9 GROUND CONDITIONS

9.1 Introduction

9.1.1 This Chapter, prepared by Arup, reports the likely significant effects of the Proposed Development in terms of Ground Conditions (including major hazards) in the context of the Site and surrounding area. In particular it considers the likely significant effects on geology, soil resources, hydrogeology and contamination.

9.1.2 This Chapter (and its associated appendices) is not intended to be read as a standalone assessment and reference should be made to the front end of this ES (Chapters 1 – 6), as well as the final chapters, 'Summary of Residual and Cumulative Effects' and 'Conclusions' (Chapters 21 - 22).

9.1.3 This Chapter makes use of available information for the Arena and Hotel development, making reference to the Desk Study and Geotechnical and Geoenvironmental Interpretative Report detailed in Section 9.1.4. Additional desk study information has been added to the Chapter to ensure coverage of the Proposed Development Site. Areas of the Atlantic Wharf, Butetown Masterplan are at different stages of development, and as such, at this stage more information is available for the Arena and Hotel area of the Site.

9.1.4 The following appendices are attached to this Chapter:

- Appendix 9.1: Legislation, Policy and Guidance.
- Appendix 9.2: Mott MacDonald, 'Cardiff Arena Desk Study 412678 | 0001 | P04', Cardiff, 2020. Referred to subsequently as the Desk Study.
- Appendix 9.3: Envirotreat, 'Cardiff Arena Factual Ground Investigation Report', 2020. Referred to subsequently as the Factual Ground Investigation Report (Covering both Appendix 9.3 and Appendix 9.4).
- Appendix 9.4: Envirotreat, 'Cardiff Arena Additional Factual Ground Investigation Report', 2021. Referred to subsequently as the Factual Ground Investigation Report (Covering both Appendix 9.3 and Appendix 9.4).
- Appendix 9.5: Arup, 'Cardiff Arena Geotechnical and Geoenvironmental Interpretative Report', CAH-ARP-XX-XX-RP-Y-10-0001, 2021. Referred to subsequently as the Geotechnical and Geoenvironmental Interpretative Report.

9.2 Legislation, Policy and Guidance

9.2.1 The relevant legislation, policy and guidance are listed below, with details provided in Appendix 9.1.

Legislative Framework

9.2.2 The applicable legislative framework is summarised as follows:

- Part IIA of the Environmental Protection Act 1990
- Environment Act 1995
- Environment (Wales) Act 2016
- Contaminated Land (Wales) Regulations 2006, (as amended in 2012)
- Environmental Permitting Regulations 2016, (as amended)
- Wildlife and Countryside Act 1981 (as amended)
- National Parks and Access to the Countryside Act 1949

9.2.3 The Environment (Amendment etc.) (EU Exit) Regulations 2019 came into force in accordance with the European Union (Withdrawal) Act 2018 on 31st December 2020. Part 2 amends Environmental Protection Act 1990, the Environment Act 1995 and the Contaminated Land (Wales) Regulations 2006.

9.2.4 A list of additional legislation and guidance considered within this assessment and relating to contamination and water environment includes:

- Water Resources Act 1991 as amended in Wales by the Water Resources Act 1991 (Amendment) (England and Wales) Regulations 2009
- EU Water Framework Directive (WFD) 2000/60/EC (as amended by supplementary directives and decisions)
- The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017 which implement Water Framework Directive (2000/60/EC), and transpose aspects of the Groundwater Directive (2006/118/EEC) and the Priority Substances Directive (2008/105/EC)
- The Water Framework Directive (Standards & Classification) Directions (England and Wales) 2015

- The Groundwater (Water Framework Directive) (Wales) Direction 2016
- The Environmental Damage (Prevention and Remediation) (Wales) Regulations 2009
- Flood and Water Management Act 2010

Planning Policy

9.2.5 The applicable planning policy is summarised as follows:

- Planning Policy Wales (Edition 11, February 2021)
- Future Wales: The National Plan 2040 (February 2021)
- Cardiff Local Development Plan 2006 – 2026 (Adopted January 2016)

Guidance

9.2.6 The applicable key guidance is summarised as follows:

- Design Manual for Roads and Bridges (DMRB) Guidance LA 104 Environmental assessment and monitoring (referred to hereafter as 'LA 104')
- DMRB Guidance LA 109 Geology and soils
- Land contamination risk management (LCRM) guidance
- Development of Land Affected by Contamination: A Guide for Developers
- Cardiff Council, Cardiff Green Infrastructure SPG, Soils and Development, Technical Guidance Note (Consultation Draft) June 2017
- DEFRA Construction code of practice for the sustainable use of soils on construction sites, 2009
- BS 5930:2015: Code of Practice for Site Investigations (as amended)
- BS 10175:2011: Code of Practice for Investigation of Potentially Contaminated Sites (as amended)
- Groundwater protection guidance, including the Environment Agency's approach to groundwater protection
- CIRIA 552: Contaminated Land Risk Assessment, A guide to good practice
- CIRIA 681: Unexploded ordnance (UXO) A guide for the construction industry

- CL:AIRE Definition of Waste: Development Industry Code of Practice
- Eurocode 7 (BS EN 1997-1 & EN 1997-2) and all relevant normatives
- Natural Resources Wales (NRW) Guidance for Pollution Prevention (these replace the withdrawn Pollution Prevention Guidance (PPG)) of relevance in relation to protection of soils and waters.

9.3 Assessment Methodology and Significance Criteria

Scope of the Assessment

9.3.1 The assessment will consider the potential for significant environmental effects on sensitive receptors during construction and operational phases of the Proposed Development.

9.3.2 It is anticipated that sensitive receptors potentially affected by the Proposed Development during construction will be:

- demolition / construction workers, given the potential for human health hazards during such works; and
- groundwater due to potential for pollution arising from construction phase activities.

9.3.3 It is anticipated that sensitive receptors potentially affected by the Proposed Development during operation will be:

- Site end users and maintenance workers exposed to the potential sources of contamination present within the Proposed Development area such as reused made ground and ground gas; this may impact the identified human receptors. If made ground was reused within landscaped areas, it may result in leaching of contaminants into the underlying groundwater.

9.3.4 Piled foundations may be required. This may impact human and environmental receptors. This may result in the creation of pathways for contamination and ground gas migration.

Effects Not Considered within the Scope

9.3.5 No effects have been scoped out from the assessment.

Extent of the Study Area

9.3.6 The study area will include all potential contaminated land sites that intersect the Proposed Development and those sites that have plausible pollutant linkages that may impact the Proposed Development, typically within 250 metres (m) of the Site. However, contamination pollution linkages will be considered on a case by case basis.

9.3.7 The study area used to assess the potential impacts on geology and hydrogeology will consider features within the redline boundary of the Proposed Development, as well as hydrogeological features and sensitive receptors within 500m of the Proposed Development.

Consultation Undertaken to Date

9.3.8 The pre-application and scoping responses with respect to the ground conditions assessment from Cardiff Council (CC) and Natural Resources Wales (NRW) are detailed in Table 9.1.

Table 9.1: Summary of Consultation Undertaken to Date

Organisation	Individual(s)	Meeting Date and other forms of Consultation	Summary of Outcome of Discussion
Natural Resources Wales	Paige Minahan, Advisor – Development Planning	Scoping response dated 14th July 2021	NRW acknowledged the Site's industrial history and potential for significant contamination and proposed assessment approach. Should the ES conclude that remediation is necessary, a verification plan outlining monitoring programmes would be required. NRW welcomed the approach to maximise retention of materials on-site in line with CL:AIRE Definition of Waste Code of Practice and the use of a Materials Management Plan. Should significant contamination be identified, a controlled waters piling risk assessment may be required.
Cardiff Council	N/A	Pre-application consultation response	With respect to climate change, CC underline the importance of trees and soils as carbon sinks and as playing crucial role in mitigating the effects of climate change at the local level. Landscaping details should be upfront with any full or reserved matters

Table 9.1: Summary of Consultation Undertaken to Date			
Organisation	**Individual(s)**	**Meeting Date and other forms of Consultation**	**Summary of Outcome of Discussion**
			application and comprise topsoil and subsoil specification for all planting types, including full details of soil assessment in accordance with the Cardiff Council Soils and Development Technical Guidance Note (Soils TGN), soil protection, soil stripping, soil storage, soil handling, soil amelioration, soil remediation and soil placement to ensure it is fit for purpose. Where imported planting soils are proposed, full specification details shall be provided including the parameters for all imported planting soils, a soil scientist's interpretive report demonstrating that the planting soil not only meets British Standards, but is suitable for the specific landscape type(s) proposed. The specification shall be supported by a methodology for storage, handling, amelioration and placement. A Soil Resource Survey and Plan (see the Soils TGN) informing landscaping details and specifications will be required.
Cardiff Harbour Authority / Cardiff Council	Gareth Ballett Principal Engineer, Maintenance	Email response dated 23rd July 2021	It is understood that the agreement between the Cardiff Harbour Authority and Natural Resources Wales allows for impoundment levels for Cardiff Bay of between +4.0m and +4.8m Ordnance Datum (OD). The Bay level outside of summer / low river level periods is normally held and regulated at 4.55mAbove Ordnance Datum (AOD).

