out for PAH sampling only. A third monitoring round was carried out where boreholes were dipped to determine depth to resting water levels. The monitoring records are shown in Appendix G.

Development of the monitoring wells following installation was undertaken comprising the removal of three well volumes using a dedicated bailer.

Depths to groundwater were recorded using an interface probe on each of the return monitoring visits.

Groundwater samples were retrieved using dedicated bailers. Water samples were dispatched to the laboratory in cool boxes under chain of custody documentation.

5.6 Laboratory testing

Laboratory testing was undertaken at a UKAS accredited laboratory with ISO17025 and MCERTS accredited test methods were specified where applicable for contamination testing and as shown in the laboratory test certificates appended.

5.6.1 Chemical analysis of soil samples

The soil sampling strategy was designed to characterise made ground and/or natural strata typically within the upper 1.0m of the ground profile whilst also characterising deeper strata and the potential for contaminant migration from relevant sources of identified within the preliminary CSM.

The programme of chemical tests undertaken on soil samples obtained from the intrusive investigation is presented in Table 8 with the laboratory testing results contained in Appendix H.

Table 8: Summary of chemical testing of soil samples

Stratum	Tests undertaken	No. of tests
Made ground	Asbestos screening and ID	8
	Metals (inc CRVI)	8
	PAH	8
	TPHCWG, BTEX, MTBE	4
	VOC's & SVOC's	2
	TOC	8

5.6.2 Chemical analysis of groundwater

Groundwater samples were collected in containers appropriate to the anticipated testing suite required. The containers were filled to capacity and placed in a cool box to minimise volatilisation.

Chemical testing undertaken on water samples obtained during the monitoring programme is presented in Table 9 with the laboratory testing results contained in Appendix H.

Table 9: Summary of chemical testing of soil samples

Sample type	Tests undertaken	No. of tests
Groundwater	As Cd tCr CrVI Cu Ni Pb Zn Hg B Se	1
	EC Electrical Conductivity	
	Chloride (water soluble 2:1)	1
	pH	1
	TPHCWG (C5-36) BTEX & MTBE	1
	DOC	1
	Calcium	1
	Hardness (1mg/l)	1
	Speciated PAH	1

6 SITE INVESTIGATION FACTUAL FINDINGS

The results of the intrusive investigation and subsequent geo-environmental laboratory analysis undertaken are detailed below.

6.1 Ground conditions encountered

The descriptions of the strata encountered, notes regarding visual or olfactory evidence of contamination, list of samples taken, field observations of soil and groundwater, in-situ testing and details of monitoring well installations are included on the exploratory hole records presented in Appendix F.

The exploratory holes revealed that the site is underlain by a variable thickness of made ground over superficial deposits associated with the Blown Sand deposits and Glacial Till underneath. The Coal Measures Bedrock was encountered at depth. This appears to confirm the stratigraphical succession described within the preliminary CSM.

For the purpose of discussion, the ground conditions encountered during the fieldworks are summarised in Table 10 with the strata discussed in subsequent subsections.

Table 10: General succession of strata encountered

Stratum	Exploratory holes encountered	Depth to top of stratum m bgl	Proven thickness (m)
Made ground	All	Ground level	3.2
Blown Sand	All except WS1 and WS4	1.9	12.4
Glacial till	BH2 only	13.0	8.2
Middle Coal Measure bedrock	BH2 only	21.2	Not proven

6.1.1 Made ground

The made ground generally comprised a granular soil with a significant proportion of cohesive matrix and ranged in thickness from 1.9m to 3.2m. It is our understanding the made ground has been used as engineered fill to raise levels. Further to the granular fill encountered, in-situ concrete was identified at varying depths across the site. Anecdotal evidence suggests that in some areas a concrete slab is present at depths of upto 2m. This would correspond with some of the findings during the investigation.

A summary of the in-situ test results recorded in the stratum are presented in Table 11.

Table 11: Summary of in-situ test results for made ground

Soil parameters	Min. Value	Max. Value	Reference
SPT 'N' values	15	>50	Appendix F

Soil parameters	Min. Value	Max. Value	Reference
Notes: n/a			

6.1.2 Blown Sand

This stratum was encountered at a depth of between 1.9m and 3.2m below ground level and varies between 11.1m and 12.2m in thickness. Based on the site descriptions and laboratory and in-situ tests carried out this layer can be described as a medium dense to dense predominately granular soil.

A summary of the in-situ test results recorded in the stratum are presented in Table 12.

Table 12: Summary of in-situ test results for Blown Sand

Soil parameters	Min. Value	Max. Value	Reference
SPT 'N' values	12	>50	Appendix F
Density term	Medium dense	Very dense	Appendix F
Notes: n/a			

6.1.3 Glacial Till

This stratum was encountered from beneath the Blown Sands and comprised a layer of stiff to very stiff gravelly clay and dense to very dense clayey gravels between 13.0m and 21.2m, approximately 8.2m in thickness.

A summary of the in-situ test results recorded in the stratum are presented in Table 13.

