



LanzaTech UK Limited

**Project Dragon – Sustainable Aviation Fuel
(SAF) Production Facility:
Temporary Construction Area at Margam
Wharf**

Ground Investigation Report





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Project Dragon – Sustainable Aviation Fuel (SAF) Production Facility: Temporary Construction Area at Margam Wharf

Ground Investigation Report

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EXECUTIVE SUMMARY

BACKGROUND INFORMATION	Client	LanzaTech UK Limited
	Site Details	The site currently comprises a disused parcel of land, owned by Associated British Ports (ABP), in the docks area of Port Talbot. The eastern site area is adjacent to TATA Steel owned land. The site covers an area of approximately 2.1 hectares, with the centre of the site situated at National Grid Reference 277010, 188760. The nearest postcode is SA13 1RA.
	Site Objectives	The purpose of the ground investigation, is to provide information on the geoenvironmental and ground engineering conditions and constraints associated with the site, with regards to the proposed development.
	Proposed Development	Whilst full details of the proposed development have not been provided to TEC at this stage, it is understood that it is to comprise a temporary construction facility, which is likely to be temporarily capped with granular material to facilitate the construction of the nearby proposed sustainable jet fuel production facility.
	Current Land Use and Description	The site currently comprises a disused plot of largely scrub land, with remnants of infrastructure, associated with Margam Wharf (concrete slabs and access roads) present across the site.
	Geology	The site is recorded to be underlain by superficial Tidal Flat Deposits typically described by the British Geological Survey (BGS) as a consolidated soft silty clay with layers of sand, gravel and peat. Alluvial Fan Deposits are reported by the BGS to be located further north-east of the site. However, during a previous phase of investigation undertaken by TEC, Alluvial Fan Deposits, generally described by the BGS as relatively flat to gently sloping masses of loose rock, were encountered below the Wind Blown Sand and Tidal Flat Deposits. The underlying bedrock geology is recorded as the South Wales Middle Coal Measures and is described as grey coal bearing mudstones/siltstones with seatearths and minor sandstones. In addition, the BGS reports the site and surrounding area to comprise 'Landscaped Ground', described as mainly redeveloped areas and others where extensive earth moving has occurred.
	Unexploded Ordnance	No evidence of bomb damage to the section of the steelworks within the site boundary has been identified within historical aerial imagery and OS mapping. Given recorded bombing to the steelworks, the risk from German UXBs is slightly elevated and has been assessed as Low to Moderate.
	Initial Conceptual Site Model	Human Health (end users and construction workers) – potential exposure to CoPCs and asbestos within the shallow made ground via ingestion, inhalation and dermal contact. Controlled waters (Secondary aquifers and docks) – potential vertical and horizontal migration of leachable contaminants within groundwater along preferential pathways.
GEOTECHNICAL INVESTIGATION	Geotechnical Ground Investigation Rationale	The scope of ground investigation works includes the requirements detailed with TEC's drawing titled "Geotechnical/Geoenvironmental Proposed Exploratory Hole Plan", Sketch 006, dated 30 March 2023, aiming to refine the risks and potential source-pathway-receptor contaminant linkages identified in the initial conceptual model by undertaking intrusive ground investigations, and then providing recommendations in relation to ground engineering for the proposed development.
	Scope of Works	10No. Cable percussive boreholes to approximately 4mbgl to determine the underlying ground conditions 13No. Trial pits to provide a general coverage of the site and to characterise the shallow ground conditions as well as to collect geotechnical and geo-environmental samples for laboratory analysis.

	Ground Conditions	The encountered made ground was noted to mainly comprise granular material, recovered to a maximum encountered depth of 4.2mbgl (3.6mAOD) and described as slightly silty sandy gravel; silty sandy gravel; and slightly clayey silty sandy gravel with a low cobble and boulder content. The gravel component was generally described as concrete, brick, coke, slag, clinker, cloth (fabric), tiles and tile fragments, plastic, iron ore, rubber, rubber matting, porcelain fragments, wood fragments, metal fragments, rebar and metal wire. The cobbles and boulders generally comprised concrete, coke and rare relicts of brick walls. Cohesive made ground material was encountered within a single exploratory location, TP209, from 1.75m (5.85mAOD) and a depth exceeding 2.5mbgl (5.1mAOD) The encountered material was described as greyish brown and grey mottled slightly gravelly very silty clay. The gravel component was recorded as slag. A number of concrete slabs were observed across the site, and within 5No. exploratory locations (BH201, BH201A, BH202, BH202A, TP208 and TP216) recorded concrete slabs between depths of 0.2mbgl (7.4mAOD) and 0.45mbgl (7.15mAOD). No superficial deposits (Tidal Flat Deposits) were recorded within any of the exploratory locations.
	Contaminant Characterisation	The results of the assessment recorded a single exceedance of cyanide when considering a commercial site end use (BH201B at 2.5-2.8mbgl) no further exceedances of the relevant GAC's were reported for organic or inorganic contaminants. The laboratory screening for asbestos identified asbestos fragments and fibres within 3No. locations. Further quantitative analysis was completed on these samples with the results indicating concentrations of <0.001% - 0.003% of asbestos by weight to be present. PFAS testing was undertaken on 5No. samples, of which all the samples tested below the detection limit. Elevated leachable concentrations of heavy metals, cyanide, Total Phenol and PAH compounds were recorded within the made ground materials.
	Updated Conceptual Site Model	Human Health (end users and construction workers) – potential exposure to CoPCs and asbestos within the shallow made ground via ingestion, inhalation and dermal contact. Controlled waters (Secondary aquifers and docks) – potential vertical and horizontal migration of leachable contaminants within groundwater along preferential pathways.
	Preliminary Pavement Design	A preliminary design CBR value of less than 2.5% is recommended. It should be noted that all road formations should be proof rolled and soft spots removed and replaced with selected granular fill.
	Buried Concrete	The results of the sulphate and pH testing from the soils at the site indicate an aggressive chemical environment class (ACEC) of AC-3 requiring a design sulphate class of DS-3. However, should any structures be proposed for the site, a DS-5 would be recommended due to past experience of similar ground conditions in the near vicinity of the site. Unless a greater number of tests are completed, it may therefore be prudent to up-grade the protection for concrete accordingly.
	UXO	The Margam Steelworks, within which the site is located, were involved in the production of steel for munitions, tanks, ships, and other war materials and was consequently a target for German air raids carried out by the Luftwaffe. No evidence of bomb damage to the section of the steelworks within the site boundary has been identified within historical aerial imagery and OS mapping. Given recorded bombing to the steelworks, the risk from German UXBs is slightly elevated and has been assessed as Low-Moderate. 16No permanent Heavy Anti-Aircraft batteries were active within range of the site during WWII. In addition, Light Anti-Aircraft guns are likely defended Port Talbot. While Luftwaffe activity in the region was relatively infrequent, it is possible that an unexploded anti-aircraft shell struck the site. However, Brimstone consider the risk to be analogous to that of German UXBs.



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Recommended further works	Recommended further works	Due to ecological constraints which made the northernmost site area inaccessible at the time of works, additional ground investigative works may be required to fully identify the ground conditions.
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1 INTRODUCTION

1.1 Terms of Reference

1.1.1 TEC has been appointed by LanzaTech UK Limited to undertake a Ground Investigation of the proposed temporary construction area at Margam Wharf, Port Talbot. All works were undertaken in accordance with our proposal letter dated 16 June 2023 and referenced RE.2111006.006.

1.2 Background

1.2.1 The site currently comprises a disused parcel of land (formerly Margam Wharf), partially owned by Associated British Ports (ABP) and partially owned by TATA Steel, in the docks area of Port Talbot (Figure 1). The site covers an approximate area of approximately 2.1 hectares, with the centre of the site situated at National Grid Reference 277010, 188760. The nearest postcode is SA13 1RA.

1.2.2 Whilst full details of the proposed development have not been provided to TEC at this stage, it is understood that it is to comprise a temporary construction facility to be capped with granular material to allow it to be used for the duration of the construction of the nearby proposed sustainable jet fuel production facility at the land off Crown Wharf.

1.2.3 A Desk Study of the site was prepared by TEC in June 2023 as detailed within the following document:

- *‘Project Dragon – Sustainable Aviation Fuel (SAF) Production Facility: Temporary Construction Area at Margam Wharf – Desk Study’, report ref.: 2111006.006.01 Rev. C. Prepared for LanzaTech UK Limited, dated June 2023 and revised October 2023.*

1.2.4 The above report included review of desk study information and subsequent ground investigation of the nearby proposed sustainable jet fuel production facility site (located approximately 275m west), which were prepared by TEC in May 2022, June 2022, August 2023 and October 2023, as detailed within the following documents:

- *‘Project Dragon – Sustainable Aviation Fuel (SAF) Production Facility: Production Development Zone (PDZ) – Desk Study’, report ref.: 2111006.002.01 Rev. G. Prepared for LanzaTech UK Limited, dated May 2022 and revised October 2023;*
- *‘Project Dragon – Sustainable Aviation Fuel (SAF) Production Facility: Production Development Zone (PDZ) – Ground Investigation Report’, report ref.: 2111006.003.01. Rev. D. Prepared for LanzaTech UK Limited, dated June 2022 and revised August 2023;*
- *‘Project Dragon – Sustainable Aviation Fuel (SAF) Production Facility: Production Development Zone (PDZ) – Geotechnical Assessment Report’, report ref.: 2111006.005.02. Rev. C. Prepared for LanzaTech UK Limited, dated July 2023 and revised October 2023; and*
- *‘Project Dragon – Sustainable Aviation Fuel (SAF) Production Facility: Production Development Zone (PDZ) – Geoenvironmental Assessment Report’, reference 2111006.005.01A. Prepared for LanzaTech UK Limited, dated August 2023 and revised October 2023.*

1.2.5 While the pertinent information from these reports in relation to the current assessment are summarised in the following sections, reference should be made to the reports for full detail.

1.2.6 The aim of these works is to provide further information on land contamination risk and the ground engineering conditions and constraints associated with the site with regard to the proposed development.

1.3 Scope of Works and Objectives

1.3.1 The objectives and scope of works undertaken as part of this report are presented below:

- **Tier 2: Generic Quantitative Risk Assessment - Evaluation of the risks:** This phase of assessment involves updating the initial site conceptual model developed as part of the Preliminary Risk Assessment based on the findings of a geoenvironmental ground investigation. Generic assessment

criteria taking account of different land uses and receptor sensitivities, are used to identify relevant contaminant linkages.

- **Ground Engineering:** general recommendations in relation to ground engineering for the proposed development are provided on the basis of the findings of the ground investigation.

1.3.2 The above scope of work has been undertaken in accordance with current guidance such as LCRM - *Land contamination: risk management* (Environment Agency, 2023), BS10175+A2:2017, BS5930:2015+A1:2020 and, where appropriate, Eurocode 7 and NHBC Standards/ LABC Technical Manual.

2 SITE OVERVIEW

2.1 Previous Site Report Summary

2.1.1 Information for the site has been obtained through a review of the following report prepared by TEC:

- *‘Project Dragon – Sustainable Aviation Fuel (SAF) Production Facility: Temporary Construction Area at Margam Wharf – Desk Study’, report ref.: 2111006.006.01 Rev. C. Prepared for LanzaTech UK Limited, dated June 2023 and revised October 2023.*

2.1.2 In addition, information, relevant to the current assessment has been summarised from the Desk Study and a Ground Investigation Report of the nearby proposed sustainable jet fuel production facility site (located approximately 275m west) by TEC, as detailed within the following documents:

- *‘Project Dragon – Sustainable Aviation Fuel (SAF) Production Facility: Production Development Zone (PDZ) – Desk Study’, report ref.: 2111006.002.01 Rev. G. Prepared for LanzaTech UK Limited, dated May 2022 and revised October 2023;*
- *‘Project Dragon – Sustainable Aviation Fuel (SAF) Production Facility: Production Development Zone (PDZ) – Ground Investigation Report’, report ref.: 2111006.003.01. Rev. D. Prepared for LanzaTech UK Limited, dated June 2022 and revised August 2023;*
- *‘Project Dragon – Sustainable Aviation Fuel (SAF) Production Facility: Production Development Zone (PDZ) – Geotechnical Assessment Report’, report ref.: 2111006.005.02. Rev. C. Prepared for LanzaTech UK Limited, dated July 2023 and revised October 2023; and*
- *‘Project Dragon – Sustainable Aviation Fuel (SAF) Production Facility: Production Development Zone (PDZ) – Geoenvironmental Assessment Report’, reference 2111006.005.01A. Prepared for LanzaTech UK Limited, dated August 2023 and revised October 2023.*

2.1.3 A summary of relevant information from these previous TEC reports, in relation to this current assessment, is summarised in Table 2.1. Reference should be made to these previous reports for full information.

Table 2.1: Previous Ground investigation Summary

Project Dragon – Sustainable Aviation Fuel (SAF) Production Facility: Temporary Construction Area at Margam Wharf Desk Study (June 2023, Rev. G October 2023)	
Site History	Earliest available mapping indicates the site comprised an undeveloped parcel of land and water on the tidal flats of Port Talbot, consisting of a combination of rough grassland, shingle and marsh. It is noted that the Ffrwd-Wyllt (stream/river) is present in the north of the site, flowing into the sea. A small peninsular of land is present in the western site area, with a structure depicted on the peninsula just off site to the west. Although no structures were depicted on site, the eastern site area was depicted as forming part of the Margam Copper Works, with a number of access roads/tracks depicted on site. By 1899, a railway siding was depicted extending into the northern site area, with a number of small structures depicted in the northeast of site and the route of the Ffrwd-Wyllt (stream/river) is shown to have been diverted slightly north. By 1940, the entire site has been infilled, with Margam Wharf now present at the western site boundary (current site boundary). The site now comprises multiple buildings and infrastructure (including railway sidings, tanks, settling tanks, travelling cranes, overhead pipes, chimneys, reservoirs, conveyors, hoppers and Margam Wharf) of the wider Margam (Iron and Steel) Works site. The 1953 and 1991 mapping depicted slight alterations to the building layouts in the eastern half of the site. By 2009, no buildings are depicted on site (current site layout). A single concrete slab is present in the centre of the site and access tracks are depicted around the site periphery. A concrete ‘overflow’ structure is depicted in the north of the site, understood to allow the River Ffrwd-Wyllt to flow into the adjacent docks.