Assessment Methodology

9.3.9 The methodology includes a review of the existing baseline conditions which are used to assess the potential impacts due to the construction and operation of the Proposed

Development.

9.3.10 The following sources of information have been consulted:

- Available 1:10,000 and 1:2,500 scale historical and present-day Ordnance Survey maps, dating between 1880 and 2020
- Available historical and present-day aerial photography, dating between 1942 and 2020
- Geological mapping information obtained from the British Geological Survey (BGS)
- BGS online GeoIndex Onshore database and the BGS Lexicon
- Topographic maps and information
- Environmental sensitivity information from the Lle database
- Available recent and historical ground investigation reports. Intrusive investigations within the Arena and Hotel site from 2020 and 2021. The results and assessments of the encountered ground conditions are presented in the Factual Ground Investigation Reports (enclosed in Appendix 9.3 and 9.4)
- Information gathered from the relevant statutory bodies and the local planning authorities, as detailed in Section 9.3
- Desk study review of the Arena development completed to support the design of the Proposed Development. This is presented in Appendix 9.2
- Geotechnical and Geoenvironmental Interpretative Report (enclosed in Appendix 9.5)

9.3.11 The above information has been used to develop Conceptual Site Models (CSMs) in order to identify sensitive receptors that could be potential affected by the Proposed Development.

9.3.12 The assessment of risks associated with contaminated land has been based on the risk management framework provided in the guidance on 'Land contamination: risk management'. This has involved preparation of a CSM for the baseline conditions, which has formed the basis for preliminary (qualitative) followed by generic quantitative and, if required, detailed quantitative risk assessments.

9.3.13 A preliminary assessment has been undertaken to assess the potential impacts on

ground conditions during construction and operation and to determine the likely significance of such impacts from land contamination.

9.3.14 The need for further focused assessment has been considered where existing or suspected contaminated land may have an effect as a result of construction and operation, i.e. by creating or altering pollutant linkages between sources of potential contaminants and sensitive receptors such as people, surface water and groundwater bodies.

9.3.15 The conceptual site models have been used to establish the risks posed by the viable pollution linkages and the need or otherwise for further land contamination assessments.

9.3.16 The impact assessment of land contamination has been undertaken on the identified viable pollution linkages. The assessment criteria, including the sensitivity of the receptors and magnitude of impact will be derived from the DMRB guidance – 'LA109 Geology and soils'.

9.3.17 The impacts and effects on the ground conditions arising from construction has been assessed by review of baseline conditions in the context of the extent, method and programme of the proposed construction activities that will be required. These have been outlined in Chapter 3(Development Description) and will be outlined in the Construction Environmental Management Plan (CEMP).

9.3.18 Assessment of the likely impact on the ground conditions arising from the operation has been undertaken by a review of baseline conditions in the context of the final end use.

9.3.19 Potential interrelationships have been identified between the ES chapters concerned with water resources, air quality (dust) and climate change. The assessment of effects has taken into account these interrelationships.

Significance Criteria

9.3.20 The significance of impacts has been assessed by attributing a value or sensitivity to each receptor impacted, in combination with the magnitude of impact that will occur to it. The sensitivity of each receptor has been assessed in line with Table 9.2, and the magnitude of impact in accordance with Table 9.3.

9.3.21 The significance of impact has then been assessed by considering the sensitivity of the

receptors in combination with the magnitude of impact in accordance with Table 9.4.

9.3.22 The criteria of sensitivity, magnitude of impact and evaluation of effects have been adopted from the DMRB guidance for the assessment of potential impacts on soils and geology (LA109).

9.3.23 Effects that are deemed to be significant for the purposes of this assessment are those that are described as being of a moderate or major beneficial or adverse level.

Table 9.2: Criteria and EIA Definitions of Sensitivity or Value

Value (sensitivity)	Typical Descriptors
Very high	Geology: Very rare and of international importance with no potential for replacement (e.g. UNESCO World Heritage Sites, UNESCO Global Geoparks, Site of Special Scientific Interest (SSSI) and Geological Conservation Review sites where citations indicate features of international importance). Geology meeting international designation citation criteria which is not designated as such. Soils: Soils directly supporting an EU designated site (e.g. SAC, SPA, Ramsar). Land Contamination: Human health: High sensitivity land use scenario such as residential and allotments. Controlled waters (Groundwater / Surface water): as per sensitivity value assigned in ES Chapter 8 (Water Resources).
High	Geology: Rare and of national importance with little potential for replacement (e.g. geological SSSI). Geology meeting national designation citation criteria which is not designated as such. Soils: Soils directly supporting a UK designated site (e.g. SSSI). Land Contamination: Human health: High sensitivity land use scenario such as public open space. Controlled waters (Groundwater / Surface water): as per sensitivity value assigned in ES Chapter 8 (Water Resources).
Medium	Geology: Of regional importance with little potential for replacement (e.g. Regionally Important Geological Sites). Geology meeting national designation citation criteria which is not designated as such. Soils: Soils supporting non-statutory designated sites (e.g. Local Nature Reserves, Local Geological / Geodiversity Sites, Sites of Nature Conservation Importance).

Table 9.2: Criteria and EIA Definitions of Sensitivity or Value	
Value (sensitivity)	**Typical Descriptors**
	Land Contamination: Human health: Medium sensitivity land use scenario such as commercial or industrial. Controlled waters (Groundwater / Surface water): as per sensitivity value assigned in ES Chapter 8 (Water Resources).
Low	Geology: Of local importance / interest with potential for replacement (e.g. non-designated geological exposures, former quarry / mining site). Soils: Soils supporting non-designated notable or priority habitats. Land Contamination: Human health: Medium sensitivity land use scenario such as construction site, highways or rail. Controlled waters (Groundwater/ Surface water): as per sensitivity value assigned in ES Chapter 8 (Water Resources).
Negligible	Geology: No geological exposures, little / no local interest. Soils: Previously developed land formerly in 'hard uses'. Land Contamination: Human health: undeveloped surplus land / no sensitive land use proposed. Controlled waters (Groundwater / Surface water): as per sensitivity value assigned in ES Chapter 8 (Water Resources).

Table 9.3: Criteria and EIA Definitions of Impact Magnitude	
Magnitude of Impact	**Typical Criteria Descriptors**
Major	Geology: Loss of geological feature / designation and / or quality and integrity, severe damage to key characteristics, features or elements. Soils: Physical removal or permanent sealing of soil resource. Land Contamination: Human health: Significant contamination identified. Contamination levels significantly exceed background levels and relevant screening criteria with potential for significant harm to human health. Controlled waters (Groundwater / Surface water): Reduction of water quality rendering groundwater or surface water unfit to drink and / or substantial

	adverse impact on groundwater dependent environmental receptors. Discharge of hazardous substances to groundwater.
Moderate	Geology: Partial loss of geological feature / designation and / or quality, potentially affecting integrity, partial loss of / damage to key characteristics, features or elements. Soils: Permanent loss / reduction of one or more soil function(s) and restriction to current or approved future use (e.g. through degradation, compaction, erosion of soil resource). Land Contamination: Human health: Contamination levels exceed background levels and are in line with relevant screening criteria. Significant contamination can be present. Control / remediation measures are required to reduce risks to human health / make land suitable for intended use. Controlled waters (Groundwater / Surface water): Reduced reliability of a supply at a groundwater or surface water abstraction source. Discharge of non-hazardous substances to groundwater and surface water resulting in pollution (i.e. contaminants present above the Environmental Quality Standard (EQS)).
Minor	Geology: Minor measurable change in geological feature / designation, quality or vulnerability; minor loss of, or alteration to one (or maybe more) key characteristics, features or elements. Soils: Temporary loss / reduction of one or more soil function(s) and restriction to current or approved future use (e.g. through degradation, compaction, erosion of soil resource). Land Contamination: Human health: Contamination levels are below relevant screening criteria. Significant contamination is unlikely with a low risk to human health. Best practice measures can be required to minimise risks to human health. Controlled waters (Groundwater / Surface water): Marginal reduced reliability of a supply at a groundwater or surface water abstraction source. Discharge of non-hazardous substances to groundwater and surface water not resulting in pollution (i.e. contaminants present below the EQS).
Negligible	Geology: Very minor loss or detrimental alteration to one or more characteristics, features or elements of geological feature / designation. Overall integrity of resource not affected. Soils:

	No discernible loss / reduction of soil function(s) that restrict current or approved future use. Land Contamination: Human health: Contamination concentrations substantially below levels outlined in relevant screening criteria. No requirement for control measures to reduce risks to human health / make land suitable for intended use. Controlled waters (Groundwater / Surface water): Non-measurable change to quality.
No change	Geology: No temporary or permanent loss / disturbance of characteristics, features or elements of geological feature / designation. Soils: No loss / reduction of soil function(s) that restrict current or approved future use. Land Contamination: Human health: Reported contamination levels below background levels. Controlled waters (Groundwater / Surface water): No change to quality.