Table 13: Summary of in-situ test results for Glacial Till

Soil parameters	Min. Value	Max. Value	Reference
SPT 'N' values	30	>50	Appendix F
Consistency term from field description	Stiff	Very stiff	Appendix F
Notes: n/a			

6.1.4 Coal Measures Bedrock

This stratum was encountered at a depth of 21.1m below ground level in BH2 only, the thickness was not proven. Based on the site descriptions and nearby borehole data, this layer can be described as interbedded mudstone, siltstone and sandstone. Coal was not encountered.

6.1.5 Visual/olfactory evidence of soil contamination

Evidence of Hydrocarbon contamination was noted within WS3 only, within the made ground at 2.0m. Head space analysis of the sample, with the use of a PID, returned a result of 80.2ppm.

Within the same hole olfactory evidence of hydrocarbon contamination was also suspected at 3.25m, head space analysis of the sample returned a result of 10.2ppm. Head space analysis of the strata between the layers returned similar diminishing results with a sample tested at 2.6m returning a result of 11.0ppm.

No visual evidence of asbestos containing material (ACM) was noted.

6.2 Groundwater and surface water

6.2.1 Groundwater encountered during intrusive works

Groundwater was encountered during the intrusive investigation works as detailed on the logs in Appendix F.

6.2.2 Groundwater encountered during monitoring

Rest groundwater levels recorded during the monitoring programme are summarised in Table 14 based on the data provided in Appendix G. Field data measurements are also shown in Appendix G.

Table 14: Summary of groundwater monitoring results

Monitoring well	Response zone stratum	Depth to water (mb TOC)	Product thickness (m)
BH1	Blown Sand	2.76 -3.18	N/A
BH2	Blown Sand	1.78 – 1.90	N/A
WS1	Made Ground	N/A (dry)	N/A
WS3	Made Ground	1.68 – 1.86	N/A

The findings reflect the groundwater table in the Blown Sand deposits, with a potential perched groundwater body within the made ground.

It should be noted that groundwater levels may fluctuate for a number of reasons including seasonal and tidal variations. On-going monitoring would be required to establish both the full range of conditions and any trends in groundwater levels.

6.2.3 Visual/olfactory evidence of groundwater contamination

No evidence of contamination was noted within the water samples.

6.3 Chemical laboratory results

The soil and groundwater testing results are presented in Appendix H.

Loose Actinolite asbestos fibres were identified within 1No sample (TP1 at 0.30m). Subsequent quantification analysis has shown that <0.001% of fibres are present by % weight.

Elevated levels of TPH, PAH and metals have been encountered on site with respect to laboratory limits of detection, however no exceedances of GAC's have been identified for the proposed commercial end use.

6.4 Ground gas monitoring

The results of the ground gas monitoring and testing carried out to date are given in Appendix G and discussed in section 7.5.

6.5 Constraints and Limitations

Due to the site still being in use, with numerous underground services, paved walkways, pathways under constant use by staff/students/groundworkers, all exploratory holes were placed in areas without services in the near vicinity and that was accessible for plant and to avoid unnecessary risk to current site users.

The area of soft landscaping in the central southern/southeast portion of the site was mounded. It is RSK's understanding that a nature reserve is present. Further to this specialised plants and trees have been planted within the south western area. It is RSK's understanding that an ecological survey is due for both areas in the near future.

The presence of concrete and gravel/cobbles with the fill material restricted locations of holes and also the depth and number of exploratory holes that could be achieved.

7 GEO-ENVIRONMENTAL ASSESSMENT

7.1 Refinement of initial CSM

The ground conditions encountered during the intrusive investigation works are such that the initial conceptual site model detailed in **Section 3** is considered representative of the potential risks requiring further assessment.

7.2 Linkages for assessment

In line with CLR11 (Environment Agency, 2004), there are two stages of quantitative risk assessment, generic (GQRA) and detailed (DQRA). The GQRA comprises the comparison of soil, groundwater, soil gas and ground gas results with generic assessment criteria (GAC) that are appropriate to the linkage being assessed. This comparison can be undertaken directly against the laboratory results or following statistical analysis depending upon the sampling procedure that was adopted.

Following the refinement of the initial CSM, the potentially complete contaminant linkages that require further assessment and the methodology of assessment are presented in Table 15.

Table 15: Linkages for GQRA

Potentially relevant contaminant linkage	Assessment method
Soil	
1. Oral, dermal and inhalation exposure with impacted soil and groundwater, soil and groundwater vapour and soil dust by end users.	Human health GAC in Appendix I for a proposed commercial end use.
2. Inhalation exposure of future end users to asbestos fibres	Qualitative assessment based on the asbestos minerals present, their form, concentration, location and the nature of the proposed development.
3. Uptake of contaminants by vegetation potentially impacting plant growth (phytotoxicity)	Comparison of soil data to GAC in Appendix J for phytotoxicity.
4. Contaminants permeating potable water supply pipes	Comparison of soil data to GAC in Appendix K for plastic water supply pipes using UKWIR (2010) guidance.
5. Leaching of soil contaminants and dissolved phase migration	Since no leachate data is available the potential for leaching will be considered qualitatively using soil and groundwater results.