Environmental Setting	The site is recorded to be underlain by superficial Tidal Flat Deposits typically described by the BGS as older Coastal Zone Deposits – clay, silt, sand and peat (including ‘submerged forest’). The underlying bedrock geology is recorded as the South Wales Middle Coal Measures Formation, described by the BGS as grey, (productive) coal-bearing mudstones/siltstones, with seatearths and minor sandstones. In addition, BGS reports the site and surrounding area comprises ‘Landscape Ground’, described as mainly redeveloped areas and others where extensive earth moving has occurred. The superficial deposits recorded on site are reported as a Secondary (Undifferentiated) Aquifer of high groundwater vulnerability. The underlying solid geology is designated as a Secondary Aquifer A of high groundwater vulnerability. There are no groundwater abstractions or Environment Agency Source Protection Zones within 1km of the site. There are two discharge consents to groundwater reported within 1km, with the nearest reported approximately 295m north of site. The site is reported to be within an area with potential for groundwater flooding to occur at the surface. The nearest surface water feature is the on-site River Ffrwd-Wyllt, along with the adjacent (tidal) docks. There are 13No. reported surface water abstraction records within 500m, 3No. reported discharge consents and 4No. pollution incidents to controlled waters reported within 500m of the site. The site is reported to lie within an area within the extent of flooding and extreme flooding from rivers or sea without defences, as well as an area benefitting from flood defences. No landfill sites are recorded within 500m of the site.
Ecology	It is understood that oxtongue broomrape is present over a large part of the site area and is particularly prevalent within the northern part of the site. Oxtongue broomrape is understood to be fully protected under WCA Schedule 8 and it is an offence to intentionally pick, uproot or destroy any of these plants.
Contamination	No visual or olfactory evidence of contamination was recorded during the site walkover.
Ground Gas/ Radon	The site is recorded to be in a lower probability radon area with less than 1% of homes estimated to be at or above the Action Level. Therefore, no radon protection measures are required.
Relevant Contaminant Linkages	The relevant contaminant linkages identified for the site were limited to; - Human health (future site users) – Exposure to potential contaminants through ingestion, inhalation and dermal contact of the made ground and infilled ground. - Human Health (future site users) and proposed structures – migration, ingress and accumulation of ground gases sourced from both potential made ground and potential organic-rich superficial deposits. - Controlled waters (Secondary Aquifers and surface waters) - Leaching of potential contaminants from made ground and vertical and lateral migration through the saturated zone to controlled waters
Project Dragon: PDZ Exploratory Ground Investigation Report (June 2022, Rev. D August 2023), Geotechnical Assessment Report (July 2023 Rev. C October 2023) ; and Geoenvironmental Assessment Report (August 2023, Rev A October 2023)	
Scope of Works	20No. Cable percussive boreholes were advanced to approximately 22mbgl to determine the depth of the Alluvial Fan Deposits and underlying bedrock South Wales Middle Coal Measures Formation, as well as the installation of groundwater monitoring boreholes across the site. 30No. Trial pits to provide a general coverage of the site and to characterise the shallow ground conditions as well as to collect geo-environmental samples for laboratory analysis. 13No. Dynamic sample boreholes to provide spatial coverage across the site area, as well as to characterise shallow ground conditions and for the installation of shallow gas monitoring wells. 2No. Hand pits were advanced at targeted locations based on visual observations from the site walkover.

Ground Conditions	Made ground material was encountered within all exploratory locations to depths of between 0.35m (8.1mAOD) and 6.9m (1.3mAOD) and was noted to be highly variable, but was generally noted to be cohesive in nature. This material included slag, vesicular slag, clinker, coke, wood fragments, metal fragments, metal wire, metal lintel, rebar, plastic fragments, plastic pipes, brick, concrete, glass, tiles, terracotta and porcelain fragments tyres, rubber, sandstone, mudstone, siltstone, lime and plaster. No exploratory works were undertaken within the concrete hardstanding located within the central site area, however based on the previous investigation undertaken by TEC, the concrete slab thickness was recorded to between 0.12m and 0.13m thick based on 2No. exploratory holes undertaken within this area. The Wind Blown Sand was encountered to depths between ground level (8.48mAOD) and 6mbgl (2.2mAOD) and maximum depths of 2.4mbgl (6.1mAOD) and 9.5mbgl (-0.9mAOD). The encountered material was generally described as slightly silty fine to medium grained sand. The Tidal Flat Deposits were encountered across the site at depths of between 1mbgl (6.2mAOD) and 6.9mbgl (1.3mAOD) to maximum encountered depths of between 10mbgl (-3.2mAOD) and 16.5mbgl (-7.9mAOD). The material generally comprised cohesive material of low to very low strength silty clay with occasional pockets of amorphous to fibrous peat and pockets of fine to medium grained sand. The more granular material encountered within the Tidal Flat Deposits generally comprised grey, brownish grey and greyish brown slightly clayey slightly silty sand to silty clayey sand with occasion pockets of silty clay. Across the site, within the cable percussive boreholes, peat beds were recorded as slightly clayey plastic to spongy fibrous to amorphous peat, with a weak to strong organic odour. Alluvial fan deposits were encountered between depths of 10mbgl (-3.2mAOD) and 16.5mbgl (-7.9mAOD) and observed to be underlying the Tidal Flat Deposits across the site, to maximum encountered depths of between >18mbgl (-10.8mAOD) and 25mbgl (-16.5mAOD). The encountered ground conditions were generally described as slightly clayey slightly gravelly sand and sandy gravel with low to medium cobble content. The gravel generally comprised fine to coarse subangular to rounded sandstone. Within the rotary cored boreholes, the bedrock was encountered at depths of between 21.4mbgl (-16.5mAOD) and 29mbgl (-20.1mAOD) with an encountered depth of 54mbgl (-45.8mAOD) and 62mbgl (-53.5mAOD). The encountered bedrock generally comprised interbedded medium strong to very strong sandstone, extremely weak to medium strong siltstone and mudstone with rare to occasional veins of quartz. Within two boreholes, BH113 and BH119, very weak to weak black coal and weak dark grey dark grey to black mudstone with occasional very thinly bedded bands of coal with rare to occasional very thin veins of pyrite between fractures were recorded between 30.5mbgl to 30.6mbgl, 31.2mbgl to 31.85mbgl and 31.9mbgl to 32.15mbgl respectively. <i>Groundwater</i> Standing groundwater levels were recorded between 0.35mbgl to 1.91mbgl and 0.99mbgl and 4.85mbgl across the site area. It should also be noted that localised areas were prone to flooding due to limited permeability of the underlying ground materials and/or hardstanding surfaces. Continuous groundwater monitoring was undertaken between 13 July to 24 July 2023 and indicated that groundwater at the site is tidally influenced.
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Contaminant Characterisation	Laboratory analysis of made ground materials recorded elevated concentrations of several PAH compounds in excess of the adopted general assessment criteria relevant to a commercial site end use. In addition, asbestos fibres, fibrous debris and cement was recorded within 17No. of the samples. No concentrations of any contaminant of potential concern in excess of the adopted screening criteria was identified from any sample of the natural ground materials. Elevated leachable concentrations of heavy metals and PAH compounds were recorded within the made ground materials. Samples from the perched water and shallow groundwater within the Tidal Flat Deposits recorded elevated levels of PAHs, heavy metals and total phenols in excess of the relevant EQS. Samples from the deeper Alluvial Fan Deposits record exceedances of heavy metals whilst groundwater within the bedrock South Wales Middle Coal Measures Formation recorded exceedances of both heavy metals and some PAH compounds when compared to relevant EQS. Gas monitoring undertaken to date suggests the site may be classified as CS3. Ongoing monitoring is currently being undertaken to fully characterise the site. An area of localised hydrocarbon impact was identified around a historical borehole U1 and the adjacently located DS112. Soil samples from DS112 recorded marginally raised aliphatic and aromatic TPH CWG levels, which were subsequently found to be below the adopted GAC for a commercial site end use. Groundwater samples from both wells record elevated concentrations of heavy metals, PAH, BTEX compounds and aromatic TPH CWG fractions in excess of the EQS.
Updated Conceptual Site Model	The relevant contaminant linkages identified for the site were limited to; • Human Health (end users and construction workers) – potential exposure to CoPCs and asbestos within the shallow made ground via ingestion, inhalation and dermal contact. • Human health (end users, construction workers and proposed development) – potential ingress and accumulation of bulk ground gas into proposed structures and chronic inhalation by future site end users. • Controlled waters (Secondary aquifers and docks) – potential vertical and horizontal migration of leachable contaminants within groundwater along preferential pathways.
Foundations	It was considered that conventional foundations for all but very lightly loaded structures are unlikely to be suitable for the proposed development without deep soil improvement and it was considered likely that a piled foundation would be required for the more heavily loaded structures. As a result of the recorded generally poor ground conditions recorded across the site together with the need to provide a level development area, it was noted that it may be more economical to treat the site won materials to allow them to be easily incorporated into the earthworks and while the advice of a specialist ground improvement contractor should be sought it was noted that the materials could be improved using cement stabilisation to provide a suitable formation level that potentially may be suitable as a piling platform.
Preliminary Pavement Design	A preliminary design CBR value of less than 2.5% was recommended.
Drainage	Vertical infiltration rates of between 1.4×10^{-6} m/s and 4.8×10^{-5} m/s were determined for the near surface materials. However, observations made during the ground investigation indicate high groundwater levels during the winter period with the site noted to have numerous areas of standing water and saturated marsh areas and therefore drainage to the ground may not be suitable.
Buried Concrete	Concrete piles may be designed to DS-3, based on the recorded soluble Sulphate concentrations as the soils would not be 'disturbed' (resulting in oxidation of the pyrite) during piling activities. However, where soils are disturbed, ie for near surface concrete structures, a design sulphate class of DS-5 would be required within the made ground and Tidal Flat Deposits due to the high Total Potential Sulphate concentrations recorded. Where concrete is within the Wind Blown Sands, a design class of DS-1 may be used.

Earthworks	<u><i>Made Ground</i></u> A review of the site material for the made ground indicates the materials to be a combination of 4No. classes including primarily Class 1A (well graded granular material) requiring Method 1 compaction; Class 1B (uniformly graded granular material) requiring method 3 compaction; Class 2A (wet cohesive material), requiring method 1 and to a lesser extent, Class 2B (dry cohesive material), requiring method 2 compaction. It was further noted that the single granular sample classed as Class 2A recorded a higher percentage fine (>0.63mm) of 27%, of which 22.3% silt was recorded. <u><i>Wind Blown Sand</i></u> The majority of the samples tested within the Wind Blown Sand indicated to be Class 1B (uniformly graded granular material) requiring Method 3 compaction and locally Class 2A (wet cohesive material), due to a higher percentage fine (>0.63mm) recorded within a single sample, therefore requiring method 1 compaction. <u><i>Tidal Flat Deposits</i></u> Following a review of the Tidal Flat Deposits tested, the material indicates to be of Class 2A, requiring method 1 compaction. However, due to a liquid limit of greater than 50% recorded in the majority of the Tidal Flat Deposits deemed as Class 2A, when compacting, only deadweight tamping, or vibratory tamping rollers or grid rollers should be used as specified by BS 1377: Part 2.
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2.2 Comment on previous reports

- 2.2.1 Given the assessments undertaken by TEC on and in proximity to the site (as summarised above), additional works were considered necessary in relation to the geoenvironmental and geotechnical constraints associated with the site and the proposed development following these works are presented in the following sections.

2.3 UXO

- 2.3.1 Following a Preliminary Risk Assessment, a Detailed UXO Desk Study and Risk Assessment has been completed by Brimstone Site Investigation (ref: PRA-23-2043, dated 22 February 2023; and DRA-23-1532 rev2, dated 6th September 2023) to assess the risk from Unexploded Ordnance (UXO). A summary of the main finding of this assessment in relation to the Margam Wharf site is presented in the following sections. The full stage 2 UXO Risk Assessment can be found in Appendix B.

German UXO

- 2.3.2 The Margam Steelworks, within which the site is located, were involved in the production of steel for munitions, tanks, ships, and other war materials and was consequently a target for German air raids carried out by the Luftwaffe.
- 2.3.3 No evidence of bomb damage to the section of the steelworks within the site boundary has been identified within historical aerial imagery and OS mapping, i.e. areas of clearance, missing roofs, repair works etc. The presence of significant and important infrastructure in these locations indicate that a UXB strike will likely have been observed and dealt with at the time. However, given recorded bombing to the steelworks, the risk from German UXBs is slightly elevated and has been assessed as Low-Moderate.

British / Allied UXO

- 2.3.4 Evidence indicates that the Margam Steelworks was purpose built during WWI for war production. Further research suggests that the steelworks produced steel utilised for munitions, tanks, ships and other war materials. Three WWII-era bombs/shells have been uncovered at Tata Steel in the 21st century (none have been recorded on the site, although specific locations are unknown). No evidence has been found to suggest that shells were filled at the steelworks in Port Talbot. It is likely that the aforementioned shells consisted solely of the outer casing, given that each of them was certified inert and no mention was made of a high-explosive fill. Therefore, the risk from Allied UXO is assessed to be Low across the site.
- 2.3.5 16No permanent Heavy Anti-Aircraft batteries were active within range of the site during WWII. Light Anti-aircraft guns likely defended Port Talbot. While Luftwaffe activity in the region was relatively infrequent, it is possible that an unexploded AA shell struck the site. Brimstone consider the risk to be analogous to that of German UXBs.