Table 9.4: Approach to Evaluating Significance of Effect

		Magnitude of Impact				
		No Change	**Negligible**	**Minor**	**Moderate**	**Major**
Value/ Sensitivity	Very high	Neutral	Slight	Moderate or large	Large or Very large	Very large
	High	Neutral	Slight	Slight or moderate	Moderate or Large	Large or Very large
	Medium	Neutral	Neutral or slight	Slight	Moderate	Moderate or Large
	Low	Neutral	Neutral or slight	Neutral or slight	Slight	Slight or Moderate
	Negligible	Neutral	Neutral	Neutral	Neutral or slight	Slight

9.4 Baseline Conditions

9.4.1 This section presents the baseline conditions with respect to geological, hydrogeological, geoenvironmental setting and resources within the study area. It also describes the conceptual site model in relation to potential contaminants, pathways and receptors of contamination and their linkages.

9.4.2 The baseline conditions are presented in the Desk Study and Geotechnical and

Geoenvironmental Interpretative Report. The investigations and assessments focused on the area of the proposed Arena and Hotel only, however based on the Site context, these are likely to be indicative of the potential level of contamination across the whole of the Proposed Development. This will be confirmed through further ground investigations and assessments targeting the remainder of the Proposed Development areas.

Site location and topography

9.4.3 The Proposed Development Site location and context are detailed in Chapter 2 (Site Description) of the ES. The topography of the Site is generally flat at approximately 8-15m AOD. The highest ground is in the northeast of the Site, proximal to the existing Cardiff Council offices (Cardiff County Hall). Ground levels generally fall to the west and south. Refer to the Geotechnical and Geoenvironmental Interpretative Report (presented in Appendix 9.5) for details.

Site history

9.4.4 Prior to industrial development the Site was part of a salt marsh. Construction of the Cardiff Docks started in the early 1800s. The docks development generally included importing material to reclaim land from the marshes. The Site contained parts of the Bute East and Bute West Docks. The Site also contained a reservoir (now infilled), a timber pond (now infilled), timber yards, a wagon works, an iron foundry, saw mills, engine houses and a high density of railway trackways and sidings.

9.4.5 By the early 1940s, both the reservoir and the timber pond had been infilled and these areas were dominated by railway sidings and trackways.

9.4.6 With the decline in coal demand, by the mid-1960s, the coal staithes were no longer annotated along the dock walls and by the early-1970s, Bute West Dock had been infilled. The majority of railway sidings were also removed by the late 1970s.

9.4.7 By the mid to late-1980s, the construction of the Cardiff County Hall and car park had taken place, along with the A4234 (Hemingway Road) and Schooner Way. The most southernly part of the Bute East Dock had been reclaimed and subsequently infilled.

9.4.8 The A4232 had been constructed by the early 1990s, including the road tunnel through the Site. By 1999, the Red Dragon Centre had been built to the north of the A4232.

9.4.9 The existing Travelodge hotel is shown to have been developed between 1999 and 2019.

9.4.10 The key features are annotated on Figure 9.1 presented in Appendix 9.6.

Published geology

9.4.11 The Proposed Development Site is overlain by the Tidal Flat Deposits (Estuarine Alluvium) and Glaciofluvial Deposits, which overlie the Mercia Mudstone Group bedrock.

9.4.12 Given the historical development of the area as dockland, and more recent redevelopment, the natural ground is expected to have been disturbed and overlain by made ground materials. The thickness of made ground will be variable and be heterogenous, with the most significant thicknesses anticipated to be within the infilled docks, reservoir and timber pond features. The made ground is likely to comprise a mixture of natural reworked and man-made materials. Made ground is considered to be a potential source of contamination.

9.4.13 The Tidal Flat Deposits typically comprise clay and silt with beds of peat overlying sand and gravel. These deposits are underlain by Glaciofluvial Deposits, which comprise sand and gravel, with local lenses of silt, clay or organic material.

9.4.14 The superficial deposits are underlain by bedrock of the Mercia Mudstone Group. The Mercia Mudstone comprises predominantly mudstone with subordinate siltstone and sandstone beds. The upper boundary of the Mercia Mudstone Group rises steadily inland from the coast.

9.4.15 The encountered ground conditions are discussed in the sections below.

Geological and geomorphological designated sites

9.4.16 There are no statutory or non-statutory geological or geomorphological designations within the Proposed Development Site boundary. The geological landscape is classified as man-made with engineered features and reclaimed / infilled land. The Site is located within a highly developed urban environment, with the majority of the study area covered in hardstanding or buildings.

Hydrology and hydrogeology

9.4.17 The superficial deposits and bedrock geology are both classified by the Environment Agency (EA) as secondary aquifers with high vulnerability. The high vulnerability indicates a potential for high leachability rates in soils and/or rocks, with the potential to transmit contamination to groundwater. The superficial Tidal Flat Deposits are

designated as a Secondary Undifferentiated aquifer while the underlying Glaciofluvial Deposits are designated as a Secondary A aquifer. The Mercia Mudstone bedrock geology is designated as a Secondary B aquifer.

9.4.18 The main water-bearing strata that lies beneath the Site is formed by the Glaciofluvial gravels and the upper weathered parts of the Mercia Mudstone bedrock. Where present, the overlying alluvium confines the water in this stratum. In the coastal margin the water pressures in the gravel stratum will have historically been tidally influenced, however the impoundment of Cardiff Bay has resulted in stabilisation of the groundwater levels in the gravels and the mudstone at piezometric pressure of approximately 4.5mOD, at the same level as Cardiff Bay.

9.4.19 The Proposed Development is located on low-lying land, historically reclaimed dock land. Historically, the Bute East Dock was connected with the Roath Basin via Scott's Harbour to the south and with the then tidal Cardiff Bay via the Inner Lock and Lock Junction to the southwest. The Bute West Dock, which is situated across the western boundary of the Site, was infilled between 1964 and 1974, prior to the infilling of the southern part of the Bute East Dock. Following the infilling of the southern part of the Bute East Dock and in order to sustain a connection between the northern part of the Bute East Dock (now called Atlantic Wharf) and the main dock system, a culverted dock feeder was constructed within the dock fill. The Docks Feeder Culvert was constructed around 1985 after the Bute West Dock was infilled and maintained flows from the canal that used to serve the dock. The construction of the A4232 tunnel resulted in a diversion of that culvert and construction of the open channelled Dock feeder to the south of the Site as it is present today.

9.4.20 An existing deep sewer is situated along Schooner Way and intersects the Bute West Dock at approximately 2-4mOD, which is below the level of Cardiff Bay impoundment. If this sewer is not adequately sealed, there is the potential for leakage to occur which could reduce site groundwater levels. The Butetown tunnel, which runs east to west approximately 250m south of the Site, provides a barrier to southerly groundwater flow, which likely disrupts the wider Cardiff Bay hydrogeology. Other features, including historical drainage to prevent water levels rising due to impoundment of the bay, could also act to reduce site levels.

9.4.21 The Site is not within or in the vicinity of a Source Protection Zone.

Mining

9.4.22 The Proposed Development is located outside of a Coal Authority mining reporting area and the review of historical maps and aerial images did not identify any evidence of coal or other mining within or near to the Proposed Development Site.

Unexploded ordnance

9.4.23 The Site area is known to have been targeted by bombing raids during World War II. Therefore, there is a risk of encountering unexploded bombs within the Site. Based on publicly available high-level World War II unexploded bomb risk mapping from Zetica, the Site is indicated to be in an area of moderate UXO risk. This is summarised as areas having *"a bomb density between 11 and 50 bombs per 1,000 acres that may contain potential WWII targets. Action to mitigate the risk is considered essential, albeit more likely that a reduced scope of work is required compared with that needed for high-risk regions".*

9.4.24 The potential for unexploded ordnance for the Arena Site has been assessed in the Desk Study, enclosed in Appendix 9.2. In summary, it has been recommended that prior to any groundworks, an Operational UXO Emergency Response Plan should be in place. This should be in conjunction with delivering site specific UXO safety and awareness briefings to all personnel working on-site.

9.4.25 A detailed UXO risk assessment report (presented in the Desk Study) for the Cardiff Arena development, concluded that the UXO risk is high. It concluded the most probable UXO threat was posed by WWII German High Explosive (HE) bombs, with a residual threat present from Incendiary Bombs (IBs) and British Anti-Aircraft Ammunition (AAA). Whilst there is a residual UXO risk present within the Proposed Development Site, it is not believed to be a significant risk pathway to warrant on site pro-active mitigation measures.

9.4.26 The report recommends mitigation measures for all ground works, which include:

- an operational UXO emergency response plan to be held on the Proposed Development Site;
- UXO safety and awareness briefings for all personnel working on-site; and
- Magnetometer probing to assess the risk of UXO where boreholes, excavation and piled foundations are proposed.

9.4.27 Undertaking these mitigation measures has been recommended to reduce the UXO risk to as low as reasonably practicable (ALARP).

Soil resources

9.4.28 Discrete areas of topsoil are present within the study area, mainly within grass verges within the existing Cardiff County Hall car park and around the edges of the Red Dragon Centre, and with a larger grassed area forming part of Silurian Park, located in the north-western part of the Proposed Development. The Preliminary Ecological Appraisal which forms an appendix to Chapter 10 (Biodiversity) includes a Habitat Survey Map (Figure 1 – page 33) which details the grassland across the site.

9.4.29 The completed ground investigations in the area of the proposed Arena and Hotel development (current Council car parking area and part of Silurian Park) encountered 0.1-0.3m of topsoil in landscaped areas. However, no intrusive investigations have been completed in the remainder of the Site and therefore it has been assumed that topsoil is present in all areas of soft landscaping.