Potentially relevant contaminant linkage	Assessment method
6. Migration of contaminants to wider secondary A aquifer body and controlled water receptors (Severn Estuary)	Comparison of groundwater data to GAC in Appendix L for secondary A aquifer and controlled waters (Transitional estuaries and coastal waters)

7.3 Methodology and assessment of soil results

The analysis of laboratory results relating to soil samples submitted for testing is included in the following sections.

7.3.1 Oral, dermal and inhalation exposure with impacted soil and groundwater by future site users – linkage 1

In order to assess the soil results against the appropriate GAC, the soil results have been split into appropriate data sets relevant to the oral, dermal and inhalation linkage.

Since targeted soil samples were obtained during the site investigation, the results were directly compared to RSK's GAC (where available), as well as readily available GAC selected in accordance with the hierarchy outlined in CLR11.

It has been determined that the use of the generic assessment criteria (GAC) for Human Health (commercial scenario) is most appropriate for the proposed development.

No exceedances for the relevant GAC have been recorded therefore it is considered that the soils and water analysed do not pose a risk to human health through the direct contact pathways.

Anthropogenic material was encountered within the made ground across the site. Although chemical analysis of soil samples indicates that a significant risk is not posed to future site users through direct contact, it is recommended clean cover in any soft landscaping of 0.30m thick is employed to limit contact from future users with potentially undesirable materials.

Inhalation exposure from VOC within groundwater has initially been assessed through the direct comparison of groundwater data with the RSK GrAC presented in Appendix L.

The GrAC for groundwater is based on indoor inhalation exposure to contaminants in the vapour-phase.

The analytical results are below the GrAC indicating that the contaminant linkage with regards to vapours from groundwater is incomplete.

It should be noted that evaluation of VOCs concentrations in groundwater samples provides only an indicative assessment of vapour risks. Construction of dedicated vapour wells and soil vapour sampling would be needed to evaluate this potential linkage further.

7.3.2 Inhalation exposure of future occupants/site users to asbestos fibres – Linkage 2

The laboratory screening for asbestos identified detectable asbestos fibres within 1no samples of made ground. These samples were then further analysed and the presence of fibres of actinolite were confirmed, with a maximum of <0.001 % by weight present in the sample from TP1 at 0.3m depth.

Due to the presence of asbestos fibres, this is not suitable to remain in the shallow soils within an area of soft landscaping and should be capped or removed.

Based on the recorded quantifiable asbestos content, it is unlikely that specialist protection measures under the Control of Asbestos Regulations (CAR) 2012 would be required during construction. However, it would be prudent to remove the localised material as a hotspot excavation prior to general groundworks (regardless of whether it is within proposed soft landscaping or not) to mitigate any residual risk to groundworkers and adjacent site users.

7.3.3 Uptake of contaminants by vegetation potentially inhibiting plant growth (phytotoxicity) – linkage 3

The results have been compared with the GAC presented in Appendix J for this linkage. The soil screening output spreadsheet for this linkage is presented in Appendix M.

The results indicate that a relevant contaminant linkage is unlikely to exist associated with phytotoxic effects.

7.3.4 Impact of organic contaminants on potable water supply pipes - linkage 4

For initial assessment purposes, the results of the investigation have been compared with the GAC presented in Appendix K for this linkage, which are reproduced from *UKWIR Report 10/WM/03/21. Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites* (UKWIR, 2010).

The results indicate that a relevant linkage is unlikely to exist associated with organic contaminants and therefore pollutant polyethylene (PE) and/or polyvinyl chloride (PVC) water supply pipes are expected to be suitable for use on the development.

It should be noted that at the time of this investigation the future routes of water supply pipes had not been established, hence the investigation and sampling strategy may not be fully compliant with UKWIR recommendations.

7.4 Methodology and assessment of water results

7.4.1 Leaching of soil contaminants and dissolved phase migration of contaminants to wider secondary A aquifer body and controlled water receptors (Severn Estuary) – Linkages 5 & 6

The groundwater results found to exceed the GAC protective of groundwater receptors presented in Appendix M are summarised in Table 16.

Table 16: Summary of groundwater GQRA results with respect to wider aquifers for GQRA

Determinand	GAC (µg/l)	Exceedances µg/l
Zinc	6.8	1No BH2 – 14
Benzo(a)pyrene (w)	0.00017	1No BH2 – 0.02
Fluoranthene	0.0063	3No BH1 0.01, BH2 0.58, WS3B 0.02

Table 16 indicates exceedances of the GAC in groundwater are present for PAH and Zinc suggesting that groundwater beneath the site has been marginally impacted. Borehole BH2 was found to be the most impacted at the site with zinc and PAHs. WS3B located down gradient of BH2 indicated moderate exceedances of fluoranthene only with other analytes being below GAC. Given the marginal exceedances of the down gradient borehole WS3B, risks posed to the underlying aquifer and nearby Severn Estuary are considered to be low.

7.5 Ground gas risk assessment

7.5.1 Appropriate guidance

The risks to development from ground gases have been assessed in accordance with BS8485:2015, which provides guidance on ground gas (methane and carbon dioxide) characterisation and hazard assessment, as well as a framework for the prescription of protection measures within new buildings.