3 GROUND INVESTIGATION METHODOLOGY

3.1 Background

- 3.1.1 The ground investigation undertaken was designed to provide information on the ground conditions to aid with the design of the development; and to investigate the potential contaminant linkages identified as part of the Tier 1: Preliminary Risk Assessment. All approximate exploratory locations were determined by Technip prior to the ground investigation.
- 3.1.2 All site works were undertaken, following completion of the desk-based review and site reconnaissance/walkover survey. Where potential on site hazards were identified during the site reconnaissance/walkover survey, the proposed exploratory hole locations were adjusted, using a non-targeted investigation approach to evaluate the risks.
- 3.1.3 Plate load tests were undertaken within the areas specified by Technip in advance of the works.
- 3.1.4 Tier 2 works were undertaken in accordance with BS5930:2015+A1:2020, BS10175+A2:2017 and, where appropriate, Eurocode 7. Works were supervised by a suitably experienced geoenvironmental consultant from TEC.

3.2 Methodology

- 3.2.1 A summary of the ground investigation works undertaken and the rationale for each location is provided in in Table 3.1, as follows:

Table 3.1: Summary of Ground Investigation Works

Investigation Method	Location	Date(s)	Location Rationale	Purpose
Trial Pitting (JCB 3CX and Volvo ECR88)	TP204; TP206; TP208 to TP209; TP211; and TP213 to TP219	18.05.2023; 27.06.2023; 30.06.2023	Positioned to provide spatial coverage across the site area at locations determined by Technip	Characterisation of shallow ground conditions Collection of geochemical and geotechnical samples for analysis
Cable Percussive Borehole	BH201 – BH202C	15.05.2023 – 19.05.2023	Positioned to provide spatial coverage across the site area at locations determined by Technip	Characterisation of deeper ground conditions Collection of geochemical and geotechnical samples for analysis
Plate Bearing Tests	TP204, TP213 and TP214	19.05.2023 and 27.06.2023	Located in approximate areas of proposed access roads/parking at locations determined by Technip	Provision of indicative Californian Bearing Ratio (CBR) values
Clegg Hammer Testing	TP204; TP206; TP208, TP215; TP217 to TP219	30.06.2023	Located in approximate areas of proposed access roads/ parking	Provision of indicative Californian Bearing Ratio (CBR) values

- 3.2.2 Trial pit and cable percussive borehole exploratory hole locations are presented on Figure 2 and detailed descriptions of encountered ground conditions are shown on exploratory hole logs presented in Appendix D. Plate Load test and Clegg Hamer test locations are presented on Figure 3.

3.3 Limitations

- 3.3.1 Due to ecological constraints no work was carried out within the northernmost site area. It is currently understood that further works would be undertaken at a later stage in order to assess the underlying ground conditions within this part of the site.

3.4 Field Testing

3.4.1 A summary of in situ field testing undertaken as part of these ground investigation works is provided in Table 3.2

Table 3.2: Summary of Field Testing

Field Test	Purpose
Hand Shear Vane (HSV)	Estimation of undrained shear strengths of cohesive strata
Pocket Penetrometer (PP)	Indication of unconfined compressive strength of cohesive strata
Standard Penetration Test (SPT)	Provision of strength profile of underlying ground conditions Provision of in situ densities of granular deposits
Photo-Ionisation Detector (PID)	Indication of the presence of free product
Plate Load and Clegg Hammer Testing	Indication of CBR for pavement design

3.5 Chemical Testing

3.5.1 Laboratory testing was scheduled on the basis of the potential contaminants identified within the Tier 1: Preliminary Risk Assessment and field observations.

3.5.2 Representative soil samples were collected and chemically tested at i2 Analytical Ltd, a UKAS/MCERTS accredited laboratory, for a selection of the following parameters:

Soils (Totals and Leachate)

- *Heavy metals and metalloids;*
- *Total Organic Carbon (TOC);*
- *Phenols (monohydric);*
- *Total Cyanide;*
- *Sulphate, sulphide, elemental sulphur and pH;*
- *Speciated Polyaromatic Hydrocarbons (PAH);*
- *Total Petroleum Hydrocarbons (TPH-CWG), including BTEX and MTBE;*
- *Per- and polyfluoroalkyl substances (PFAS); and*
- *Asbestos Screening and Quantification*

3.5.3 Geochemical certificates of analysis are presented within Appendix E.

3.6 Geotechnical Testing

3.6.1 Selected soil samples were submitted for geotechnical analysis at K4 Soils Ltd and The Environmental Laboratory Ltd (ELab). Laboratory testing was scheduled upon the basis of field observations for a selection of the following:

- *Atterberg limit tests – natural moisture content, liquid limit and plastic limit;*
- *Particle size distribution (PSD) tests;*
- *BRE SD1 Suite D – Water soluble and acid soluble sulphates, water soluble chloride, nitrate and magnesium, total sulphur and pH.*

3.6.2 Soil geotechnical certificates of analysis are presented in Appendix F.

3.7 General Sampling

3.7.1 Samples were collected in accordance with the following guidance;

- BS5930:2015+A1:2020 – Code of practice for ground investigations;
- BS-EN 1997-2:2007 - Eurocode 7 — Geotechnical design —Part 2: Ground investigation and testing
- BS ISO 10175:2011+A2:2017 - Investigation of potentially contaminated sites – Code of practice;
- BS ISO 18400-105:2017 Soil quality – Sampling - Packaging, transport, storage and preservation of samples; and
- BS ISO 18400-106:2017 Soil quality – Sampling - Quality control and quality assurance.

4 GROUND INVESTIGATION FINDINGS

4.1 Introduction

- 4.1.1 A summary of encountered ground conditions for the site is provided below, while detailed descriptions are shown on exploratory hole logs presented in Appendix D. Photographs of the materials encountered, together with a selection of photos of exploratory locations are presented within Appendix A.

Made Ground

- 4.1.2 Made ground was encountered across the site to depths in excess of 4.2mbgl (3.6mAOD) and was noted to be primarily granular in nature, comprising slightly silty sandy gravel; silty sandy gravel; and slightly clayey silty sandy gravel with low cobble and boulder content.
- 4.1.3 The gravel component was noted to include concrete, brick, coke, slag, clinker, cloth (fabric), tiles and tile fragments, plastic, iron ore, rubber, rubber matting, porcelain fragments, wood fragments, metal fragments, rebar and metal wire. The cobbles and boulders generally comprised concrete, coke and rare relicts of brick walls.
- 4.1.4 Cohesive made ground material was encountered within a single exploratory location (TP209) from 1.75m (5.85mAOD) to in excess of 2.5mbgl (5.1mAOD). The encountered material was described as greyish brown and grey mottled slightly gravelly very silty clay. The gravel component was recorded as slag.
- 4.1.5 Concrete slabs were observed in numerous locations across the site. 5No. exploratory locations (BH201, BH201A, BH202, BH202A, TP208 and TP216) recorded concrete slabs below ground level between depths of 0.2mbgl (7.4mAOD) and 0.45mbgl (7.15mAOD).
- 4.1.6 The base of the made ground materials was not proven in any of the exploratory locations advanced across the site during the current phase of investigation.

4.2 Perched Water

- 4.2.1 Perched water was encountered within two exploratory locations (BH202B and TP214). Within BH202B, perched water was recorded at 3.1mbgl, with a resting level of 1.7mbgl after a period of 20minutes. Within TP214, the perched water was encountered at 2.1mbgl, with a resting level of 2.0mbgl after a period of 15minutes. Water strikes/ observations are also shown on the exploratory hole logs in Appendix D.
- 4.2.2 It should be noted that groundwater conditions recorded during the investigation may not be representative of long-term conditions and that groundwater levels may vary in response to meteorological/ seasonal changes.

4.3 Contamination Observations

- 4.3.1 No visual or olfactory evidence of potentially gross contamination was recorded during the ground investigation. Screening of soil samples with a photo-ionisation detector (PID) recorded concentrations of volatile organic compounds (VOCs) to be generally between 0.1ppm and 0.8ppm.

5 LAND CONTAMINATION - GENERIC QUANTITATIVE RISK ASSESSMENT

5.1.1 The generic quantitative risk assessment comprises a screening of potential contaminants identified within the Tier 1: Preliminary Risk Assessment against carefully selected generic assessment criteria (GAC) that are appropriate to the site setting and the receptors concerned.

5.1.2 GAC's are screening criteria which are derived using a standard set of generic assumptions. They are designed to be broadly applicable to a wide range of site conditions and exposure scenarios. For this site GAC's relevant to Human Health and Controlled Waters have been selected, as detailed in sections 5.2 and 5.3 below.

5.2 Human Health

Methodology

5.2.1 Detailed information on the background legislation and selection of the GAC used within this assessment for human health is presented in Appendix G.

5.2.2 TEC have referenced the Environment Agency SGV's, DEFRA Category 4 Screening Levels (C4SLs) and LQM/CIEH S4ULs for Human Health Risk Assessment 'Copyright Land Quality Management Limited reproduced with permission; Publication Number S4UL3126. All rights reserved.'.

5.2.3 The standard land use for the site, for use in this generic assessment, has been defined as "commercial" based on the proposed development and in accordance with current guidance.

5.2.4 All GAC's used within the assessment are based on a sandy loam as defined in SR3 (Environment Agency, 2009) and Soil Organic Matter (SOM) of 1% where applicable, which is considered the most conservative initial screening approach.

5.2.5 As the site investigation methodology involved targeted sampling, statistical analysis has not been undertaken and the results have been directly compared to the GAC.

Summary of Results

5.2.6 The full human health generic quantitative risk assessment is presented in Appendix G.

Made Ground

5.2.7 The results of the assessment recorded a single exceedance of total cyanide when considering a commercial site end use (BH201B at 2.5-2.8mbgl) no further exceedances of the relevant GAC's were reported for organic or inorganic contaminants.

Asbestos

5.2.8 The laboratory screening for asbestos identified asbestos fragments and fibres within 3No locations, as detailed within Table 5.1 below.

Table 5.1: Summary of Asbestos Identification

Exploratory Location	Depth (mbgl)	Asbestos Identification
TP208	0.3	Amosite – loose fibrous debris
TP211	0.4	Amosite – loose fibres
TP211	1.3	Chrysotile – loose fibres

5.2.9 Further quantitative analysis was completed on these samples with the results indicating concentrations of <0.001% - 0.003% of asbestos by weight to be present.

PFAS

5.2.10 PFAS testing undertaken on 5No. samples recorded all samples to be below the Laboratory limit of detection.

5.3 Controlled Waters

Methodology

- 5.3.1 Leachate analysis has been undertaken on selected samples to determine the likely risk to identified controlled water receptors. Detailed information on the background legislation and selection of the GAC used within this assessment for controlled waters is presented in Appendix H.
- 5.3.2 With regards to controlled waters receptors, a conservative preliminary risk assessment has been undertaken by comparing the soil leachate analytical results to published Environmental Quality Standards (EQS). In the absence of EQS values, Drinking Water Standards have been utilised.

Summary of Results

- 5.3.3 The controlled waters generic quantitative risk assessment is presented in Appendix H.
- 5.3.4 The results of the leachate analysis recorded exceedances of the relevant SSV 's and therefore the following contaminants of potential concern (CoPC) have been identified within the leachate;
- *Heavy metals – arsenic, chromium, lead, selenium and zinc;*
 - *Cyanide;*
 - *Total Phenol; and*
 - *PAH's - Benzo(a)pyrene and anthracene*

5.4 Ground Gas Risk Assessment

Methodology – Characterisation without gas monitoring data

- No landfills or coal mine entries/ workings have been identified within proximity to the site;
 - While made ground was encountered to depth in excess of 4.0mbgl, the encountered material was noted to comprise general infill construction/slag materials with a TOC ranging between 0.5% and 2.5%. Given the composition of the made ground, it is not considered a potential source of significant ground gas generation;
 - The site is not located within a radon affected area.
 - While the anticipated natural soils based on BGS mapping, and previous intrusive works undertaken in proximity to the site by TEC (Tidal Flat Deposits) are typically of medium to high organic content, given the absence of structures as part of the proposed development, no credible source or pathway for ground gas has been identified at the site as part of these works. Therefore, no further ground gas monitoring or assessment is considered to be required and no specific ground gas protection measures are considered necessary for the proposed development at this stage.
- 5.4.1 Notwithstanding the above, should the proposed development change to include structures, additional assessment may be required.

5.5 Updated Conceptual Model

- 5.5.1 The findings of the site investigation and the GQRA have been used to update the conceptual model and confirm the relevant contaminant linkages associated with the proposed development.

5.6 Identified Sources

- 5.6.1 Sources of contamination identified on and within the vicinity of the site are summarised below:

Identified On Site Sources

- Elevated contaminant concentrations within the made ground recorded across the site.
- Potentially contaminative historic land uses/ processes associated with historic Margam Copper Works.

Identified Off Site Sources

- Potentially contaminative current and historic land uses/processes – including wider Iron and Steel Works, industrial docks area, copper works, gas works, railway sidings.

5.7 Identified Receptors

5.7.1 Receptors identified as part of this updated conceptual model are:

- Current/future site users (most sensitive receptor being workers on the site) from contaminated soils;
- Construction and maintenance workers; and
- Controlled waters (Secondary A Aquifer and Secondary (undifferentiated) Aquifer and nearby surface waters) from contaminated groundwater).