9.4.30 No agricultural land is present within the study area.

Site investigations

9.4.31 Targeted ground investigations information is available within the proposed Arena area of the Site and some information within the wider Site is available as discussed below:

- The 'Preliminary Ground Investigation' was conducted for the Arena and Hotel development in September 2020. This investigation comprised twelve boreholes, one trial trench and two trial pits, groundwater and ground gas monitoring, chemical testing on soil, surface water and groundwater samples, laboratory and in-situ geotechnical testing. Factual information including exploratory hole logs, testing and monitoring results, is presented in the Factual Ground Investigation Reports, enclosed in Appendix 9.3 and 9.4.
- The 'Supplementary Ground Investigation' was conducted for the Arena and Hotel development in March 2020. This investigation comprised 16 boreholes (including seven rotary probe holes), two trial trenches and ten trial pits, groundwater and ground gas monitoring, chemical testing on soil, surface water and groundwater samples, laboratory, and in-situ geotechnical testing. Factual information

including exploratory hole logs, testing and monitoring results, is presented in the Factual Ground Investigation Report, enclosed in Appendix 9.3 and 9.4.

- BGS online viewer boreholes ('BGS boreholes') within and surrounding the Proposed Development Site footprint from previous with ground investigations comprising nine boreholes.

The exploratory hole locations are shown on Figure 9.1 (Appendix 9.6). Details are provided within the Geotechnical and Geoenvironmental Interpretative Report, enclosed in Appendix 9.5.

Encountered ground conditions

9.4.32 The completed ground investigations, as listed in section 9.4.31, encountered the typical ground conditions within the Proposed Development Site summarised in Table 9.5 and detailed in the Geotechnical and Geoenvironmental Interpretative Report, enclosed in Appendix 9.5, including geological long / cross-sections and detailed descriptions and properties of the encountered strata.

9.4.33 The ground conditions encountered throughout the Arena and Hotel area of the Site were generally consistent with the geology predicted from the published geology sources.

Table 9.5: Summary of encountered ground conditions

Material Name		**Typical Description**	**Thickness (m)**	**Typical Top Level (mOD)**
Topsoil/Bituminous material (asphalt)		Topsoil	0.1 to 0.3	GL
		Bituminous material (asphalt)	0.15 to 0.20	GL
Made ground	Infilled Bute West Dock	Generally soft to firm, reddish brown, very sandy, gravelly CLAY with low cobble content. Sand is fine to coarse. Gravel is fine to coarse, angular to subrounded brick, ash, flint, mudstone and sandstone, with rare wood, tar, coal and quartzite. Rare cobbles of angular brick and mudstone.	8.00 to 13.00	+10.06 to +11.70

Table 9.5: Summary of encountered ground conditions				
Material Name		**Typical Description**	**Thickness (m)**	**Typical Top Level (mOD)**
	Outside of infilled structures	Generally loose to medium dense, reddish brown to grey, very clayey, silty, sandy, rare ash, fine to coarse, angular to subrounded GRAVEL of igneous rock (microgabbro, dolerite) sandstone, and mudstone, with rare coal, wood, glass, metal and brick fragments with low cobble content.	1.10 to 6.50	+9.37 to +11.57
	Infilled Timber Pond	Loose becoming dense with depth, brownish black, ashy, clayey, very sandy, fine to medium, angular to subangular GRAVEL of dolerite and microgabbro.	7.20 to 9.60	+11.21 to +14.34
	Infilled Reservoir	Generally medium to dense black slightly clayey sandy GRAVEL. Sand is coarse. Gravel is fine to cobble size colliery spoil, ash, coal, sandstone, whole red bricks.	5.70	+10.12
Tidal Flat Deposits	Bute West Dock	Generally soft to firm, slightly sandy, blueish grey / brown CLAY with occasional to frequent pockets of peat and organic clay.	0.80 to 5.30	+0.20 to +2.70
	Outside of infilled dock		7.00 to 9.50	+4.15 to +9.40
	Infilled Timber Pond		4.80 to 7.40	+3.60 to +5.47
	Infilled Reservoir		7.80	+4.42
Glaciofluvial Deposits		Generally loose to dense, dark grey / brown, sandy, angular to rounded GRAVEL of sandstone, mudstone, limestone, quartzite, chert, dolerite with low to medium cobble content.	0.60 to 4.70	-5.04 to +1.10
Mercia Mudstone		Weathered mudstone over extremely weak to weak, with	>0.90 to 21.40	-8.34 to +0.35

Table 9.5: Summary of encountered ground conditions			
Material Name	**Typical Description**	**Thickness (m)**	**Typical Top Level (mOD)**
	open fractures red occasionally brown MUDSTONE (Grade II – IVA) weathered to firm to stiff silty sandy gravelly clay with gravel lithorelicts.		
	Medium strong to strong, reddish brown to greenish grey, massive MUDSTONE (typically Grade I).	1.55 to >11.00	-23.06 to -6.70

Soil quality

9.4.34 Historical activities such as land reclamation for the development of the Cardiff Docks in the 1800s, construction and operation of the dockland, and more recently infilling of the dock structures allowing the redevelopment of the Cardiff Bay area has resulted in the presence of made ground beneath the Site area. In addition, there are numerous buried structures and foundations that underlie the Site area.

9.4.35 Ground investigations completed to date encountered made ground in all exploratory holes and pits. Evidence of metal and PAH contamination has been encountered within the Arena and Hotel development made ground.

9.4.36 Localised evidence of hydrocarbon contamination was identified during Preliminary and Supplementary Ground Investigations for the Arena and Hotel development.

9.4.37 Organic odours were observed within the Tidal Flat Deposits, associated with the peat deposits.

Encountered groundwater conditions

<u>Groundwater strikes</u>

9.4.38 Groundwater strikes were recorded during the completed investigations as summarised in the Geotechnical and Geoenvironmental Interpretative Report enclosed in Appendix 9.5. The water strikes observed during the Preliminary and Supplementary Ground Investigations are also shown on exploratory hole logs (refer to Factual Ground Investigation Reports enclosed in Appendix 9.3 and 9.4). Shallow groundwater strikes were recorded within made ground materials, between 2 and 4m

below ground level (bgl), typically 6-4mOD. Deeper groundwater strikes were encountered from 10.3m to 15m bgl, within the Tidal Flat Deposits, Glaciofluvial Deposits and Mercia Mudstone, typically 0.24m to -3.38mOD.

9.4.39 The low permeability of the Tidal Flat Deposit clays means that it is unlikely that groundwater seepages during drilling would be observed. It is likely that the encountered water strikes are associated with bands / pockets of more permeable peat or sandy / silty layers within the Tidal Flat Deposits.

Groundwater monitoring

9.4.40 The Preliminary and Supplementary Ground Investigations included a combined six rounds of groundwater level monitoring and six rounds of sampling and chemical testing. The results are presented in the Factual Ground Investigation Reports (enclosed in Appendix 9.3 and 9.4). The monitored installations and assessments of the results are detailed in the Geotechnical and Geoenvironmental Interpretative Report (Appendix 9.5).

9.4.41 Shallow groundwater monitoring within the made ground typically recorded groundwater at 2.5m to 3mbgl, approximately 7m to 8mOD.

9.4.42 The results of the groundwater level monitoring showed groundwater within the Glaciofluvial Deposits to be present at approximately 6m bgl, typically 4mOD. This was encountered at shallower depths in the location of the infilled Timber Pond, at between 4.85m and 5.15m bgl (6.36m to 5.06mOD).

9.4.43 Groundwater within the made ground and Glaciofluvial Deposits both indicate a slight hydraulic gradient towards the west, with a maximum 1.72m difference in head levels for shallow made ground installations and 2.22m for deeper Glaciofluvial Deposits installations. For the majority of the Arena and Hotel Proposed Development Site, there is a circa 2m difference in the monitored water levels between the shallow and deep zones, suggesting such zones are not in hydraulic continuity. It is, however, likely that in some areas of the infilled Bute West Dock, deeper groundwater may be in hydraulic continuity with that within the made ground, notably in the location of BH-R01, where there is an absence of Tidal Flat Deposits. Monitoring results indicate there may be drawdown of shallow groundwater in the locale of BH-R01, likely resulting from the absence of Tidal Flat Deposits in this area. Groundwater monitoring results are detailed in the Geotechnical and Geoenvironmental Interpretative Report enclosed in Appendix 9.5.

9.4.44 The assessment of the chemical testing results indicated the presence of elevated concentrations of arsenic, chromium, and petroleum hydrocarbons with respect to potential risk to aquatic environment. The assessments however concluded that considering the degree of exceedances and frequency, the identified exceedances were not of concern with respect to controlled waters, and in the case of the elevated metals were likely to be representative of a wider background water quality.

9.4.45 It is not considered that the concentrations of heavy metals are outside the expected range in relation to the Site's urban setting and previous historic land use on the Site and in the immediate setting.

9.4.46 Based on the hydrogeological setting it is envisaged that a similar groundwater regime will exist within the wider Proposed Development Site.

Ground gas monitoring and assessment

9.4.47 The Preliminary and Supplementary Ground Investigations included a combined six rounds of ground gas monitoring undertaken in line with a strategy presented in Appendix 9.5. The results are presented in the Factual Ground Investigation Reports (enclosed in Appendix 9.3 and 9.4). The assessments are detailed in the Geotechnical and Geoenvironmental Interpretative Report (enclosed in Appendix 9.5).