The process involves characterising the gas hazard from combining the qualitative assessment of risk (using the conceptual site model) with ground investigation data so that a 'characteristic situation' (CS) can be derived for the site. Characteristic situations range from CS1 to CS6, the higher the CS the higher the hazard potential. Protection measures within new buildings can be prescribed using a point scoring system, taking into consideration the CS and the proposed building type.

BS8485 indicates that the gas hazard can be characterised using the following methods:

- an empirical semi-quantitative approach using gas monitoring data to determine the 'characteristic situation' of the site (or zones of the site) and subsequent protective measures (Wilson and Card approach).

- an empirical semi-quantitative approach using TOC data to determine the 'characteristic situation' of the site (or zones of the site) and subsequent protective measures (CL:AIRE RB17 approach); or
- detailed quantitative assessment methodologies.

For the purpose of this assessment, the first approach listed above has been used to characterise the gas hazard and provide advice on the protective measures likely to be required within new buildings at the site.

7.5.2 Empirical semi-quantitative approach using borehole monitoring data (Wilson and Card approach)

7.5.2.1 Permanent gases – methane and carbon dioxide

The empirical semi quantitative approach using gas monitoring data is based on calculations of the gas screening value (GSV). BS8485 defines the GSV as the 'flow rate (l/hr) of a specific hazardous gas representative of a site or zone, derived from assessment of borehole concentration and flow rate measurements and taking account of all other influencing factors, in accordance with a conceptual site model'.

Once derived for both methane and carbon dioxide the GSVs are compared to the thresholds presented in Table 2 of BS8485, so that a CS can be determined for the site, or a zone. It is important to note that the GSV thresholds are guideline values and not absolute. The GSV thresholds may be exceeded in certain circumstances, if the site conceptual model indicates it is safe to do so. Similarly, consideration of additional factors such as very high concentrations of methane, should lead to consideration of the need to adopt a higher risk classification than the GSV threshold indicates.

The results of the ground gas monitoring and testing undertaken at the site are given in Appendix G.

The maximum results recorded are presented in Table 18.

The range of atmospheric pressure over the monitoring rounds was between 999-1022 mbar.

Table 18: Ground Gas Monitoring

Borehole	Response zone/ stratum	Probable source(s) of ground gas	Number of monitoring visits	Methane (%)	Carbon dioxide (%)	Oxygen (%)	Flow rate (l/hr)	Water level (m b TOC)	Atmospheric pressure (mbar)
BH1	Blown Sands/ Glacial	Natural deposits	3	<0.1	0.1	20.5-20.9	0.1	2.76-3.18	999 - 1022

Borehole	Response zone/ stratum	Probable source(s) of ground gas	Number of monitoring visits	Methane (%)	Carbon dioxide (%)	Oxygen (%)	Flow rate (l/hr)	Water level (m b TOC)	Atmospheric pressure (mbar)
	Till								
WS1	Made Ground	Made Ground	3	<0.1	0.1	20.0-20.5	0	Dry	
Note: Maximum concentrations for CH₄ and CO₂ and flows and lowest concentrations of O₂ are presented in this table. BH2 and WS3B have been discounted as the groundwater level was above the slotted screen									

BS8485 suggests that the GSV should be derived by multiplying the worse credible (worst case) recorded flow value in any standpipe in that strata or zone with the maximum gas concentration in any other standpipe in that strata or zone. Further guidance is given in BS8485 section 6.3.

A spreadsheet showing the calculated hazardous gas flow rates per borehole is provided in Appendix G. Considering the assessment of the gas monitoring results the following maximum GSVs have been derived for the site.

- methane GSV (0 l/hr) = methane concentration (0.1 % v/v) x flow rate (0 l/hr)
- Carbon Dioxide GSV (0.014 l/hr) = carbon dioxide concentration (0.1 % v/v) x flow rate (0.1 l/hr).

Based on the GSVs derived and the method for determining the CS presented within Table 2 of BS8485, the site has been characterised as CS1.

7.5.3 Implications

Based on the current understanding of the conceptual site model and the assessment undertaken, the site has been classified as CS1. Considering the foregoing and in accordance with BS8485, ground gas protective measures are not considered necessary within proposed buildings.

7.6 Uncertainties and implications in refined CSM and GQRA

With regards to the Conceptual Model, the results of the GQRA indicate that the majority of the pollutant linkages identified do not require remedial measures. The exception to this is the presence of asbestos fibres within TP1; the soils in this location will either need to be removed or capped if within an area of soft landscaping. Further to this is considered prudent to include for capping of all soft landscaped areas due to the present of Made Ground containing various anthropogenic materials.

Measured concentrations of Zinc, Fluoranthene and benzo(a)pyrene in groundwater have been identified in excess of the EQS for transitional and coastal water standards. Based on current site conditions potential risks to the underlying Secondary B aquifer are considered to be below as the Blown Sand deposits are likely to be already impacted from historical activities in the area and down gradient well WS3B was found only to be minimally impacted. However, increased infiltration following removal of hardstanding across the site during development will increase the risks to the underlying aquifer. The impacts identified are anticipated to be associated with the historic infrastructure and the oil storage tank within the area.

It is possible that the works may reveal different conditions from those revealed by the site investigation (i.e. the presence of discrete/visually identifiable asbestos inclusions). If this is the case, works should cease pending sampling and analysis of any suspect materials to confirm their nature. It is recommended that the Local Authority be contacted at an early stage to seek their views on the assessment of contamination on the site.