5.8 Identified Pathways

5.8.1 Identified contaminant pathways relating to the identified receptors and contaminants of concern include:

Human Health

- Dermal contact – Direct skin contact with soil, dust, or water. Certain contaminants can also be absorbed into the body through skin, or enter directly through cuts or abrasions; and
- Ingestion - ingestion of soil by consumption of un-washed produce grown on site or eating with unwashed hands causing cross contamination, or ingestion of fugitive dust from surfaces etc., or indirect ingestion of fruit and vegetables grown in contaminated soil.
- Inhalation – inhalation of soil, dust or vapours which may result in short term acute risks of asphyxiation of toxicity, and /or long-term chronic risks to human health.

Controlled Waters

- Infiltration and contaminant migration through permeable strata such as the unsaturated zone to the underlying groundwater; and
- Leachate Generation: Mobile/leachable contaminants (e.g. surface spillages/leakage of hydrocarbons) migrating vertically down through the near surface unsaturated zone until meeting the groundwater table below, after which free/dissolved phase contaminants may potentially migrate beyond the site boundaries and impact off site receptors; and
- Leachate migration: Leachate horizontally migrating and impacting on surface water quality in nearby watercourses and below the ground along preferential pathways including drainage pipe bedding, jointing and fracturing within the underlying strata;

Building Materials/Services

- Aggressive attack: building materials can be damaged by direct contact with aggressive/contaminated ground, especially if mobile groundwater is present, for example sulphate attack on concrete or the aggressive contaminants coming into direct contact with membranes used within the structures; and
- Permeation of contaminants: Contamination within soil and groundwater can permeate through water supplies.

5.8.2 The updated conceptual model is presented in Table 5.2. References to risk estimations are made in accordance with the methodology presented in CIRIA publication C552 (2001) titled 'Contaminated Land Risk Assessment: A Guide to Good Practice' and summarised in Appendix C.

Table 5.2: Updated Conceptual Model (Hazard Assessment and Risk Estimation)

Potential Source Location	Identified Hazard/ Source	Identified Receptor	Identified Pathway	Potential Consequence of Contaminant Linkage	Potential Probability for Contaminant Linkage	Risk Classification (Risk = Probability x Consequence)
On site	Made ground and potentially contaminative processes.	Current and future site users and construction workers	Exposure to potential contaminants through ingestion, inhalation and dermal contact.	Medium	Low Likelihood: Laboratory analysis of the made ground encountered across the site recorded an elevated concentration of cyanide within a single location. In addition, asbestos fibres and fibrous debris was recorded within 3No. samples of the made ground materials. Notwithstanding this, it is understood that much of the proposed development will be laid to hardstanding, which in turn will mitigate the contaminant pathways. However, where soft landscaping is proposed and where made ground materials remain on-site after finished site levels have been achieved, exposure to potential contaminants cannot be discounted.	Moderate/low Risk
		Controlled waters	Leaching of potential contaminants from made ground and vertical and lateral migration through the saturated zone to controlled waters.	Medium	Low Likelihood to Likely: Elevated leachable contaminant concentrations have been recorded within the made ground material across the site.	Moderate/ Moderate to low Risk
Off site	Potentially contaminative current and historic processes – off site	Future (temporary) site users, construction workers and controlled waters	Exposure to potential contaminants through ingestion, inhalation and dermal contact.	Medium	Unlikely to Low Likelihood: The field observations and laboratory analysis suggest no significant migration of contaminants from off-site sources within the soil sampled and analysed. Notwithstanding this, the potential for the elevated PAH and TPH concentrations identified within the sampled perched water to be associated with off-site sources cannot be discounted at this stage.	Low to Moderate/low Risk

6 LAND CONTAMINATION - CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

- 6.1.1 No visual or olfactory evidence of potentially significant contamination was noted during the ground investigation.
- 6.1.2 Laboratory analytical results of the encountered made ground materials reported both organic and inorganic contaminants to be generally below the relevant GAC for a commercial end use. However, a single exceedances of the GAC was recorded for total cyanide, and asbestos fibres / debris was recorded within 3No. samples analysed from site.
- 6.1.3 In addition, leachable contaminants of potential concern have been recorded within the made ground.
- 6.1.4 PFAS testing was undertaken on 5No. samples, of which all the samples tested below the detection limit.
- 6.1.5 Based on the proposed development, understood to comprise the temporary capping of the site with granular material to allow it to be used for the duration of the construction of the nearby proposed sustainable jet fuel production facility, no credible source or pathway for ground gas has been identified at the site as part of these works. Therefore, no further ground gas monitoring or assessment is considered to be required and no specific ground gas protection measures are considered necessary for the proposed development at this stage. In addition no radon protective measures are considered necessary within the construction of any temporary structures.

6.2 Preliminary Remediation Options Appraisal

Human Health

- 6.2.1 Localised contaminants of potential concern (CoPC) have been recorded within the near surface materials when considering a commercial end use.
- 6.2.2 Therefore, where soft landscaping is proposed in such areas and where made ground remains after finished site levels have been achieved, localised exposure to potential contaminants cannot be discounted and a suitable cover system may be required within areas of soft landscaping.

Controlled Waters

- 6.2.3 Leachable contaminants of potential concern have been recorded within the sampled made ground materials from site in relation to the conservative EQS values adopted.
- 6.2.4 The potential for vertical migration of CoPC into the underlying groundwater cannot be discounted at this stage and further assessment would be required to determine any potential risk.

6.3 General Considerations

- 6.3.1 Given the presence of general made ground, good brownfield site working practices should be adopted by construction workers to mitigate against potential risks.
- 6.3.2 Should water supply pipes be placed within the made ground encountered at the site, due consideration would need to be given to the UK Water Industry Research Ltd (UKWIR) guidance.
- 6.3.3 Based on our conceptual understanding of the site to-date, it would be anticipated that similar ground conditions to those encountered as part of this assessment exist across the site areas where access has been possible. However, should significant thicknesses of made ground be encountered, or visual or olfactory evidence of potentially significant contamination be identified during the development works, further investigation and assessment may be required.

7 GROUND ENGINEERING

7.1 Proposed Development

- 7.1.1 The site currently comprises a disused plot of largely scrub land, with remnants of infrastructure associated with Margam Wharf (concrete slabs and access roads), present across the site.
- 7.1.2 Whilst full details of the proposed development have not been provided to TEC at this stage, it is understood that it is to comprise a temporary construction facility which is likely to be temporarily capped with granular material to allow it to be used for the duration of the construction of the nearby proposed sustainable jet fuel production facility.
- 7.1.3 Although no details have been provided to TEC, it is currently understood that no structures would be present on site as part of the development. However, at this preliminary stage and for information purposes only, should temporary structures be proposed, friction angles of 28° to 32° would be considered appropriate.

7.2 Site Preparation

- 7.2.1 The site was observed as being generally flat and at an approximate elevation of 7.6mAOD.
- 7.2.2 BT Services were noted parallel to the access road located at the western site boundary. A harbour wall was observed immediately west off site, forming part of the larger Port Talbot Docks.
- 7.2.3 No structures were recorded on site. However, a number of concrete slabs were noted across the site. during the ground investigation south of the site.
- 7.2.4 Consideration to these features may be required as part of the development works.

7.3 Geotechnical Test Data Summary

- 7.3.1 Laboratory test data are presented in Appendix F while in situ test results are presented on the engineering logs Appendix D.

Plasticity

- 7.3.2 Atterberg Limit testing was undertaken on a single cohesive sample encountered within TP209 as summarised in Table 7.1 below:

Table 7.1: Summary of Laboratory Test Results

Moisture Content (%)	Plasticity Index (%)	% passing 425µm sieve	Modified Plasticity Index ⁽¹⁾ (%)	Volume Change Potential ⁽¹⁾
26	14	95	13.3	Low

Note 1: Based on recommendations provided in the NHBC Standards

Particle Size Distribution

- 7.3.3 Particle Size Distribution (PSD) testing was undertaken on 14No. samples of the granular made ground material. The results indicate a clay component of between 0.1% and 2.9%, a silt component of between 1.2% and 9.4%, sand component of between 12.53% and 28.53% and a gravel component of between 61.39% and 84.32%. A very coarse component of 10.5% was recorded within TP218 at 0.4 – 0.6mbgl.
- 7.3.4 In addition, Particle Size Distribution (PSD) testing was undertaken on a single sample of the more cohesive made ground material with a clay component of 10.2%, a silt component of 49.9% sand component of 38.05% and a gravel component of 1.85% recorded.

Soil Strength

- 7.3.5 A summary of the geotechnical field test data is provided in Table 7.2 below.

Table 7.2: Summary of Geotechnical Field Test Data

Stratum	SPT 'N' Value Range	Hand Shear Vane Range (kPa)	Pocket Penetrometer Range (kg/cm ²)
Made Ground (Cohesive)	-	72 - 84	1.6 – 2.0
Made Ground (Granular)	14 - >50	-	-

7.4 Suggested Design Parameters

7.4.1 Based on the findings of the ground investigation works to-date, the following design parameters are suggested:

Table 7.3: Indicative Design Parameters

Parameter	Made Ground	
	Sandy Gravel	Silty Clay
Plasticity Index (%)	-	14
Modified plasticity (%)	-	13.3
Volume change potential	-	Low
Uncorrected SPT 'N' value	14 - >50	-
Unit weight ⁽¹⁾ (kN/m ³)	18.5	17.5
Undrained strength (kN/m ²)	-	75
Drained cohesion, c' (kN/m ²)	0	20 - 30
Drained friction, ϕ'	28 - 33°	12° - 17°

Notes: 1. Based on BS8002:2015

7.5 In-situ Testing

Made Ground: Plate Load Testing

7.5.1 In situ plate loading tests of the made ground materials were completed at 3No. locations across the site within TP204 (at 0.3m and 0.6m), TP213 (0.45m) and TP214 (0.3m, 0.6m and 0.9m), utilising a 13-tonne excavator as kentledge. The results are provided in Appendix I and summarised within Table 7.4

Table 7.4: Summary of CBR Data

Test Location	Pressure (kN/m ²)	Settlement (mm)	Modulus (kN/m ² /m)	CBR (%)
TP204 (0.3m)	521.29	1.2	184205	81
TP204 (0.6m)	376.79	1.45	13342	46
TP213(A) (0.45m)	1597.82	1.0	564606	>100
TP214 (0.3m)	174.03	1.4	61496	12
TP214 (0.6m)	397.72	1.35	140538	51
TP214 (0.9m)	364.45	1.4	128781	44

7.5.2 CBR values of between 12% and >100% within the made ground material with a Modulus of Sub-Grade Reaction between 61496kN/m²/m and 564606kN/m²/m was recorded within the made ground.

7.5.3 Furthermore, no natural material was tested within this phase of works.

Made Ground: Clegg Hammer Testing

- 7.5.4 The CBR results are summarised in Table 7.5 including recommended values for preliminary design purposes based upon these initial findings. The results are presented in Appendix J.

Table 7.5: Summary of CBR Data

Stratum	Method	Derived CBR Values (%)	Recommended CBR for Preliminary Design (%)
Made Ground at 300mm	Clegg Hammer ⁽¹⁾	16.6 - 103	14.5
	Clegg Hammer ⁽²⁾	21.2 - 133	
Made Ground at 600mm	Clegg Hammer ⁽¹⁾	18.6 – 36.3	
	Clegg Hammer ⁽²⁾	23.4 – 37.5	
Made Ground at 900mm	Clegg Hammer ⁽¹⁾	14.2 – 36.3	
	Clegg Hammer ⁽²⁾	18.3 – 37.5	

Note 1: Equation 1 - Baghabra Al-Amoudi et al (2002) equation: $CBR = 0.1691 (CIV)^{1.695}$

Note 2: Equation 2 - Clegg (1986) equation: $CBR = (0.24 (CIV) + 1)^2$ (considered more applicable for CBR values of <5%)

- 7.5.5 Notwithstanding this, given the recorded thickness of made ground across the site, a CBR of <2.5% would be recommended where formations are within this material.
- 7.5.6 It should be noted that all road formations should be proof rolled and soft spots removed and replaced with selected granular fill and, where adoptable, a pavement of sufficient thickness (>450mm) to prevent the penetration of frost should be employed.
- 7.5.7 CBR values of the subgrade should be confirmed by in situ testing when final formation levels are known.

7.6 Excavations

- 7.6.1 Excavations at the site may be achievable using conventional equipment, although it is anticipated that a breaker may be required at relatively shallow depth, should excavation within the concrete slabs be required.
- 7.6.2 Groundwater strikes were recorded at depths between 2.1m and 3.1mbgl. Based on observations made during the ground investigations, groundwater ingress into excavations is considered unlikely to be significantly problematic, although some dewatering may be required, particularly where excavations are left open for any length of time. It would be recommended that formation levels are protected to mitigate against softening associated with any such water ingress.
- 7.6.3 It should be noted that groundwater levels might fluctuate according to the season and from year to year. This may have implications on recommendations, including those for foundations and excavations. Accordingly, a careful watch should be maintained during any future groundworks and the recommendations presented in this report may be subject to amendment should additional information becoming available.
- 7.6.4 It is recommended that appropriate shoring/temporary works are used in accordance with current Health and Safety requirements where access for personnel is required into excavations.

7.7 Protection of Buried Concrete

- 7.7.1 The desk study and observations of the encountered ground materials during the intrusive works indicate the site would be categorised as 'Brownfield locations', including potential aggressive materials or leachates, that contain pyrite.
- 7.7.2 At this stage, there is insufficient data to confirm the mobility of groundwater at the site (and potential changes that may result during construction) and therefore a mobile groundwater has been assumed.
- 7.7.3 It should be noted that groundwater samples have not been collected as part of this scope of work.

7.7.4 The results of the testing of the soil samples, together with the resulting Aggressive Chemical Environment for Concrete (ACEC) Class and Design Sulphate (DS) Class, as derived in accordance with BRE Special Digest 1, are presented in Table 7.6. The full laboratory results are presented in Appendix F.