9.4.48 The assessment of the monitoring results indicated the potential for vertical ground gas migration from the made ground to the near ground surface and that migration of gas from the dissolved phase to gaseous phase may be occurring.

9.4.49 Ground gas monitoring indicated the potential for significant gas generation and migration to surface. The Ground Gas Risk Assessment for the Arena and Hotel development was assessed to be a Characteristic Situation 3 site and therefore ground gas protection measures are required. The Characteristic Situation 3 assessment was driven by the conditions of the Bute West Dock, with a Characteristic Situation 2 outside of dock structures.

9.4.50 Based on the Site history and ground conditions it is envisaged that similar ground gas regime will exist within the wider Proposed Development Site. Development specific ground gas monitoring will need to be obtained to confirm assessments for other areas of the Proposed Development.

Land contamination

9.4.51 The following sections set out a Conceptual Site Model (CSM), which considers potential contaminants and pathways via which this contamination may impact the identified receptors at baseline and also during construction and operation of the Proposed Development. For the risk to exist all three components, contaminant – pathway – receptor, need to be in place.

Sources of Contaminants

9.4.52 A review of the Proposed Development Site history showed that the Site has a rich industrial heritage as the former Cardiff Docklands and associated railways. Several infilled dock structures are present across and extending beyond the Proposed

development Site, including the Bute West Dock, Bute East Dock, Timber Pond, Infilled Reservoir and southern portion of the Bute East Dock. The Timber Pond and Reservoir were infilled between 1938 and 1942. The Bute West Dock was infilled between 1964 and 1974. Between 1983 and 1991, the southern end of Bute East Dock was infilled. In addition to the above structures, engineering works, warehouses, buildings associated with ship building, timber yards, a wagon works, union foundry (iron & brass), X-ray lab, an iron foundry, sawmills, engine houses and a high density of railway trackways and sidings have been present on the Site of the Proposed Development.

9.4.53 An existing deep sewer is present within Schooner Way. The sewer location clashes with the Hotel and Arena footprint in the north of the Site. It is understood the sewer will be partially diverted as part of the proposed works.

9.4.54 There are likely to be contaminants associated with the Site's former industrial use, alongside, contamination pertaining to the constituents of the infilled dock materials. Contaminants typically associated with historical uses include hydrocarbons due to spillages of fuel or lubricants, metals, solvents, sulphates and hydrocarbons within ash. Asbestos fibres may also be present, e.g. associated with historical building fabric and / or former train braking systems. Contaminants associated with the infilled dock structures may include oils / lubricants, metals and antifouling paint. The X-ray laboratory has the potential to have caused radiological contamination of the subsurface. Based on the Site history there is the potential for significant sources of contamination.

9.4.55 The completed Preliminary and Supplementary Ground investigations in the area of the proposed Arena and Hotel development encountered made ground of up to 6.5m

thick, increasing to up to 13m in the infilled Bute West Dock, 9.6m in the Infilled Timber Pond and 5.7m within the Infilled Reservoir. The encountered made ground typically comprised a clayey silty sandy gravel with inclusions of wood, ash, colliery spoil, tar, coal, glass, metal and brick identified.

9.4.56 The Preliminary and Supplementary Ground investigations recorded a strong hydrocarbon odour within the Bute West Dock between 6.5m and 8.2m bgl (BH101). Gas bubbles and a strong organic odour were also noted within the Bute West Dock at 9m blg (BH-R01). To the northeast of the Arena and Hotel development (TP-R02) made ground at 0.25m to 2.2m bgl included metal fragments and an oil drum.

9.4.57 Peat layers have been encountered within the Tidal Flat Deposits, which could be a source of ground gas. Peat layers / lenses have been recorded at depth with a maximum thickness of 1.1m, but typically <50 millimetre (mm) thick. Ground gas monitoring as detailed in Section 9.4.5 identified a moderate risk from ground gases to the Proposed Development. Ground gas generation potential is high owing to thicknesses of made ground in infilled structures, high organic content and significant time elapsed for degradation since the filling of such structures.

9.4.58 The introduction of new sources of contamination during construction, such as fuels and oils used in construction plant, could potentially impact on the water environment as presented in Chapter 8 (Water Resources).

9.4.59 Assessment of suitability for reuse of soils within the Proposed Development will be undertaken in accordance with a CEMP and associated Materials Management Plan (MMP) and therefore only materials suitable for end use, i.e. those that would not pose an unacceptable risk to human health, would be reused. Unacceptable materials would be removed from the Site. Therefore, reused materials would not constitute a source of contamination.

9.4.60 No pollution incidents are recorded by NRW within the Arena and Hotel development area.

9.4.61 The baseline groundwater quality assessment indicated that groundwater has been impacted by contaminant sources located outside the Proposed Development area and is likely to represent wider background concentrations.

Pathways

9.4.62 The pathways associated with potential contamination are detailed in the Desk Study and Geotechnical and Geoenvironmental Interpretative Report for the Arena and Hotel site. Although these pathways were presented in a context of specific areas of the Proposed Development, based on the Site context, these are considered to be relevant to the whole of the Proposed Development. A summary of the potential pathways through which contamination sources may come into contact with receptors considered most appropriate for the Proposed Development is provided as follows:

- Soil pathway – Within the baseline conditions as well as the Proposed Development, the most prevalent pollutant linkages are associated with the ingestion, inhalation, or dermal contact with contaminated ground soils and soil derived dust in areas of soft landscaping. Construction workers are likely to be directly exposed to contaminated soils or made ground during the works on-site through dermal, ingestion and inhalation. Exposure duration is likely to be relatively short-term.

- Gas pathway – Made ground and the presence of infilled structures within the Proposed Development are considered as a potential source of ground gas. Vertical gas migration is anticipated to be restricted by the generally cohesive nature of the infilled Bute West Dock and Tidal Flat Deposits; however, gas could migrate laterally and vertically through more granular layers or within groundwater.

- Groundwater pathway – The leaching of contaminants from site soils as a result of rainwater infiltration is likely in the absence of drainage or hard cover. Additionally, due to the nature of previously encountered strata within the available ground investigations, vertical and lateral migration of contamination is considered to be limited within the Bute West Dock and Tidal Flat Deposits by the generally cohesive nature of the surrounding material. There is potential for some lateral and vertical migration through granular layers or migration through preferential flow paths potentially induced by the existing and proposed pipe network. Increased rainwater infiltration into the ground during excavation works or point discharge into the ground of water removed during dewatering activities may result in mobilisation of contaminants and vertical migration into the underlying groundwater. Introduction of piled foundations or new service

corridors may introduce new pathways for contamination migration. New drainage or underground service corridors may introduce preferential flow paths for contaminants towards groundwater receptors.

- The proximity of surface water features in relation to the Proposed Development makes the potential of surface run-off or direct discharge of potential contamination into adjacent surface waters a plausible pathway. New drainage or underground service corridors may introduce preferential flow paths for contaminants towards surface water receptors.

Receptors

9.4.63 Based on the nature of the Proposed Development, the receptors of potential contamination are presented in the Desk Study and Geotechnical and Geoenvironmental Interpretative Report. Although these receptors were presented in a context of specific areas of the Proposed Development, based on the Site context, these are considered to be relevant to the whole of the Proposed Development. Potential receptors of contamination include:

- Current and end users of the Proposed Development Site;
- Road network maintenance workers;
- Neighbours of the Proposed Development (including end users of the completed phases of the Proposed Development during construction of remaining phases);
- Surface waters, including the Atlantic Wharf and Cardiff Bay.

9.4.64 Groundwater contained within the bedrock aquifer and Glaciofluvial Deposits; groundwater contained within the Tidal Flat Deposits, classed as unproductive strata, is not considered a receptor.

9.4.65 Construction workers are likely receptors during construction. Exposures experienced by construction workers are of shorter duration than for future Site users due to the limited period of exposure. However, the nature of the exposure may be more severe than for future Site users as construction workers may be required to expose, treat, excavate and transport or otherwise engage in close contact with the exposed materials as a necessity.

Tier 1: Preliminary Risk Assessment

9.4.66 The potential contaminant linkages within the conceptual site model, and associated

risks identified for the Proposed Development are presented in the Desk Study and Geotechnical and Geoenvironmental Interpretative Report.

9.4.67 The following potential pollutant linkages potentially posing a plausible risk are summarised in Table 6.6.

Table 6.6: Potential pollutant linkages at baseline scenario.