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Geo-environmental assessment

Environmental conclusions based on the findings of the investigation are summarised below:

- There is no evidence of any significant contamination at the site with regards to the underlying soils. Based upon the testing carried out to date no exceedances of human health or phytotoxic GAC for the proposed end use have been recorded;
- The concentration of petroleum hydrocarbons locally did not exceed the suitability criteria for PE potable waterpipes. The local water supplier should be contacted to confirm the requirements of water supply pipes;

Reasonable steps have been taken to characterise potential sources of contamination at the site, however the presence of further localised impacted soils between sampling locations cannot be discounted.

Made ground is widespread at the site and generally comprised of granular material with varying degrees of anthropogenic input (bricks, concrete, slag). Based on this and the presence of asbestos fibres within TP1, it is recommended that all soft landscaped areas are capped by 0.30m of suitable clean cover material. It may be prudent to remove the asbestos impacted soils as a hotspot excavation to mitigate any residual risk during construction.

Measured concentrations of Zinc, Fluoranthene and benzo(a)pyrene in groundwater have been identified in excess of the EQS for transitional and coastal water standards. Based on current site conditions potential risks to the underlying Secondary B aquifer are considered to be low. However, increased infiltration following removal of hardstanding across the site during development will increase the risks to the underlying aquifer. The impacts identified are anticipated to be associated with the historic infrastructure and the oil storage tank within the area respectively.

Should unforeseen contamination be encountered during the development then specialist advice should be sought to determine the appropriate course of action.

All imported material should be validated before use on-site to confirm its suitability.

8.2 Geotechnical assessment

The findings of the geotechnical assessment will be provided within a separate Geotechnical design report:

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FIGURES



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AECOM Ltd

Project Title

Swansea University Bay Campus

Drawing Title

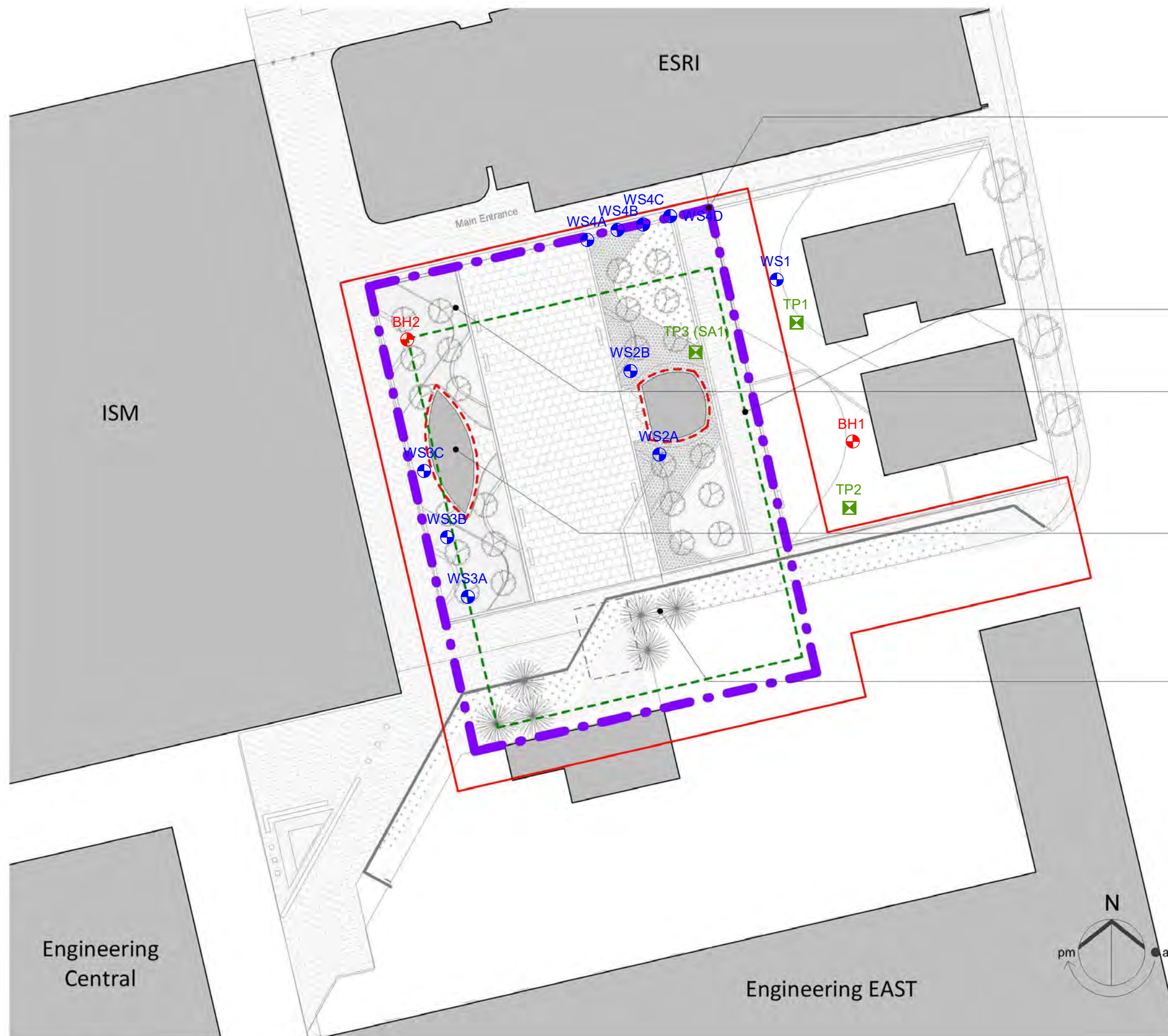
SITE LOCATION MAP

Rev	Drawn	Date	Checked	Date	Approved	Date
00	NP	03.02.20	AH	03.02.20	-	-
Dimensions		Scale		Original Size		
m		1:25,000		A4		

Project Number	Grid Ref
314617	SS 702 928



Drawing Number
FIGURE 1



Zone of

- Hard
- Soft
- Cycle
- ORACLE
- Indust
- Prop

Propose

ORACLE
line with
CISM Ex

Cycle sh
relocate
drawing
Building

Soft land
fence to
line bou

LEGEND

- TP1
Machine Excavated Trial Pit
- WS1
Dynamic (Window) Sampler Borehole
- BH1
Cable Percussion Borehole

NOTES

Drawing edited from 'Existing Site Plan and Demolition Plan - CISM SU Bay Campus' (DWG No. 152296-STL-2222-XX-PR -A-XX-19000 Rev P1) drawn by Stride Treglown dated 09.08.19.

00	14.02.2020	-	AH	CL	CL
Rev.	Date	Amendment	Drawn	Chkd.	Appd.



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Client
AECOM

Project Title
Swansea University Bay Campus

Drawing Title
Exploratory Hole Location Plan

Drawn	Date	Checked	Date	Approved	Date
AH	14.02.20	CL	14.02.20	CL	14.02.20

Dimensions	Scale	Original Size
m	NTS	A3

Project Number	Drawing Number
314617	-

Drawing File	Rev
314617 - EHLP	00

Site Plan. Existing and demolition
1 : 500

APPENDIX A

SERVICE CONSTRAINTS

1. This report and the site investigation carried out in connection with the report (together the "Services") were compiled and carried out by RSK Environment Limited (RSK) for AECOM Ltd (the "Client") in accordance with RSK Environment Standard Terms and Conditions between RSK and the Client, dated 11th December 2019. The Services were performed by RSK with the reasonable skill and care ordinarily exercised by an environmental consultant at the time the Services were performed. Further, and in particular, the Services were performed by RSK taking into account the limits of the scope of works required by the client, the time scale involved and the resources, including financial and manpower resources, agreed between RSK and the Client.
2. Other than that, expressly contained in paragraph 1 above, RSK provides no other representation or warranty whether express or implied, in relation to the Services.
3. Unless otherwise agreed in writing, the Services were performed by RSK exclusively for the purposes of the Client. RSK is not aware of any interest of or reliance by any party other than the Client in or on the Services. Unless expressly provided in writing, RSK does not authorise, consent or condone any party other than the client relying upon the Services. Should this report or any part of this report, or otherwise details of the Services or any part of the Services be made known to any such party, and such party relies thereon that party does so wholly at its own and sole risk and RSK disclaims any liability to such parties. **Any such party would be well advised to seek independent advice from a competent environmental consultant and/or lawyer.**
4. It is RSK's understanding that this report is to be used for the purpose described in the introduction to the report. That purpose was a significant factor in determining the scope and level of the Services. Should the purpose for which the report is used, or the proposed use of the site change, this report may no longer be valid and any further use of or reliance upon the report in those circumstances by the client without RSK 's review and advice shall be at the client's sole and own risk. Should RSK be requested to review the report after the date of this report, RSK shall be entitled to additional payment at the then existing rates or such other terms as agreed between RSK and the client.
5. The passage of time may result in changes in site conditions, regulatory or other legal provisions, technology or economic conditions which could render the report inaccurate or unreliable. The information and conclusions contained in this report should not be relied upon in the future without the written advice of RSK. In the absence of such written advice of RSK, reliance on the report in the future shall be at the Client's own and sole risk. Should RSK be requested to review the report in the future, RSK shall be entitled to additional payment at the then existing rate or such other terms as may be agreed between RSK and the client.
6. The observations and conclusions described in this report are based solely upon the Services which were provided pursuant to the agreement between the Client and RSK. RSK has not performed any observations, investigations, studies or testing not specifically set out or required by the contract between the client and RSK. RSK is not liable for the existence of any condition, the discovery of which would require performance of services not otherwise contained in the Services. For the avoidance of doubt, unless otherwise expressly referred to in the introduction to this report, RSK did not seek to evaluate the presence on or off the site of asbestos, invasive plants, electromagnetic fields, lead paint, heavy metals, radon gas or other radioactive or hazardous materials, unless specifically identified in the Services.
7. The Services are based upon RSK's observations of existing physical conditions at the Site gained from a visual inspection of the site together with RSK's interpretation of information, including documentation, obtained from third parties and from the Client on the history and usage of the site, unless specifically identified in the Services or accreditation system (such as UKAS ISO 17020:2012 clause 7.1.6):
 - a. The Services were based on information and/or analysis provided by independent testing and information services or laboratories upon which RSK was reasonably entitled to rely.