Table 7.6: Summary of ACEC

Stratum	No. of tests	pH	Water Soluble Sulphate (mg/l)	Oxidisable Sulphides (%)	Total Potential Sulphates (%)	ACEC ⁽¹⁾	DS Class ⁽¹⁾
Made Ground	3	10.7 – 10.8	146 - 264	0.21 – 0.52	0.36 – 0.81	AC-3	DS-3

Note 1: Based on a characteristic value derived for a data set of <5 samples per stratum (maximum water soluble sulphate concentration/ lowest pH) as per BRE SD1

7.7.5 Based on past experience of similar ground conditions in the near vicinity of the site, higher total sulphate values could be anticipated within the made ground materials associated with the steelworks, often resulting in a Design Sulphate Class of DS-5 being recommended. Unless a greater number of tests are completed, it may therefore be prudent to up-grade the protection for concrete accordingly.

8 GROUND ENGINEERING - CONCLUSIONS AND RECOMMENDATIONS

- 8.1.1 Due to ecological constraints which made the northernmost site area inaccessible at the time of this phase's of works, additional ground investigative works may be required to fully identify the ground conditions
- 8.1.2 A preliminary design CBR value in the region of 2.5% has been derived based on the test data to-date. CBR values of the subgrade should be confirmed by in situ testing when final formation levels are known.
- 8.1.3 The results of the sulphate and pH testing from the soils at the site yield an aggressive chemical environment class (ACEC) of AC-3 requiring a design sulphate class of DS-3 for the present made ground conditions. However, should any structures be proposed for the site, a DS-5 would be recommended due to past experience of similar ground conditions in the near vicinity of the site. Unless a greater number of tests are completed, it may therefore be prudent to up-grade the protection for concrete accordingly.

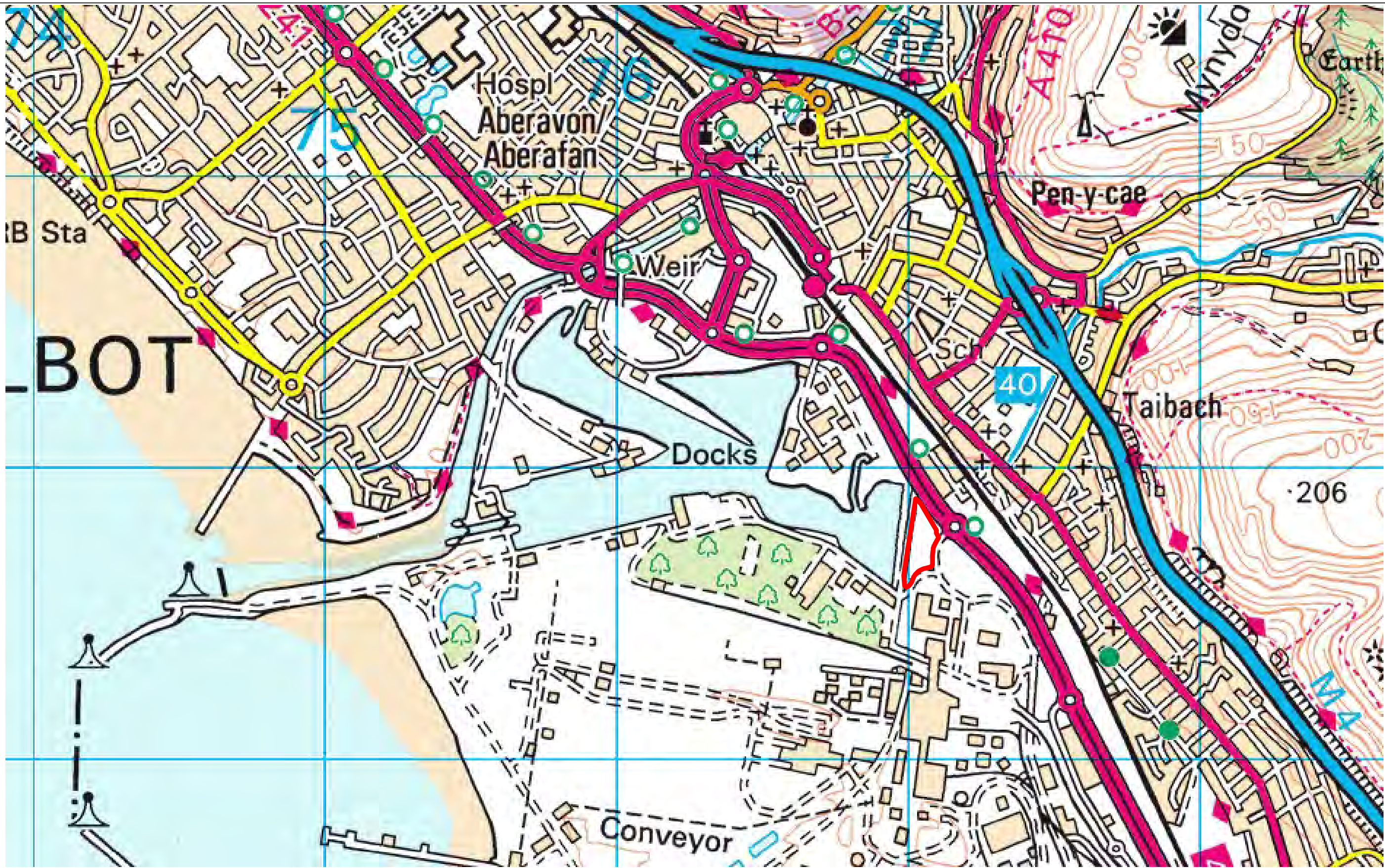
9 RECOMMENDED FURTHER WORKS

9.1.1 Given the assessment presented within this report, additional works would be recommended to fully define the land contamination risks and geotechnical issues associated with the site.

- Targeted ground investigation to provide additional site specific data
 - o Additional investigation testing within the northern site area

TEC

Figures and Drawings



 Approximate Site Boundary

PROJECT DRAGON

Project Dragon – Sustainable Aviation Fuel (SAF)
Production Facility: Temporary Construction Area
at Margam Wharf

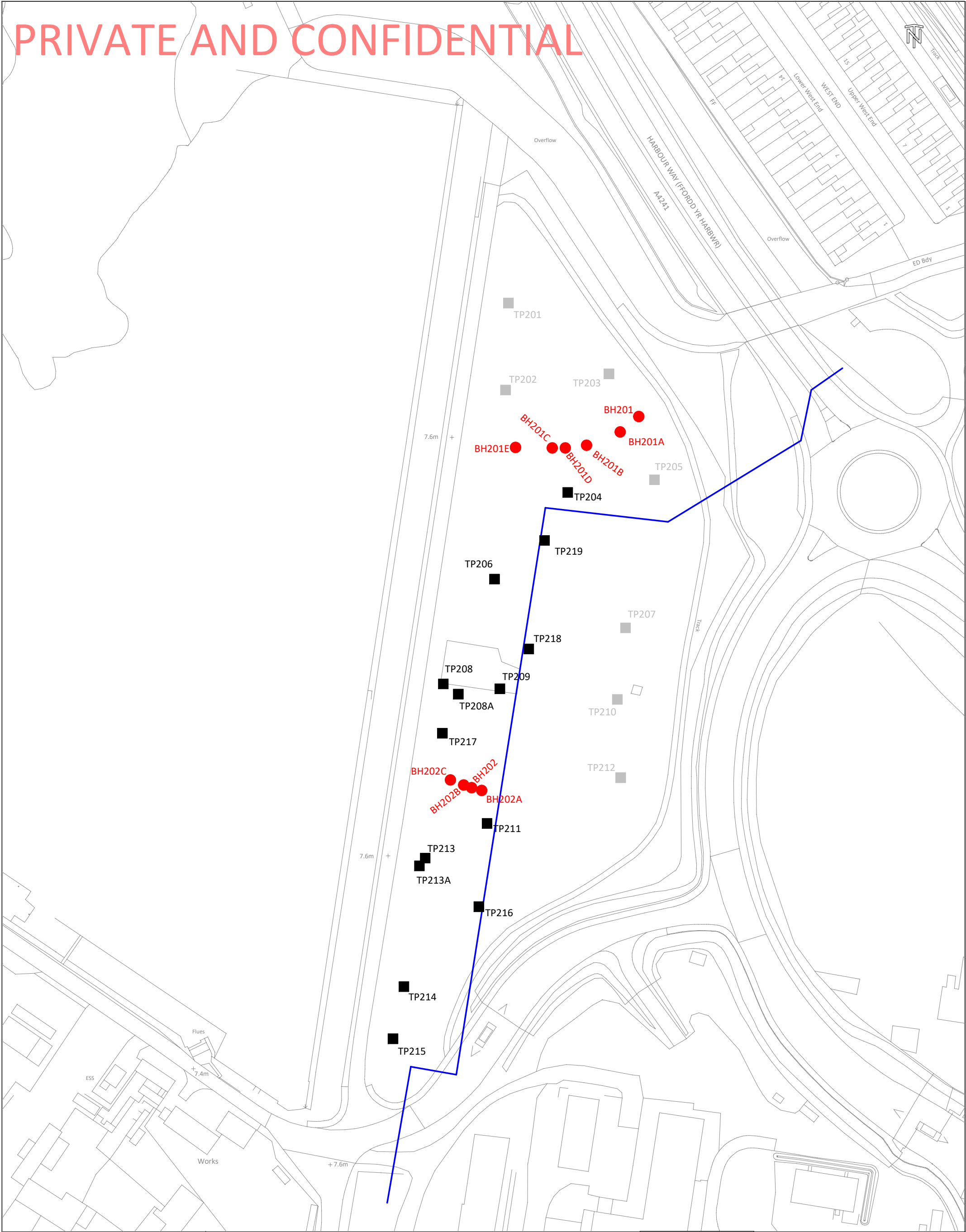
Site Location Plan

DATE: September 2023		
SCALE: N/A	DRN: RK	CHKD: CH
PROJECT No: 2111006.006	DATE: 15-09-2023	DATE: 15-06-2023

FIGURE 1

Rew

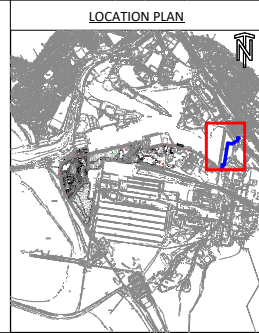
PRIVATE AND CONFIDENTIAL





- Trial Pit Location
- Inaccessible Location
- Borehole Location
- Ownership Line

LOCATION PLAN

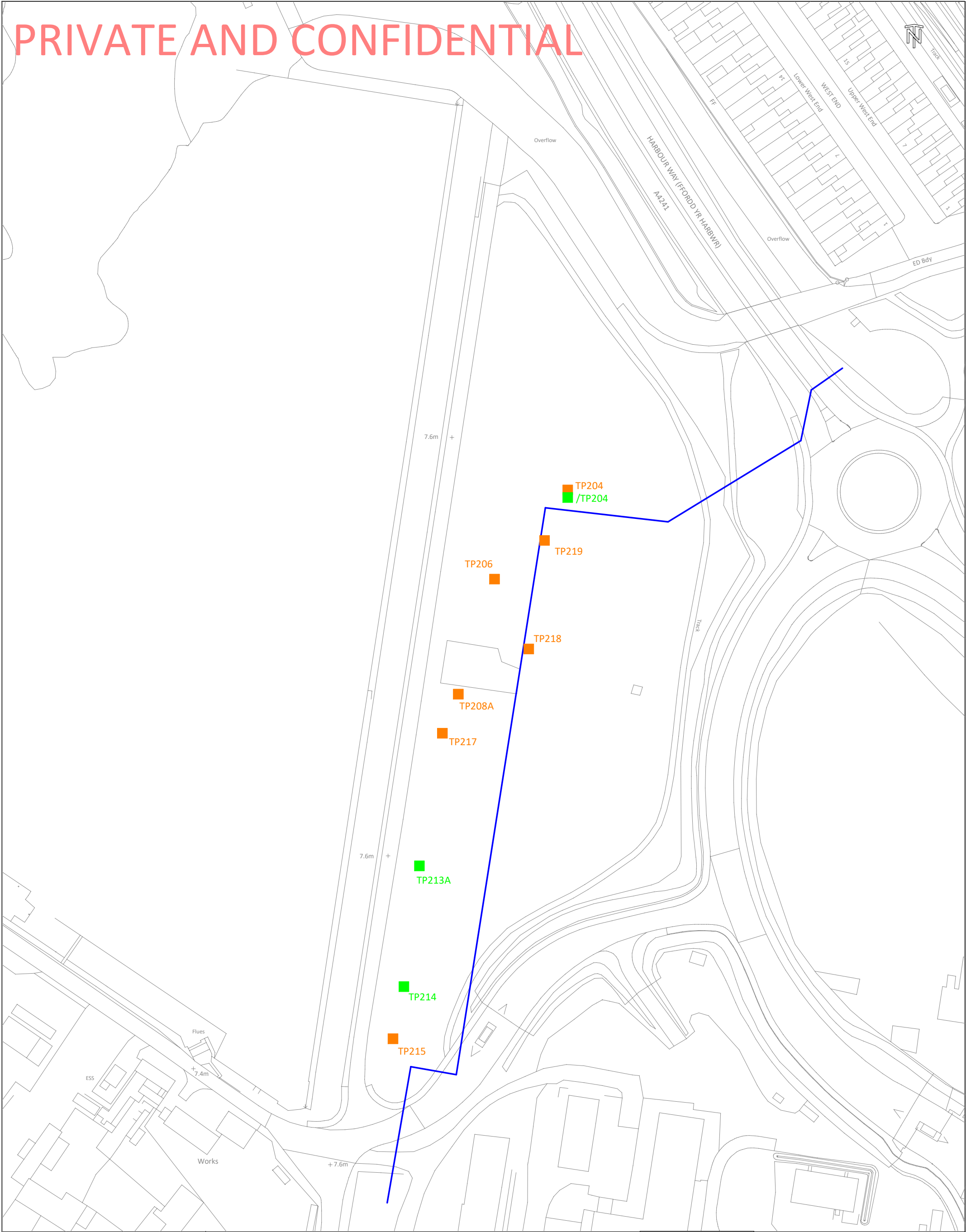


Project Dragon – Sustainable Aviation Fuel (SAF)
Production Facility: Temporary Construction Area
at Margam Wharf

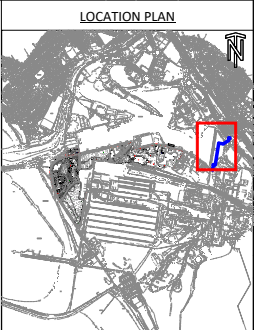
Figure 2
Geotechnical/ Geoenvironmental
Exploratory Hole Plan

DATE: September		
SCALE: N/A	DRN: AB/RK	CHKD: CH
PROJECT No: 2111006.006	DATE: 15-09-2023	DATE: 15-09-2023
DRAWING No. Sketch 006		Rev.