Potential Sources of Contaminants	Potential Receptor	Possible Pathway	Comment
Onsite Made ground – site reclamation redevelopment Bute West Dock – fill materials Infilled Timber Pond – fill materials Infilled Reservoir – fill materials Bute East Dock – fill martials. Historical Buildings and land use	Current site users and future site users Construction workers Maintenance workers Site neighbours (residents)	Direct dermal Ingestion Inhalation of gas or vapours	Long-term and frequent exposure to the identified sources of contaminants is unlikely. The nearby residents may be exposed to dust generated from areas of made ground although considering the extent and distance to these areas, the exposure is unlikely to be resulting in significant risk to human health. Ground gas generation may be occurring within the peat / organic alluvium deposits and site made ground.
	Surface waters (Bute East Dock, Cardiff Bay)	Leaching, lateral migration within groundwater, contaminated surface water run off	Due to the cohesive nature of the Bute West Dock infilled ground and Tidal Flat Deposits, the migration of groundwater through these layers is likely to be very limited. There is potential for some lateral and vertical migration through granular layers elsewhere. Surface run-off or trans-evaporation processes are likely to be principal drainage mechanism within the Site area. Groundwater within the bedrock aquifer may have been impacted by off-site sources.
	Groundwater (bedrock aquifer)	Leaching and downward migration via superficial deposits	

Tier 2: Generic Quantitative Risk Assessment

The results of chemical testing completed on soil and groundwater samples obtained during the Preliminary and Supplementary Ground Investigations within the area of the proposed Arena and Hotel were subjected to Tier 2: GQRA (Generic Quantitative

Risk Assessment) which uses generic assessment criteria and assumptions to estimate risk. The GQRA is presented in the Geotechnical and Geoenvironmental Interpretative Report and summarised below. Although these investigations and assessments focused on the area of the proposed Arena and the Hotel only, based on the Site context, these are likely to be indicative of the potential level of contamination across the whole of the Proposed Development. This will be confirmed through further ground investigations and assessments targeting the remainder of the Proposed Development Site.

Human health

9.4.68 In order to assess the risks to human health for construction and maintenance workers for the Arena and Hotel site, the chemical analysis results of soil samples obtained from the Site have been initially screened against published C4SL and S4UL values for a conservative 'residential without plant uptake' (RWPU) land use. These are considered to represent a suitable level of conservatism in the absence of specific values for construction workers and the acute exposure scenario they represent. Where these have not yet been published for some contaminants, Arup derived inhouse generic assessment criteria (GACs) for a 'residential without plant uptake' land use have been used.

9.4.69 In order to assess the risks to human health for site end users for the Arena and Hotel Site, the chemical analysis results of soil samples obtained from the Site have been initially screened against published C4SL and S4UL values for a 'commercial' land use for internal areas of the development. For external areas of proposed landscaping, substances have been screened against published C4SL and S4UL values for a 'Public Open Space Park' land use. Where these have not yet been published for some contaminants, Arup derived in-house generic assessment criteria (GACs) have been used.

9.4.70 The Tier 2: GQRA for the Arena and Hotel area of the Site identified exceedances of the 'residential without plant uptake' criteria for the assessment for construction workers for heavy metals (Arsenic, Beryllium, Lead) and PAHs (Dibenz(ah)anthracene) in the site made ground. Elevated PAHs (Dibenz(ah)anthracene, Naphthalene, Benzo(a)pyrene, Benzo(b)fluoranthene) were also identified within the Tidal Flat Deposits.

9.4.71 The Tier 2: GQRA for the Arena and Hotel area of the Site identified no exceedances of the 'commercial' criteria for volatile compounds and so it is not thought the site soils pose a risk to the end user in internal areas of the development.

9.4.72 The Tier 2: GQRA for the Arena and Hotel area of the Site identified exceedances of the 'public open space park' criteria for heavy metals (Arsenic, Lead) and PAHs (Dibenz(ah)anthracene). Arsenic and lead exceedances of the Public Open Space

criteria are considered a risk to the site end user if located in area of proposed soft landscaping. The singular Dibenz(ah)anthracene exceedance of the Public Open Space criteria is not considered a risk with respect to landscaping areas as it is situated at a significant depth below the surface.

9.4.73 Made Ground soil descriptions for the Arena and Hotel area of the Site have indicated the presence of varying proportions of bricks, metal fragments, concrete, glass fragments, coal, wood and concrete. It is considered likely that the concentrations of heavy metals and PAHs identified in the samples are derived from these made ground constituents.

9.4.74 Although no asbestos was identified during the Preliminary and Supplementary Ground Investigations, the above made ground constituents are thought to be indicative of construction materials. For this reason, it is considered that there remains the potential for asbestos to be present on-site.

9.4.75 The assessments undertaken for the Arena and Hotel have concluded that to provide protection to the site end user in proposed areas of soft landscaping, a 600mm clean capping layer suitable for use as a growing medium is recommended on account of arsenic and lead exceedances in existing soils. The applicability of the conclusion to the Proposed Development should be considered following subsequent ground investigation and geoenvironmental assessments.

Controlled waters

9.4.76 Leachable analysis of the made ground indicated exceedances of the screening criteria for heavy metals (Chromium, Copper, Vanadium, Nickel, Antimony, Arsenic, Zinc), Fluoride, Cyanide and PAH have been identified within the site made ground. These may pose a risk to surface and groundwater receptors during construction as a result of increased rainfall infiltration or surface run-off.

9.4.77 The Tier 2: GQRA identified elevated concentrations of metals (Arsenic and Chromium), petroleum hydrocarbon and PAH (Anthracene, Benzo(a)pyrene, Fluoranthene, Naphthalene) compounds in groundwater. Shallow installations within the Bute West Dock made ground recorded exceedances of the EQS for Arsenic, Chromium, Fluoranthene, frequent exceedances for Benzo(a)pyrene and, a singular exceedance for Naphthalene. Deeper installations display exceedances for fluoranthene (Infilled Reservoir, Timber Pond, outside dock structures), Chromium and a singular benzo(a)anthracene (Timber Pond).

9.4.78 Despite the exceedances of the EQS for metals and some hydrocarbons within the groundwater, levels of contamination within the underlying Secondary A aquifer are low and are not thought to be significantly different from that of the wider Cardiff dock area. On this be basis the Geotechnical and Geoenvironmental report determined that no further assessment of the groundwater on-site is considered to be necessary.

Sensitive Receptors

9.4.79 The Proposed Development may impact the following sensitive receptors as summarised in Table 9.7.

Table 9.7: Sensitive receptors

Discipline	Sensitive receptor	Receptor value	Justification
Geology	None	Negligible	The majority of the study area covered by hardstanding and buildings at baseline conditions.
Soil resources	Topsoil within existing landscaped areas	Negligible	Do not support designated, or priority or notable habitats.
Hydrogeology	Secondary A aquifers with superficial deposits and bedrock	Low and medium value, respectively	Refer to Chapter 8 (Water Resources).
Contamination	Current and end site users and site neighbours including;		Refer to Table 9.2
	• residents of residential properties	Very high	
	• commercial workers	Medium	

Table 9.7: Sensitive receptors			
Discipline	**Sensitive receptor**	**Receptor value**	**Justification**
	• visitors of the commercial venues and open public spaces	High	
	Construction and maintenance workers	Low	
	Secondary A aquifers with superficial deposits and bedrock	Low and medium value, respectively	Refer to Chapter 8 (Water Resources).
	Surface water receptors including the Atlantic Wharf and Cardiff Bay	Low and medium value, respectively	

Limitations

9.4.80 Preliminary and Supplementary Ground Investigations were undertaken within the proposed Arena and Hotel area to inform the full planning application for this phase of the works. No targeted investigations have been undertaken in the remainder of the Proposed Development Site, which constitutes the outline planning application. Further detailed desk study and intrusive investigations targeting these areas of the development will be undertaken to inform the design and full planning applications.

9.4.81 However, the available ground investigation information and published information is considered suitable to create a preliminary ground model and identify the required mitigation measures. This is considered sufficient at this design stage and to inform the Environmental Impact Assessment.

9.5 Assessment of Effects

Design Solutions and Assumptions

9.5.1 An Outline Construction Environmental Management Plan (CEMP) for the Arena and Hotel enabling works will be submitted with the hybrid planning application. It is assumed that similar CEMPs will be produced for each phase of development.

9.5.2 The CEMP contains measures to ensure that contamination is addressed during enabling works and unacceptable risks with respect to human health and controlled waters are mitigated.

9.5.3 Measures contained within the CEMP would be designed to limit the possibility for dispersal and accidental releases of potential contaminants, spread of weeds, and uncontrolled run-off during construction.

9.5.4 The CEMP would establish procedures for dealing with unexpected soil or groundwater contamination that may be encountered. Potential impacts on human health receptors including off-site receptors would be addressed through the adoption of the following measures, which are included in a CEMP:

- Dust control – to include the damping of ground with water.
- Sheeting of lorries transporting spoil off-site and the use of dust suppression equipment on plant.
- Sweeping of roadways.
- Adequate fuel / chemical storage facilities e.g. bunded tanks, hard standing and associated emergency response spillage control procedures.
- Well maintained plant and associated emergency response / spillage control procedures.
- Any temporary onsite storage of contaminated material would be stored on sheeting and covered to minimise the potential for leachate and run off from the stockpile being generated.
- Health and safety training and provision of suitable welfare facilities.
- Provision and use of Personal Protective Equipment (PPE).

9.5.5 Potential risks posed to maintenance workers would be mitigated through adherence to appropriate site and task specific health and safety documentation, required for legal compliance. Appropriate health and safety management systems would be in place during construction including provision of personal protective equipment. Information would be provided to the contractor in accordance with the Construction (Design and Management) Regulations 2015, on potential sources, including desk study and ground investigations (e.g. evidence of contamination and / or soil and groundwater chemical testing), to inform health and safety risk assessments during construction works.