- b. The Services were limited by the accuracy of the information, including documentation, reviewed by RSK and the observations possible at the time of the visual inspection.
- c. The Services did not attempt to independently verify the accuracy or completeness of information, documentation or materials received from the client or third parties, including laboratories and information services, during the performance of the Services.

RSK is not liable for any inaccurate information or conclusions, the discovery of which inaccuracies required the doing of any act including the gathering of any information which was not reasonably available to RSK and including the doing of any independent investigation of the information provided to RSK save as otherwise provided in the terms of the contract between the Client and RSK.

- 8. The intrusive environmental site investigation aspects of the Services are a limited sampling of the site at pre-determined locations based on the known historic / operational configuration of the site. The conclusions given in this report are based on information gathered at the specific test locations and can only be extrapolated to an undefined limited area around those locations. The extent of the limited area depends on the properties of the materials adjacent and local conditions, together with the position of any current structures and underground utilities and facilities, and natural and other activities on site. In addition, chemical analysis was carried out for a limited number of parameters (as stipulated in the scope between the client and RSK, based on an understanding of the available operational and historical information) and it should not be inferred that other chemical species are not present.
- 9. Any site drawing(s) provided in this report is (are) not meant to be an accurate base plan but is (are) used to present the general relative locations of features on, and surrounding, the site. Features (intrusive and sample locations etc) annotated on site plans are not drawn to scale but are centred over the approximate location. Such features should not be used for setting out and should be considered indicative only.
- 10. The comments given in this report and the opinions expressed are based on the ground conditions encountered during the site work and on the results of tests made in the field and in the laboratory. However, there may be conditions pertaining to the site that have not been disclosed by the investigation and therefore could not be taken into account. In particular, it should be noted that there may be areas of made ground not detected due to the limited nature of the investigation or the thickness and quality of made ground across the site may be variable. In addition, groundwater levels and ground gas concentrations and flows, may vary from those reported due to seasonal, or other, effects and the limitations stated in the data should be recognised.
- 11. Asbestos is often observed to be present in soils in discrete areas. Whilst asbestos-containing materials may have been locally encountered during the fieldworks or supporting laboratory analysis, the history of brownfield and demolition sites indicates that asbestos fibres may be present more widely in soils and aggregates, which could be encountered during more extensive ground works.
- 12. Unless stated otherwise, only preliminary geotechnical recommendations are presented in this report and these should be verified in a Geotechnical Design Report, once proposed construction and structural design proposals are confirmed.

APPENDIX B

SUMMARY OF LEGISLATION AND POLICY RELATING TO CONTAMINATED LAND

Part IIA of the Environmental Protection Act 1990 (EPA) and its associated Contaminated Land Regulations 2000 (SI 2000/227), which came into force in England on 1 April 2000, formed the basis for the current regulatory framework and the statutory regime for the identification and remediation of contaminated land. Part IIA of the EPA 1990 defines contaminated land as 'any land which appears to the Local Authority in whose area it is situated to be in such a condition by reason of substances in, on or under the land, that significant harm is being caused, or that there is significant possibility of significant harm being caused, or that pollution of controlled waters is being or is likely to be caused'. Controlled waters are considered all groundwater, inland waters and estuaries.

In August 2006, the Contaminated Land (England) Regulations 2006 (SI 2006/1380) were implemented, which extended the statutory regime to include Part IIA of the EPA as originally introduced on 1 April 2000, together with changes intended chiefly to address land that is contaminated by virtue of radioactivity. These have been replaced subsequently by the Contaminated Land (England) (Amendment) Regulations 2012, which now exclude land that is contaminated by virtue of radioactivity.

The intention of Part IIA of the EPA is to deal with contaminated land issues that are considered to cause significant harm on land that is not undergoing development (see Environmental Protection Act 1990: Part 2A Contaminated Land Statutory Guidance, April 2012). This document replaces Annex III of Defra Circular 01/2006, published in September 2006 (the remainder of this document is now obsolete).

Water Framework Directive (WFD)

The Water Framework Directive 2000/60/EC is designed to:

- enhance the status and prevent further deterioration of aquatic ecosystems and associated wetlands that depend on the aquatic ecosystems
- promote the sustainable use of water
- reduce pollution of water, especially by 'priority' and 'priority hazardous' substances
- ensure progressive reduction of groundwater pollution.

The WFD requires a management plan for each river basin be developed every six years.

Groundwater Directive (GWD)

The 1980 Groundwater Directive 80/68/EEC and the 2006 Groundwater Daughter Directive 2006/118/EC of the WFD are the main European legislation in place to protect groundwater. The

1980 Directive is due to be repealed in December 2013. The European legislation has been transposed into national legislation by regulations and directions to the Environment Agency.