PRIVATE AND CONFIDENTIAL



- Trial Pit (with Clegg Hammer Test)
- Trial Pit (with Plate Load Test)
- Ownership Line



Project Dragon – Sustainable Aviation Fuel (SAF)
Production Facility: Temporary Construction Area
at Margam Wharf

Figure 3
Plate Load Test and
Clegg Hammer Test
Location Plan

DATE: September		
SCALE: N/A	DRN: RK	CHKD: CH
PROJECT No: 2111006.006	DATE: 15-09-2023	DATE: 15-09-2023
DRAWING No. Sketch 006	Rev.	

Appendix A

Site Photographs



Photograph 1: View across site, facing north.



Photograph 2: View across site, facing north-east.



Photograph 3: View of trial pit, TP204.



Photograph 4: Encountered ground conditions within trial pit, TP204.



Photograph 5: View of trial pit, TP206.



Photograph 6: Encountered ground conditions within trial pit, TP206.



Photograph 7: View of trial pit, TP208.



Photograph 8: Encountered ground conditions within trial pit, TP208.



Photograph 9: View of trial pit, TP208A.



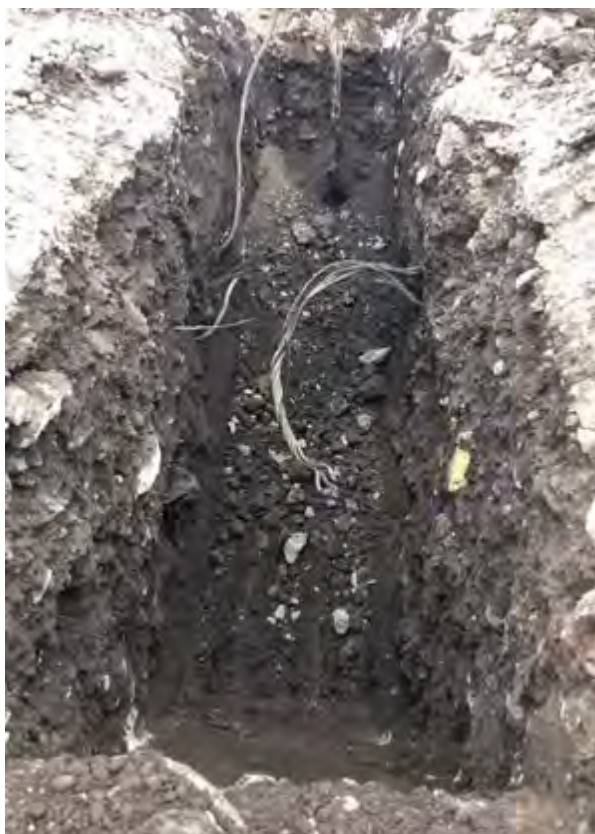
Photograph 10: Encountered ground conditions within trial pit, TP208A.



Photograph 11: View of trial pit, TP209.



Photograph 12: Encountered ground conditions within trial pit, TP209.



Photograph 13: View of trial pit, TP211.



Photograph 14: Encountered ground conditions within trial pit, TP211.



Photograph 15: View of trial pit, TP213.



Photograph 16: Encountered ground conditions within trial pit, TP213.



Photograph 17: View of trial pit, TP214.



Photograph 18: Encountered ground conditions within trial pit, TP214.



Photograph 19: View of trial pit, TP215.



Photograph 20: Encountered ground conditions within trial pit, TP215.



Photograph 21: View of trial pit, TP216.



Photograph 22: Encountered ground conditions within trial pit, TP216.



Photograph 23: View of trial pit, TP217.



Photograph 24: Encountered ground conditions within trial pit, TP217.



Photograph 25: View of trial pit, TP218.



Photograph 26: Encountered ground conditions within trial pit, TP218.



Photograph 27: View of trial pit, TP219.



Photograph 28: Encountered ground conditions within trial pit, TP219.

Appendix B

Detailed UXO Risk Assessment



BRIMSTONE

DETAILED UXO RISK ASSESSMENT

INTEGRITY

PROFESSIONALISM

KNOWLEDGE



STAGE 2 DETAILED UXO RISK ASSESSMENT

Client: TEC Ltd
Project Ref: TWEE89R
Site: Project Dragon, Port Talbot
Report Ref: DRA-23-1532-TWEE89R-ProjectDragon,PortTalbot
Revision: 2
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EXECUTIVE SUMMARY

RESULT: Brimstone concludes that German UXBs and unexploded HAA shells poses a **LOW, LOW-MODERATE** and **MODERATE RISK** to the proposed works. See **FIGURE 7** for risk mapping.

THE SITE: The Site comprises three separate areas, known as Site A (west), Site B (centre) and Site C (east). These will be referred to collectively as ‘the Site’ for the purposes of this assessment, when not discussed individually.

The Site (approximately centred on the National Grid Refs: SS 76385 88669 (Site A), SS 76750 88541 (Site B) SS 77018 88747 (Site C)) is located in Port Talbot, within the county borough of Neath Port Talbot, Wales. Port Talbot Parkway railway station is located approximately 700m north of the Site.

Site A primarily comprises undeveloped land – consisting of grassy areas and mature vegetation – intermixed with brownfield land. It is bound to the north by an unlabelled roadway and a cement works factory, to the east by a thin parcel of undeveloped land and Site B, while open/wooded ground lies to the west and south.

Site B consists of undeveloped land with mature vegetation in the south, particularly along the border, while areas of hardstanding complete with industrial infrastructure, low-rise industrial warehouses and other structures lie in the north and west. Most of the ground in the north and west is laid to hardstanding, mainly used for open air storage and car parking purposes.

Site C consists of hardstanding brownfield land with an entrance to an unnamed roadway in the south and the entrance to a river runoff in the north. It is bound to the north by the hardstanding river run off, to the east by an unnamed roadway connecting to Harbour Way, to the south by an unnamed roadway and to the west by a vegetated border to the docks.

THE PROPOSED WORKS: Ground investigation works are proposed, although specific works were not provided.

Brimstone was not made aware of any future redevelopment works.

UXO RISK ASSESSMENT:

German UXO:

- Port Talbot was a key industrial hub during World War II, with its steelworks and coal production facilities playing a vital role in supporting the British war effort. The Margam Steelworks, within which Site C was located, were involved in the production of steel for munitions, tanks, ships, and other war materials. Consequently, the town and its industries became targets for German air raids carried out by the Luftwaffe. Indeed, Luftwaffe target photography indicates industries on Site and nearby were identified as primary bombing targets. A railway yard/storage station was recorded on target photography (Site B) and a steel works which made up Site C. This is further recorded within Luftwaffe target mapping, which highlights the copper works (Kupferwerke) and hard coal briquettes (Steinkohlenbrikettebrik) within Site A as bombing targets, as well as the iron foundry (Eisengießerei) within which Site C was located.
- The majority of the official records obtained for Port Talbot did not specifically state the location of the incidents occurring, with many entries merely referring to bombing occurring over the town as a whole. It is of note, however, that one of the records reports an incident occurring at a copper works, a facility which consulted OS mapping confirms was present on and immediately adjacent to the north of Site A, as well as waste ground and railway sidings in the vicinity (partially included within / adjacent to Sites A and B), suggesting that bombing may have occurred on Site or in the immediate surrounds. Furthermore, bombing at the docks appears to have occurred on several occasions, with the south side referenced as sustaining a number of bombs, some of which were delayed action. A failure with the clockwork mechanism within the fuze of the delayed-action bombs is one cause of UXBs remaining in-situ. Sites A and B were located on the south side of the docks. The Margam Steelworks and/or its surrounding area is also stated to have been bombed on several occasions.

- No evidence of bomb damage to the copper works in Site A, the structure in the south-east of Site B, nor the section of the steelworks in Site C has been identified within historical aerial imagery and OS mapping, i.e. areas of clearance, missing roofs, repair works. Similarly, no obvious evidence of bomb damage was evident in the areas of open/undeveloped ground on Site; however, such evidence is typically less easily identifiable amongst open ground.
- However, evidence of repair works to the metal refinery in Site A has been observed within 1940 and 1946 aerial imagery, suggesting that bomb damage may have occurred early during WWII. The extent of this possible damage cannot be accurately discerned, although the whole roof appears to have been replaced. The coal briquette works, located within the north of Site B, may have sustained serious damage as identified within aerial vertical imagery. However, given the homogenous nature of this potential damage, as seen within **FIGURE 5.4**, it may be that the structure itself is incomplete or the intended design. A possible bomb crater has been identified approximately 30m south-west of Site A.
- Wartime conditions across the Site varied during WWII. Site A comprised a metal refinery, a section of a copper works, railway infrastructure and undeveloped open ground. Site B comprised a briquetting works in the north, small structure in the south-east, railway infrastructure and undeveloped open ground. Site C comprised a section of the Margam Steelworks. Any UXB strike to the undamaged structures on each of the Sites would have caused incontrovertible evidence of its incidence as it passed the structures and into the ground beneath. Similarly, a UXB strike to the railway sidings on/adjacent to each of the Sites is likely to have been identifiable at the time. Fire watchers were likely present at the industries located within each of the Sites, while the railway infrastructure located within/adjacent to each was likely subject to post-raid checks for evidence of UXO. Indeed, given the lack of identified damage in Site C within high-resolution 1946 aerial imagery, as well as to the copper works in the north-west of Site A and briquetting works in Site B, access is likely to have remained frequent in these areas. These factors increase the likelihood of bombing and subsequent evidence of UXO being observed in these areas.
- However, visual evidence of repair works to the metal refinery in Site A (white/brighter roofing) suggests that bomb damage may have occurred at this location. Evidence of a subsequent UXB strike at this location, which may have been damaged early during WWII, could conceivably have been obscured amongst existing damage and debris. It is conceivable that access may have been reduced for a time, depending on the extent of the damage. The majority of both Site A and Site B also comprised undeveloped open ground during WWII. Subsequently, any potential evidence of UXO is thought likely to have been less noticeable, with a UXB's descent into open land less obvious than through a structure or roadway, for example. Indeed, the entry hole of a 50kg UXB may be as little as 20cm in diameter and can therefore become easily obscured by growing vegetation. Furthermore, it is unlikely that the undeveloped open ground which comprised the majority of Sites A and B will have been accessed to a significant degree; these areas appear largely unused and unmaintained in 1940s aerial imagery. Evidence of a UXB strike in these areas may not have been observed, becoming obscured over time.
- In summary, factors pertinent to the risk of UXO contamination vary across each Site. As discussed above, the ground conditions within the majority of Sites A and B were un conducive to the detection of UXO. Bombs, including those with delayed-action fuzes, are recorded across the south of the docks, potentially on Sites A and B. Indeed, potential repair works indicative of bomb damage has been observed to the metal refinery in Site A. As a result, the majority of Site A and Site B has been assessed at a **Moderate Risk** from German UXBs. While evidence of a UXB will have been more readily observed amongst the undamaged structures and railway infrastructure within this zone, the potential for the J-Curve effect, whereby a UXB may travel laterally from its point of penetration, indicates that the risk from the open ground also presents at the footprint of the WWII structures and railway sidings. A buffer zone has therefore been added to account for this possibility.
- No evidence of damage to the copper works in Site A, railway infrastructure in both Site A and B, nor the structures in Site C, has been identified. The presence of significant and important infrastructure in these locations indicate that a UXB strike will have been observed and dealt with at the time. However, given recorded bombing to the copper works, south side of the docks and the steelworks, the risk from German UXBs is slightly elevated and has been assessed as **Low-Moderate**.