9.5.6 Construction activities would be undertaken in line with current best practice and

guidance in accordance with the CEMP. Construction-related receptors and sources would be managed to negate their impact on the environment. The commitments anticipated to be incorporated in the CEMP include but are not limited to:

- A watching brief for the duration of site works in areas of potential contaminated land or groundwater (by a suitably qualified and experienced person).
- An Action Plan for safely dealing with unexpected contamination.
- Management of construction-related waters.
- Sustainable use of soils on a construction site.
- Environmental monitoring including surface water and ground water monitoring.

9.5.7 It is proposed to maximise retention of materials on-site for reuse. Measures will be taken to establish acceptable reuse and import criteria and procedures defined for ensuring that the suitability of material can be demonstrated and verified. A discovery strategy will be developed to enable unforeseen ground conditions to be addressed if or when encountered during construction. A materials management plan will form part of a CEMP.

9.5.8 It is also proposed to retain and reuse topsoil and subsoil within the Proposed Development, where possible. Measures will be taken to preserve soil properties through appropriate stripping, handling, storage and placement of topsoil and subsoil in areas of soft landscaping. A soils management plan will form part of a CEMP.

9.5.9 Ground investigations to assess for presence of contamination and levels of ground gas have been undertaken within the Arena and Hotel site, and appropriate land contamination assessments have been completed as part of the Proposed Development design. These are summarised in the baseline conditions section and presented in the Geotechnical and Geoenvironmental Interpretative Report, enclosed in Appendix 9.5.

9.5.10 The completed assessments identify required remediation measures in areas of soft landscaping.

9.5.11 Ground investigations to assess for presence of contamination and levels of ground gas will be undertaken for other phases of the development, and appropriate land contamination assessments completed as part of the development design.

9.5.12 Remedial options selection and proposed measures will be set out in a remediation

strategy for each phase, with details developed at a detailed design stage and presented in a remediation implementation and verification plan. Verification of any implemented remediation measures would be undertaken prior to construction of the Proposed Development and there would mitigate the risk to the receptors from operation of the Proposed Development. These mitigation measures will be outlined in a CEMP.

9.5.13 Following the completion of construction, groundwater monitoring observation boreholes may be decommissioned. The decommissioning of the boreholes would be done in such a way that the material placed in the observation well mimics the permeability of the surrounding material.

9.5.14 As part of the detailed design, an assessment of potential risks associated with deep piled foundations will be undertaken with respect to human health, controlled waters and to identify appropriate piling techniques.

9.5.15 Following discussions with Arup, 6 Alpha Associates recommended magnetometer probing to assess the risk of UXO where excavation and piled foundations are proposed.

9.5.16 On confirmation of pile design for each phase of development, a foundation works risk assessment will be required.

9.5.17 The design will incorporate assessments in accordance with BRE Special Digest 1 on Concrete in Aggressive Ground to determine appropriate concrete class selection for the proposed structures and infrastructure.

9.5.18 The design will consider appropriate ground gas protection measures identified through ground gas risk assessments completed for each phase of the Proposed Development, including those presented in the Geotechnical and Geoenvironmental Interpretative Report. The protection measures will be designed in accordance with BS 8485:2015 or equivalent.

Assessment of Effects - Construction

9.5.19 This section presents the assessment of likely significant effects on geology, soil resources, hydrogeology and land contamination resulting from the construction of the Proposed Development.

9.5.20 The assessment of effects takes into account the potential impacts to each receptor

following the implementation of embedded and essential mitigation measures to determine the significance of the residual effects.

Geology

9.5.21 There are no designated or non-designated geological sites within the study area, with the majority of the study area covered by hardstanding and buildings at baseline conditions. Therefore, the receptor is of negligible value. The Proposed Development will retain the current site setting and therefore it would result in no change with a ***neutral*** effect, which is not significant.

Soil resources

9.5.22 The construction of the Proposed Development would affect soil resources, which are a negligible value receptor as they do not support designated, or priority or notable habitats. The Proposed Development incorporates localised areas of soft landscaping, as shown on the Atlantic Wharf Illustrative Landscape Masterplan (CAH-URB-RX-XX-DR-L-90-0002-P02). The intention is to, where possible, retain soil resources within the Proposed Development although due to the phased nature of the development the reuse of soil resources will be limited to a specific phase of the development. This may lead to a partial loss of the resource and a requirement to import and restore these resources on site. The development area for the Arena and Hotel is constrained and therefore there will not be sufficient space to stockpile topsoil materials during the construction phase. It will be necessary to export the site won topsoil for reuse elsewhere and then import topsoil to reintroduce to landscape areas at the end of construction. Considering the design assumption and presence of a soil management plan as part of a CEMP, the loss is considered to be partial and temporary with a negligible magnitude of impact. The effect of the Proposed Development is therefore considered to be ***neutral***, which is not significant.

9.5.23 The effects with respect to materials and waste are assessed in Chapter 18 (Materials and Waste).

Hydrogeology

It is thought that there is a low risk associated with preferential flow pathways created by piling works. It is likely that should any pathways be temporarily created within the Tidal Flat Deposits; the pathways would be quickly sealed by the soft nature of the alluvium. Further to this, there is evidence from the ground investigation to suggest

that the barrier between the made ground and underlying Glaciofluvial Deposits is already locally compromised.

9.5.24 The Site has been subject to highly intrusive historical development as docks and other industrial activities. This has had a major impact on local shallow hydrogeology. The Site is underlain by secondary aquifers supported by the superficial deposits and bedrock, which are of low and medium value, respectively.

9.5.25 Larger structures within the Proposed Development are likely to be founded on deep piled foundations. These foundations would penetrate the made ground and

superficial deposits and will extend into the underlying bedrock. The piled foundations are unlikely to create a barrier for groundwater flow as these would be constructed as either single piles or as pile groups with spacing sufficiently spaced not to stop or significantly alter groundwater movement. If basements or other subsurface structures are proposed as part of future phases of the development, this has the potential to impact on the flow of groundwater, as such, an assessment of this risk would need to be made.

9.5.26 The Proposed Development will have a negligible impact on aquifer recharge as the overall conditions at ground surface are likely to remain similar to the baseline conditions, with the majority of the Site covered in hardstanding and buildings. In addition, considering the cohesive nature of the Tidal Flat Deposits underlying the majority of the Site, the rainwater infiltration is likely to be limited in soft landscape areas.

9.5.27 Construction of small and lightly loaded structures may use a ground bearing foundation solution. Ground bearing foundations would only be used where the loads imposed by the buildings would not result in significant consolidation of soft natural ground. This would minimise any impact on ground permeability and groundwater flow.

9.5.28 Therefore, overall it is considered that the Proposed Development would have a negligible magnitude of impact on local hydrogeology with an overall ***neutral*** effect, which is not considered significant.

Contamination

9.5.29 The assessment of risks from contamination on human health and controlled waters

during construction of the proposed Arena and Hotel is reported in Geotechnical and Geoenvironmental Interpretative Report. The assessment includes the development of a CSM for the construction phase of the Proposed Development, qualitative Tier 1: PRA and a Tier 2: GQRA of available results. This is summarised below.

9.5.30 As discussed previously, although these investigations and assessments focused on the area of the proposed Arena and Hotel only, based on the Site context, these are likely to be indicative of the potential level of contamination across the whole of the Proposed Development. This will be confirmed through further ground investigations and assessments targeting the remainder of the Proposed Development Site.

Human health

9.5.31 The Tier 1: PRA, as presented in Section 9.4, identified construction workers and site neighbours including end users of completed phases as primary receptors of the identified sources of contamination during construction as a result of direct exposure to soils, dust and ground gas generated during ground-breaking activities.

9.5.32 The Tier 2: GQRA for the construction scenario for the Arena and Hotel development identified elevated concentrations of metals (arsenic, beryllium, lead) and PAH compounds, which may pose a risk to construction workers and scheme neighbours. These elevated concentrations were typically measured across all locations. This may have result in a minor negative magnitude of impact. However, following the application of the design solutions as presented in a CEMP, the impacts of the construction activities are considered to be reduced to negligible, with a beneficial impact, as construction works are likely to result in betterment of subsurface contamination conditions as a result of removal of any significant contamination should it be encountered within the Site area. Therefore, the overall effect of the Proposed Development on risks from contamination on human health during construction (construction workers and site neighbours) is assessed as temporary ***slight beneficial*** and not significant.

Controlled waters

9.5.33 The Tier 1: PRA identified both groundwater and surface water within the study area as potential receptors of the identified sources of contamination. Construction activities may result in contamination mobilisation and migration towards these receptors or in direct discharge of contaminants to groundwater or surface water,

resulting in pollution. The Proposed Development may also introduce new pathways for contamination migration along new drainage or deep foundations.

9.5.34 The Tier 2: GQRA identified elevated concentrations of leachable metals and PAH within the site made ground. These may pose a risk to surface and groundwater receptors during construction as a result of increased rainfall infiltration or surface run-off.

9.5.35 The Tier 2: GQRA identified elevated concentrations of metals, petroleum hydrocarbon and PAH compounds in groundwater, which may pose a risk to groundwater and / or surface water receptors during construction particularly if

dewatering is required or groundwater is intercepted during construction works.