Environmental Permitting Regulations (EPR)

The Environmental Permitting (England and Wales) Regulations 2010 provide a single regulatory framework that streamlines and integrates waste management licensing, pollution prevention and control, water discharge consenting, groundwater authorisations, and radioactive substances regulation. Schedule 22, paragraph 6 of EPR 2010 states: 'the regulator must, in exercising its relevant functions, take all necessary measures - (a) to prevent the input of any hazardous substance to groundwater; and (b) to limit the input of non-hazardous pollutants to groundwater so as to ensure that such inputs do not cause pollution of groundwater.'

Water Resources Act (WRA)

The Water Resources Act 1991 (Amendment) (England and Wales) Regulations 2009 updated the Water Resources Act 1991, which introduced the offence of causing or knowingly permitting pollution of controlled waters. The Act provides the Environment Agency with powers to implement remediation necessary to protect controlled waters and recover all reasonable costs of doing so.

Priority Substances Directive (PSD)

The Priority Substances Directive 2008/105/EC is a 'Daughter' Directive of the WFD, which sets out a priority list of substances posing a threat to or via the aquatic environment. The PSD establishes environmental quality standards for priority substances, which have been set at concentrations that are safe for the aquatic environment and for human health. In addition, there is a further aim of reducing (or eliminating) pollution of surface water (rivers, lakes, estuaries and coastal waters) by pollutants on the list. The WFD requires that countries establish a list of dangerous substances that are being discharged and EQS for them. In England and Wales, this list is provided in the River Basin Districts Typology, Standards and Groundwater threshold values (Water Framework Directive) (England and Wales) Directions 2010. In order to achieve the objectives of the WFD, classification schemes are used to describe where the water environment is of good quality and where it may require improvement.

Contaminated land is often dealt with through planning because of land redevelopment. This approach is documented in Planning Policy Statement: Planning and Pollution Control PPS23, which states that it remains the responsibility of the landowner and developer to identify land affected by contamination and carry out sufficient remediation to render the land suitable for use. The overall aim of the planning and pollution control policy is to promote the sustainable and beneficial use of land (in particular, encouraging reuse of previously developed land in preference to greenfield sites). Within this aim, polluting activities that are necessary for society and the economy should be so sited and planned, and subject to such planning conditions, that their adverse effects are minimised and contained to within acceptable limits.



APPENDIX C PHOTOGRAPHIC LOG

PHOTOGRAPHIC LOG

Site Location: Swansea University Bay Campus, Swansea

Photo No.
1

Date:
21/01/2020

General view
of site facing
north



Photo No.
2

Date:
21/01/2020

General view
of site facing
southwest
from
northeast
portion



PHOTOGRAPHIC LOG

Site Location: Swansea University Bay Campus, Swansea

Photo No.
3

Date:
21/01/2020

General view
of site facing
southwest
from
northeast
portion



Photo No.
4

Date:
21/01/2020

General view
of site facing
northwest
from
southeast
portion



PHOTOGRAPHIC LOG

Site Location: Swansea University Bay Campus, Swansea

Photo No.
5

Date:
21/01/2020

General view of area in central portion showing paved pathway. Bike shed and pathway were in constant use. Services indicated underlying slabs.



Photo No.
6

Date:
21/01/2020

General view of western portion of site. Further live services identified showing to cross pathway



PHOTOGRAPHIC LOG

Site Location: Swansea University Bay Campus, Swansea

Photo No.
7

Date:
21/01/2020

Further view of walkway in western portion with potential service identified in the bottom centre of picture.



Photo No.
8

Date:
21/01/2020

General view of area in northern portion. Numerous visible services and further service running close to base of slope (BT)



PHOTOGRAPHIC LOG

Site Location: Swansea University Bay Campus, Swansea

Photo No.
9

Date:
21/01/2020

Further view of western portion with potential service identified trending across the soft landscaping.



Photo No.
10

Date:
21/01/2020

General view of area in southern portion with services identified underlying the gravel surface



PHOTOGRAPHIC LOG

Site Location: Swansea University Bay Campus, Swansea

Photo No.
11

Date:
21/01/2020

View along southern wall of ESRI building showing 2No drainage runs north of the site.



Photo No.
12

Date:
21/01/2020

Services identified in southwest portion.



PHOTOGRAPHIC LOG

Site Location: Swansea University Bay Campus, Swansea

Photo No.
13

Date:
21/01/2020

General view of TP1. Note membrane and coarse gravel/cobble limestone.



Photo No.
14

Date:
21/01/2020

View of arisings from TP1.



PHOTOGRAPHIC LOG

Site Location: Swansea University Bay Campus, Swansea

Photo No.
15

Date:
21/01/2020

General
view of
infiltration
test in TP2.



Photo No.
16

Date:
21/01/2020

General
view of
arising
from TP2



PHOTOGRAPHIC LOG

Site Location: Swansea University Bay Campus, Swansea

Photo No.
17

Date:
21/01/2020

General
view of
infiltration
test in TP3.



Photo No.
18

Date:
21/01/2020

General
view of
arising
from TP3



PHOTOGRAPHIC LOG

Site Location: Swansea University Bay Campus, Swansea

Photo No.
19

Date:
22/01/2020

General
view of
arising
WS1.



Photo No.
20

Date:
22/01/2020

General
view failed
hand pit for
WS2. Note
concrete in
centre of pit.