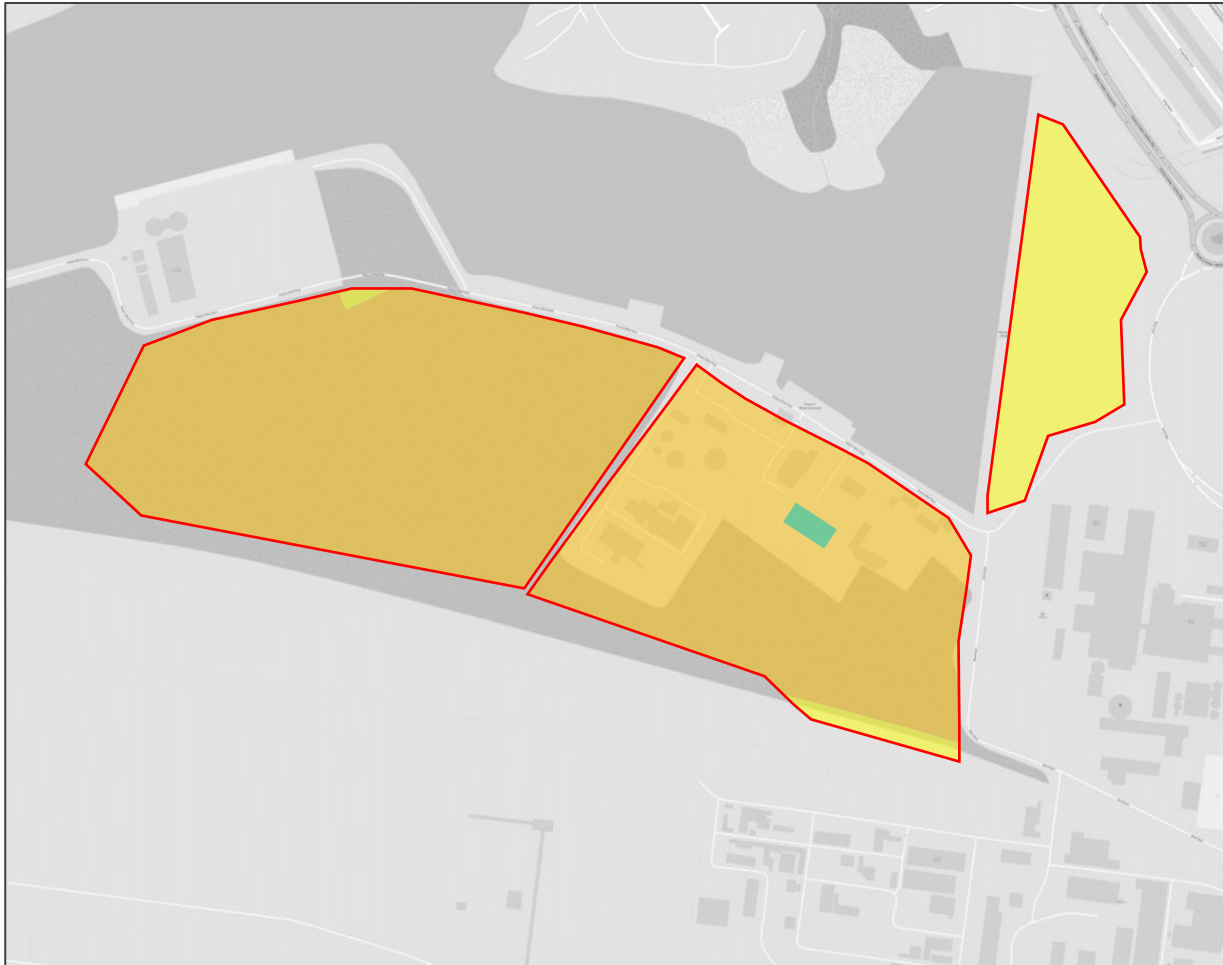
- Similar to the copper works and railway infrastructure within Site A, as well as structures in Site C, no confirmed visual evidence of damage has been observed to the briquetting works in Site B. A UXB strike is likely to have been observed at this location during WWII. Given this, a **Low Risk** has been assessed at the footprint of this structure, with the zone accounting for the possibility of J-Curve causing a UXB to come to rest beneath. As a result, this zone is smaller than the structure itself.

British / Allied UXO:

- Evidence indicates that the Margam Steelworks, within which Site C was located during WWI and WWII, was purpose built during WWI for war production. Further research suggests that the steelworks produced steel utilised for munitions, tanks, ships and other war materials. Three WWII-era bombs/shells have been uncovered at Tata Steel in the 21st century (none have been recorded on Site, although specific locations are unknown). No evidence has been found to suggest that shells were filled at the steelworks in Port Talbot. It is likely that the aforementioned shells consisted solely of the outer casing, given that each of them was certified inert and no mention was made of a high-explosive fill. Therefore, the risk from Allied UXO is assessed to be **Low** across the Site.
- Although all shells uncovered within the wider Tata Steel works have been found to be inert and are believed to be shell casings only, not ordnance, it cannot be assumed to be the case for any potential future items that are encountered. Any suspicious items should be assumed to be live / hazardous. If such an item is encountered on Site, the relevant authorities should be contacted in order to carry out an immediate investigation and initiate the necessary safety procedures.
- 16 permanent HAA batteries were active within range of the Site during WWII. LAA guns likely defended Port Talbot, within which the Site was located. Luftwaffe activity in the region was relatively infrequent. It is possible that an unexploded AA shell struck the open areas of the Site, and the risk is considered to be analogous to that of German UXBs.

Likelihood of UXO Remaining and UXO Encounter:

- Post-conflicts ground works for all three Sites have comprised the clearance of all WWII-era structures and railway lines. This would have consisted of grubbing out the foundations of the former structures, likely mitigating the risk in these areas to shallow depths (1-2m bgl). It is possible that the clearing of some structures may have required deep (>2m) intrusions, although this has not been possible to confirm. The open areas of the Site are likely to have received minimal post-WWII ground works, which will likely have been to very shallow depths (<1m bgl). Site B has seen the construction of various low-rise structures, infrastructure and the addition of hardstanding across large areas in the north and west. The depths associated with these ground works likely range from very shallow to shallow.
- The risk associated with (any) very shallow and shallow buried UXO will have been partially mitigated in areas of WWII-era structures and infrastructure, as well as post-WWII ground works. The risk associated with (any) deep buried UXO likely remains unmitigated.

Risk Map:

Low Risk from German UXBs & HAA Shells

Low-Moderate Risk from German UXBs & HAA Shells

Moderate Risk from German UXBs & HAA Shells

RECOMMENDED RISK MITIGATION MEASURES: The measures detailed below are recommended to mitigate the risk to ALARP level.

Risk Mitigation Measure	Recommendation
UXO Safety Awareness Briefings	Prior to all intrusive works commencing.
Non-Intrusive Magnetometer Probe Survey	Open excavations on greenfield land within the Moderate Risk zone.
Intrusive Magnetometer Probe Survey	Of all pile positions within the Moderate Risk zone.
EOD Engineer - On Site Supervision	Watching brief of all open excavations and magnetometer survey of all borehole locations within the Moderate Risk zone.

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FIGURES

- FIGURE 1:** Site Location Maps
- FIGURE 2:** Recent Aerial Photograph
- FIGURE 3:** Current Site Plan
- FIGURE 4:** Historical OS Mapping
- FIGURE 5:** Historical Aerial Photography
- FIGURE 6:** Luftwaffe Target Map – September 1940
- FIGURE 7:** Risk Mapping

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- APPENDIX 1:** Recent UXO Incidents and Historical Analysis
- APPENDIX 2:** Data Sheets - German WWII Air-Delivered Munitions
- APPENDIX 3:** Data Sheet - British WWII Anti-Aircraft Munitions
- APPENDIX 4:** Glossary
- APPENDIX 5:** Bibliography

QUALITY MANAGEMENT

Brimstone is committed to the provision of UXO risk mitigation services, including the safe removal and disposal, in the UK and overseas. Since our inception in 2016 it has been our goal to provide unsurpassed UXO risk mitigation services. Brimstone is a client-driven organisation, we aim to provide the client the services they need, to the agreed requirement, in accordance with national and international standards.

We are committed to providing a safe, cost-effective and quality service, underpinned by our three core values;

- Integrity in advice, information and the manner in which we conduct ourselves and our operations,
- Professionalism in the way we handle our operations, people and processes, and
- Knowledge in new skills and information, to ensure we remain at the forefront of innovation and strategy.

We are committed to the applicable requirements of the ISO 9001 standards. We set and review quality monitoring objectives to measure the performance of our quality management system. Brimstone wholly endorses the ethos of 'continual improvement efforts' and allocates resources to meet this requirement.

This policy applies to the whole of the Brimstone services and affects roles from the managing director down. All staff are responsible for helping manage quality, seeking improvement through constant review, and by encouraging supplier and subcontractor involvement. We are committed to achieving customer satisfaction using quality procedures, which will be operated to meet or exceed the applicable requirements of ISO 9001.



Aaron Florence
Founder and Managing Director
Brimstone

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1 INTRODUCTION

1.1 Background

TEC Ltd (the Client) has commissioned Brimstone to carry out a Stage 2 Detailed Unexploded Ordnance Risk Assessment (DRA) of the proposed redevelopment works at the Project Dragon, Port Talbot site (the Site).

1.2 Legislation

There are no regulations that specifically govern the UXO risk mitigation industry in the UK. There are however two pieces of legislation that require consideration. It is industry best practice (and common sense) to frame your site in the context of UXO, and to put in place measures to protect people from risks. In 2009, CIRIA published Unexploded Ordnance (UXO) - A Guide for the Construction Industry C681. This publication, though not legally binding, provides the gold-standard framework to which UXO and construction companies operate.

1.2.1 Construction Design and Management Regulations (CDM) 2015

The regulations identify the client, the CDM coordinator, the designer, and the principal contractor as responsible parties. Under the regulations, responsible parties are held accountable for the way a construction project is managed and for the health and safety of workers. Responsible parties must:

- Provide an appropriate assessment of potential UXO risks, or ensure an assessment is completed by another party.
- Put in place appropriate risk mitigation measures if necessary.
- Supply all parties with information relevant to the risks.
- Ensure the preparation of an emergency response plan.

1.2.2 The Health and Safety at Work Act 1974

The Health and Safety at Work Act 1974 had a transformative impact on health and safety, saving thousands of lives since its enactment. Employers must consider their employees, workers not in their employment, and members of the public. The act places a duty on every employer 'as far as is reasonably practicable' to protect workers from risks. It also says that information must be provided about aspects of health and safety that affect their role.

1.3 Commercial Contractor and the Authorities

1.3.1 Commercial Contractors

If your site has been given a moderate or high-risk rating, then control measures will be recommended. The measures will be specific to the scope of works on site, usually in relation to the depth and extent of excavations, piling and similar activities. There are a range of different methods at Brimstone's disposal, including:

- Non-intrusive surveying (including drone surveying)
- Intrusive surveying
- Search and clear
- Watching brief
- Support to geotechnical investigations
- Target investigation
- Site-specific training packages
- Site safety briefings

Our UXO Engineers can assess suspicious items on site when they are found. This will avoid unnecessary site evacuations. If our engineer(s) decide the item is UXO, they will coordinate with the authorities, manage disruptions, and advise on control measures, such as evacuations and a cordon.

1.3.2 UK Authorities

If Brimstone is not on site and a suspicious item is found, the local police must be immediately called on the non-emergency number. Police will visit the site. They will then inform the Joint Services Explosive Ordnance Disposal (JSEOD) office, which will coordinate the callout of an army or navy response team.

A precautionary cordon will initially be put into effect, with possible evacuation of homes and businesses, road and rail closures. The cordon may be extended following the advice from JSEOD's response team.

To manage their resources, JSEOD triages incidents. A consideration of the type, size and location of the UXO is made. If an incident is not given a high priority rating, a team may not be available for up to two days following the initial report.

The use of JSEOD is under the Military Aid to Civil Authorities (MACA) framework, therefore the budget and personnel is limited, and there are no statutory obligations made of the MOD. Often the MOD will recommend involvement of a commercial UXO contractor to manage the ongoing risk – this is especially true of former airfields and training areas where contact with land service ammunition can be frequent.

1.4 UXO Risk in the UK

Fortunately, to the best of our knowledge, there has not been a single post-war incident in the UK where a construction worker has been killed or injured because of an item of UXO exploding. There have been cases in mainland Europe where UXO had been struck and then exploded, killing workers. In 2019 a WWII general purpose bomb spontaneously detonating in a field north of Frankfurt, Germany.

However, the incident in Frankfurt is not comparable to the UK, due to the way different countries manufactured ordnance. Bombs made in different countries have different associated hazards. British WWII bombs, for example, have a fuzing system which uses chemicals which makes them very unsafe. Please see **APPENDIX 1** for recent examples of UK UXO incidents.

Between 2013 and 2016 JSEOD responded to 7,500 callouts. These callouts range from falsely identified objects, inert objects, small items of UXO and large WWII German unexploded bombs (UXBs). Each year the construction industry inadvertently unearths UXO; often this goes unreported. UXO contamination comes from three main sources:

- **Enemy action:** during WWI and WWII the air forces of Germany, and to a lesser extent Italy, bombed targets throughout the UK. The German navy bombarded several coastal targets in eastern England during WWI and then in WWII German long-range artillery on the French coast bombarded parts of Kent.
- **Allied military activity:** during WWI and WWII several Allied nations used the UK as a staging area for military action in the European Theatre; predominantly the US and Canada.
- **UK military activity:** domestic British Army, Royal Air Force (RAF) and Royal Navy (RN) training activities during peacetime and conflict as well as anti-aircraft gun and rocket batteries during WWI and WWII.

1.5 UXO Detonations

A detonation is a violent chemical reaction which creates a huge volume of gas. This reaction appears to happen instantaneously – the velocity of the shockwave moving is up to 9000m per second. This chemical reaction is started using a small amount of very sensitive explosives called primary explosives. These types of explosives are highly sensitive to shock, friction, heat, and spark. As the explosive charge undergoes high order decomposition (detonation), the brisance, or shattering effect, causes the casing to splinter, projecting razor-sharp shrapnel across long distances.

The blast wave effect and the shrapnel effect can cause significant damage. Calculating safety distances is a complex process. As a rule of thumb, in open ground, a 250kg explosive charge (as would be found inside a typical 500kg bomb) would require an omnidirectional safety distance of at least 1.6km.

Bombs work by amplifying the explosive charge from the sensitive primary explosive through to the main charge or fill of the item. This process is called an explosive train, if any link in that chain is broken, the item will fail to

function as intended. This can be due to mechanical, electrical, or manufacturing tolerances or faults. Amongst other reasons, detonation of UXO could occur under the following circumstances:

- **UXO body impact:** A substantial impact onto the main body of a UXO; borehole rigs, piling rigs, jack hammers and mechanical excavator buckets.
- **Fuse impact:** Environmental conditions during decades of burial can result in the primary explosives located in the fuse pocket to crystallise and become shock sensitive. It would then take a relatively small impact or friction impact to cause the fuse to function and detonate the UXO.
- **Re-starting a timer:** A small proportion of German WWII bombs used clockwork fuses. In 2002 an Army EOD Engineer reported that the clockwork fuse in a UXB re-started. Decades of burial cause substantial corrosion in WWII German UXBs and therefore an incident such as this is extremely rare.