9.5.36 The Tier 2: GQRA has identified localised areas where elevated contamination levels may pose a risk to the controlled water receptors during construction, with a potential for a moderate adverse magnitude of impact. However, on application of design solutions, as presented in a CEMP, the impacts of the construction activities are considered to be negligible beneficial, as construction works are likely to result in betterment of subsurface contamination as a result of removal of any significant contamination should it be encountered within the site area. Therefore, overall the effect of the scheme on risks from contamination on controlled waters during construction (both ground and surface water receptors) is assessed as temporary ***slight beneficial*** and not significant.

Summary of residual effects during construction

9.5.37 A summary of the residual effects on geology, soils and receptors for contaminated land during construction of the scheme is presented in Table 9.8.

Table 9.8: Summary of effects during construction

Potential impact	Receptor	Description	Receptor sensitivity	Design and mitigation measures	Magnitude of impact	Residual significance of effect
Direct impact on designated geological sites	Geology	No statutory or non-statutory designated sites are	Negligible	N/A	No change	Neutral

Table 9.8: Summary of effects during construction						
Potential impact	**Receptor**	**Description**	**Receptor sensitivity**	**Design and mitigation measures**	**Magnitude of impact**	**Residual significance of effect**
		located in study area.				
Damage or loss of soil resources	Soil resources	Temporary partial loss of soil resources present in existing landscaped areas.	Negligible	CEMP - Soil resources management plan to allow retention and reuse of soil resources within the Proposed Development.	Negligible	Neutral
Impact on groundwater flows and properties of the aquifer	Hydrogeology	New piled undations ay create arrier to oundwater ow. Proposed evelopment ay impact charge of quifers. round bearing ructures may use ground nsolidation.	Low to medium	N/A	Negligible	Neutral
Exposure to soil contamination	On-site users	Construction workers	Low	H&S management systems CEMP - including soils	Negligible	Slight beneficial
		End users of completed phases	Medium / High		Negligible	Slight beneficial

Table 9.8: Summary of effects during construction						
Potential impact	**Receptor**	**Description**	**Receptor sensitivity**	**Design and mitigation measures**	**Magnitude of impact**	**Residual significance of effect**
	Off-site users	Residents of nearby properties	Very high	handling and storage, dust control, dealing with known and unexpected contamination and materials management plan. Land contamination risk assessments have not identified a requirement for remediation measures.	Negligible	Slight beneficial
		Commercial workers	Medium		Negligible	Slight beneficial
Contaminated soil, leachate / groundwater / direct discharge, and pollution of groundwater Vertical and lateral migration of leachate / groundwater contamination and / or direct contact with	Groundwater	Secondary aquifers	Low to medium	CEMP - including appropriate hazardous materials storage and handling, pollution response and environmental management, materials management and dealing with known and	Negligible	Slight beneficial
	Surface water	Docks	Low		Negligible	Slight beneficial
		Cardiff Bay	Medium		Negligible	Slight beneficial

Table 9.8: Summary of effects during construction						
Potential impact	**Receptor**	**Description**	**Receptor sensitivity**	**Design and mitigation measures**	**Magnitude of impact**	**Residual significance of effect**
soil contamination Pollution migration along piles / underground structures				unexpected contamination Foundation Works Risk Assessment where deep foundations are proposed, to be confirmed subject to the design at detailed design stage.		

Assessment of Effects – Operation

9.5.38 This section presents the assessment of likely significant effects on geology, soil resources, hydrogeology and land contamination resulting from the operation of the Proposed Development.

9.5.39 The assessment of effects takes into account the potential impacts to each receptor following the implementation of design solutions to determine the significance of the residual effects.

Geology

9.5.40 The operation of the Proposed Development would result in no change to geology resources resulting in a ***neutral*** effect, which is not significant.

Soil resources

9.5.41 No further impacts are anticipated beyond those occurring during the construction phase resulting in a ***neutral*** effect, which is not significant.

Hydrogeology

9.5.42 No further impacts are anticipated beyond those occurring during the construction

phase resulting in a ***neutral*** effect, which is not significant.

Contamination

9.5.43 The assessment of risks from contamination on human health and controlled waters during construction of the proposed Arena and Hotel is reported in the Geotechnical and Geoenvironmental Interpretative Report. The assessment includes the development of a CSM for the construction phase of the Proposed Development, qualitative Tier 1: PRA and a Tier 2: GQRA of available results. This is summarised below.

9.5.44 As discussed previously, these are likely to be indicative of the potential level of contamination across the whole of the Proposed Development and will be confirmed through further ground investigations and assessments targeting the remainder of the Proposed Development Site.

Human health

9.5.45 The Tier 1: PRA, as presented in Section 9.4, identified site end users and also routine maintenance workers as primary receptors of the identified sources of contamination within the Proposed Development Site.

9.5.46 The Tier 2: GQRA for the Proposed Development operation scenario identified elevated concentrations of metals (Arsenic and Lead) in made ground outside of the dock structures. If such materials are used as part of proposed landscaping, these materials may pose a risk to the site end users with a moderate magnitude of impact. However, on application of design mitigation (remediation measures such as application of improved clean cover) the magnitude of impact would be negligible beneficial, as the concentrations to which the identified receptors would be exposed to would be reduced to below current levels. Therefore, the effect of the Proposed Development on risks from contamination on human health including residential end site users during operation is assessed as ***slight beneficial***, which is not significant.

Controlled waters

9.5.47 The Tier 1: Preliminary Risk Assessment identified made ground within the Proposed Development as a potential source of contamination with respect to both groundwater and surface water within the study area. Rainwater or groundwater infiltration through these materials may mobilise contaminants and result in

contamination migration towards these receptors resulting in pollution.

9.5.48 The Tier 2: GQRA indicated that leachable metals within made ground as well as hydrocarbon contamination may pose a risk to surface and groundwater receptors if made ground is reused in landscaped areas in close proximity to surface water receptors, or the Proposed Development introduces changes to the ground surfacing resulting in increased rainwater infiltration and subsequent increased leaching potential of contaminants into the groundwater. This may result in a moderate adverse magnitude of impact. However, on application of design solutions, as presented in a CEMP with respect to reuse of materials, the impacts of the Proposed Development during operation are considered to be negligible beneficial, as only materials not posing a risk to controlled waters would be reused within the Site area. Therefore, overall, the effect of the Proposed Development on risks from contamination on controlled waters during operation (both ground and surface water receptors) is assessed as ***slight beneficial*** and not significant.

9.5.49 *Summary of residual effects during operation*

9.5.50 A summary of the residual effects on geology, soils and receptors for contaminated land during operation of the scheme is presented in Table 9.9.

Table 9.9: Summary of effects during operation

Potential impact	Receptor	Description	Receptor sensitivity	Design and mitigation measures	Magnitude of impact	Residual significance of effect
Direct impact on designated geological sites	Geology	No statutory or non-statutory designated sites are located in study area	Negligible	N/A	No change	Neutral
Damage or loss of soil resources	Soil resources	No further impact on soil resources	Negligible	N/A	Negligible	Neutral

Table 9.9: Summary of effects during operation						
Potential impact	**Receptor**	**Description**	**Receptor sensitivity**	**Design and mitigation measures**	**Magnitude of impact**	**Residual significance of effect**
Impact on groundwater flows and properties of the aquifer	Hydrogeology	No further impact on hydrogeology	Low to medium	N/A	Negligible	Neutral
Exposure to soil contamination	On-site users	Maintenance workers	Low	Remediation measures followed by verification.	Negligible	Slight beneficial
		End users	Medium/ High		Negligible	Slight beneficial
	Off-site users	Residents of nearby properties	Very high		Negligible	Slight beneficial
		Commercial workers	Medium		Negligible	Slight beneficial
Contaminated soil, leachate / groundwater / and pollution of groundwater	Groundwater	Secondary aquifers	Low to medium	Mitigation measures implemented during construction with respect to materials reuse.	Negligible	Slight beneficial
	Surface water	Docks	Low		Negligible	Slight beneficial
		Cardiff Bay	Medium		Negligible	Slight beneficial

9.6 Mitigation

9.6.1 The completed assessments did not identify significant effects resulting from construction or operation of the Proposed Development and therefore no additional mitigation is required.

9.7 Residual Effects

9.7.1 The completed assessments did not identify significant effects resulting from construction or operation of the Proposed Development and therefore no additional mitigation is required. Therefore, the residual effects are as presented in Table 9.8 for construction and Table 9.9 for operation.

9.8 Assessment of Cumulative Effects

9.8.1 The completed assessment did not identify significant effects on the Site during construction or operation. Effects that have been identified are considered to be localised. Given the non-significance and localised nature of the potential effects it is considered unlikely that any cumulative effects would occur. This assumes that other developments take due consideration of potential impacts and mitigation measures and contaminated land issues are addressed with via the planning process.

9.9 Conclusion

9.9.1 The Site has known historical developments, including backfilled areas, however ground investigation to date for the Arena and Hotel Site has found no significant contamination. However, clean capping was recommended in proposed areas of soft landscaping to protect the health of Site end users. For other areas of the wider Site, ground investigation and detailed assessment has yet to be undertaken. Once further investigation of the wider Site has been undertaken the baseline conditions and the design of any remedial measures can be confirmed.

9.9.2 Based on current available data, it is thought that with appropriate mitigation introduced as part of the design, there are no significant construction or operation stage effects in relation to geology, soil resources, hydrogeology or land contamination.