2 ASSESSMENT METHODOLOGY

2.1 Introduction

This assessment has been produced in accordance with the relevant CIRIA guidelines; *Unexploded Ordnance (UXO) - A Guide for the Construction Industry C681* (published in 2009). CIRIA C681 is a publication which originated from round table best practice discussions from industry leaders.

2.2 SPRC Risk Model

The Source, Pathway, Receptor, Consequence (SPRC) risk model can be applied to buried UXO as follows:

- **Sources:** UK and allied UXO sources include military firing ranges, bases, storage depots, munitions factories, anti-aircraft batteries, amongst others. There are many wartime causes of UXO contamination. The source for enemy contamination is overwhelmingly from WWII German air raids.
- **Pathways:** the pathway describes how the UXO reaches receptors. Usually UXO is buried and therefore pathways can be any activity which involve breaking ground. Examples include ground investigation works, site enabling works and excavations.
- **Receptors:** receptors are the people, assets and infrastructure that can be adversely affected by UXO exposure. This includes site personnel, plant, equipment, buildings, the general public, , and the environment.
- **Consequence:** the consequences of an inadvertent UXO detonation are catastrophic. They include injury and loss or life, as well as damage to property. Fortunately, the likelihood of UXO detonating is low, even when it is uncovered during works. Another consequence to consider however is delays to works, which itself can be a risk.

2.3 Assessment Structure

In accordance with CIRIA C681 this assessment addresses the following considerations in the appropriate order:

- The likelihood that the site was contaminated with UXO.
- The type of UXO that could have contaminated the site, and their associated hazards.
- The likelihood that UXO remains on the site.
- Theoretical bomb penetration depths.
- The likelihood that UXO will be uncovered during the proposed works.
- Risk rating and risk mapping (as appropriate).
- Risk mitigation recommendations.

2.4 Information Sources

To complete this risk assessment Brimstone has gathered information from a wide range of sources. Brimstone's research team has completed detailed historical research, including access of original archived records. The following is a general list of information sources that are consulted during the research process:

- The National Archives,
- Local archive centres,
- Ministry of Defence,
- The Council for British Archaeology,
- Groundsure mapping services,
- Historical aerial photography (Historic England, Britain From Above, Bluesky),
- Google open-source mapping,
- The British Geological Society,
- Open sources; published book, articles, web resources,
- Site specific information supplied by the Client,
- Brimstone's library and historical database, and
- Brimstone's former armed forces employees.

2.5 ALARP Principle

The ALARP (as low as reasonably practicable) principle corresponds to the actions that should be taken to reduce risks. The term 'ALARP' is in the Health and Safety at Work Act 1974, which says that risks must be controlled in a reasonable way.

Infinite time, effort and money could be spent trying to eliminate risk entirely. HSE uses the example that spending £1m to prevent five employees bruising their knees is disproportionate, whereas spending the same amount to prevent an explosion which could kill 150 people is proportionate.

Using this principle, Brimstone aims to reduce client costs by recommending strategies that are proportionate to the assessed risks, if any elevated risk is found at all.

2.6 Risk Tolerances

The Brimstone risk assessment process divides UXO risk into two tolerances:

- **Tolerable:** negligible risk or low risk ratings are tolerable. Where the risk cannot be completely discounted, it may be a useful strategy to opt for a low-cost measure, such as a UXO safety briefing from a qualified UXO engineer.
- **Intolerable:** moderate risk or high-risk ratings are intolerable. Proactive risk mitigation measures should be put in place. Various strategies are at Brimstone's disposal to meet your project-specific needs.

2.7 Reliance and Limitations

This report has been prepared using published information and information provided by the Client. Brimstone is not liable for any information which has become available following the publication of this report. No third-party liability or duty of care is extended. Any third-party using information contained in this assessment do so at their own risk.

3 THE PROJECT

3.1 The Site

The Site comprises three separate areas, known as Site A (west), Site B (centre) and Site C (east). These will be referred to collectively as ‘the Site’ for the purposes of this assessment, when not discussed individually.

The Site (approximately centred on the National Grid Refs: SS 76385 88669 (Site A), SS 76750 88541 (Site B) SS 77018 88747 (Site C)) is located in Port Talbot, within the county borough of Neath Port Talbot, Wales. Port Talbot Parkway railway station is located approximately 700m north of the Site.

Site A primarily comprises undeveloped land – consisting of grassy areas and mature vegetation – intermixed with brownfield land. It is bound to the north by an unlabelled roadway and a cement works factory, to the east by a thin parcel of undeveloped land and Site B, while open/wooded ground lies to the west and south.

Site B consists of undeveloped land with mature vegetation in the south, particularly along the border, while areas of hardstanding complete with industrial infrastructure, low-rise industrial warehouses and other structures lie in the north and west. Most of the ground in the north and west is laid to hardstanding, mainly used for open air storage and car parking purposes.

Site C consists of hardstanding brownfield land with an entrance to an unnamed roadway in the south and the entrance to a river runoff in the north. It is bound to the north by the hardstanding river run off, to the east by an unnamed roadway connecting to Harbour Way, to the south by an unnamed roadway and to the west by a vegetated border to the docks.

FIGURE 1: Site Location Maps

FIGURE 2: Recent Aerial Photograph

3.2 The Proposed Works

Ground investigation works are proposed. All buildings on Site B are to be demolished. Once cleared, twelve trial pits, fifteen cable percussive boreholes and fifteen window samples are planned. Brimstone was not made aware of any future redevelopment works.

FIGURE 3: Existing Site Plan

4 SITE HISTORY

4.1 Site Introduction

Site-specific history can be assessed by reviewing historical mapping, historical aerial photography and by carrying out additional Site-specific research where appropriate. Below are descriptions of a selection of records relevant to the Site:

4.2 Mapping

Period	Map Date	Map Scale	Review
Pre-WWI	1896-1897	1:10,560	Site A comprises mud and heathland. Site B comprises mud and heathland with a small area of open water in the north. Site C comprises heathland, railway sidings and two minor structures, with small areas of open water in the west.
Pre-WWI / WWI	1913-1914	1:10,560	The composition of Site A varies. A coal works lies within the central section, with a small section of a copper works within the north-west, encompassed by undeveloped open ground. Both of these works are linked to extensive railway infrastructure, some of which lies within the south and west of Site A. The majority of the rest of Site A consists of undeveloped open ground. The dock and copper works lie to the north of Site A, railway infrastructure and heathland lie to the east and west with solely railway sidings to the south. Mud is no longer recorded. Site B mainly comprises heathland and an area of wet open land, with an unnamed structure in the south-east, and railway sidings which bisect Site B south-west to north-east in the south-eastern section. Site B is bound to the north by a tramway, railway infrastructure lies to the east and south, while undeveloped open ground lies to the west. Site C comprises railway sidings and undeveloped heathland, as well as a section of Military Road.
WWII	1939-1940	1:2,500	FIGURE 4.1: A metal refinery works has replaced the coal works in Site A. The open ground is now all labelled as heathland, while a large railway embankment and associated sidings lie within the south. An unlabelled large structure is now present in the northern section of Site B. No other changes are recorded. Site C now comprises a section of the Margam steel works, with associated industrial buildings in the eastern and northern areas, as well as railway sidings in the north. The west/south-west of the Site comprises undeveloped open ground. Railway infrastructure lies to the north, additional industrial buildings to the east and partially to the south alongside heathland, while the Copper Works Railway lies to the west.
Post-WWII	1947-1949	1:2,500	FIGURE 4.2: Additional railway infrastructure, a new structure in the east, and an extension to the metal refinery works (now labelled as a Steel Ceilings Factory) are recorded within Site A. A large section of railway has also been cleared, while several ponds and gravel pits are now recorded in the west. The previously unlabelled structure in the south-east of Site B is now recorded as an electrical substation, whilst the larger structure in the northern section is labelled as the Phoenix Briquetting Works. Additional railway sidings are now present in the south-east and north-east of the Site. Structures in the north-west of Site C have been cleared, with a travelling crane replacing them and the previously undeveloped open ground in the west/south-west. The east of Site C remains occupied by industrial structures; however, the structural layout has changed in areas, with several structures replaced as well as newer additions recorded.

4.3 Photography/Aerial Photography

Period	Photo Date	Review
WWII	21 st December 1940	FIGURE 5.1 & 5.2: This low-resolution photograph was taken early during WWII. The layout of each Site aligns with pre-WWII OS mapping. Site A mainly comprises open ground, as well as railway infrastructure and two industrial works in the centre and north-west. Site B also consists mainly of open ground, as well as two structures in the north and south-east, respectively. Railway sidings are also present. Site C comprises numerous structures associated with a large steelworks. Possible repair works have been identified to the metal refinery in Site A, as well as potential severe damage to the structure in the north of Site B. A possible bomb crater is located approximately 30m south-west of Site A.
Post-WWII	7 th June 1946	FIGURE 5.3: No significant change has been observed within this high-resolution photograph, taken less than a year after the end of WWII. No evidence of bombing or associated damage, other than that already discussed above, has been identified.
	1947	FIGURE 5.4: This oblique aerial image shows the vast majority of the Site two years after the end of WWII. The north of Site C is not visible. The briquette works in the north of Site B is shown in high-resolution within this image. What appeared to be damage in the images discussed above now appears more similar to the design of the building or still under construction. No obvious debris or ruins have been identified.

4.4 Additional Site-Specific History

Some sites will have been occupied by landmarks or significant buildings historically and in such cases specific written histories including significant wartime details are occasionally available in the public domain. Site C was located within the Margam Steelworks during WWII, which played a significant role in munitions production during World War II. The steel produced at Margam was used for various purposes, including the manufacturing of munitions, tanks, ships, and other war materials. The steelworks, along with the wider industrial infrastructure of Port Talbot, contributed to the British war effort.

5 UXO RISK - GERMAN BOMBING

5.1 WWII Bombing History of the Site

5.1.1 Port Talbot

Port Talbot, a town in South Wales, was a key industrial hub during World War II, with its steelworks and coal production facilities playing a vital role in supporting the British war effort. The Margam Steelworks, in particular, were involved in the production of steel for munitions, tanks, ships, and other war materials. Consequently, the town and its industries became targets for German air raids carried out by the Luftwaffe.

During the course of the war, Port Talbot experienced several air raids by the Luftwaffe, resulting in damage to its infrastructure, industries, and residential areas. While the town did not face the same level of bombardment as some larger British cities, it still faced disruption and destruction due to its strategic importance.

The air raids on Port Talbot led to the loss of lives, damage to property, and disruption of vital industrial operations. The local community faced significant challenges in coping with the aftermath of the bombings, including rebuilding efforts and the ongoing threat of further attacks. Despite these setbacks, the town and its industries continued to contribute to the British war effort throughout the conflict.

5.1.2 Site Specific

Luftwaffe target photography indicates that Port Talbot, within which the Sites are located, was a primary target. A railway yard/storage station was recorded on target photography (Site B) and a steel works which made up

Site C. This is further recorded within Luftwaffe target mapping (**FIGURE 6**), which highlights the copper works (Kupferwerke) and hard coal briquettes (Steinkohlenbrikettebrik) within Site A as bombing targets, as well as the iron foundry (Eisengießerei) within which Site C was located.

5.1.3 Bombing Decoy Sites

In mid-1940 bombing decoys were introduced. The decoys used either;

- A system of lighting to simulate an urban area or a military airfield's runway
- Deliberately started fires to simulate a previously bombed target
- Dummy buildings and vehicles to simulate a military facility

792 static decoy sites were built at 593 locations in Britain. They were estimated to have drawn at least 5% of the total weight of bombs away from their intended targets. No decoys were operational within a significant radius of the Site during WWII. The closest was approximately 2.5km to the south.

5.2 WWII Bombing Records

5.2.1 Introduction

The bomb census recorded the location and type of bomb strikes to help with intelligence gathering and planning. It was compiled using information recorded by ARP wardens. These records were gathered by the Ministry of Home Security to calculate bombing density within administrative areas.

The bomb census was unreliable in the early stages of the war, though by 1941 procedures had been standardised. The quality of the census records also depended on where in the UK the records were produced. Some records are held at the National Archives and some are held at local borough archives.

Relevant records held at the National Archives and the West Glamorgan Archive Service were obtained for this risk assessment.

5.2.2 Bombing Density Statistics

The table below records the Ministry of Home Security's bombing density calculation for the Municipal Borough of Port Talbot. It gives a breakdown of the types of large German bombs reported and is understood to not include UXBs.

Admin Area	Port Talbot
Area Acreage	23,444
High Explosive Bombs (all types/weights)	87
High Explosive Parachute Mines	1
Flam (Oil) Bombs	3
40kg Phosphorus Incendiary Bombs (IBs)	0
40kg 'Fire Pot' IBs	0
V1 Flying Bomb	0
V2 Long Range Rocket	0
Total (excluding V-Weapons and 1kg / 2kg IBs)	91
Bombs Per 1,000 Acres	3.9

1kg / 2kg incendiary bombs (IBs) and 2kg anti-personnel (AP) bombs were often too numerous to record accurately and therefore are not included in the above figures.

5.2.3 Wales Air Raid Summaries of Occurrences

These summaries, obtained from the National Archives, provide general summaries of air raids across Wales. Only vague locations are recorded, with the number of bombs sometimes listed.

Port Talbot is mentioned on three occasions, affected by incendiary bombing, a UXB and HE bombing. No specific details are provided.

5.2.4 Air Raid Summaries of Occurrences

This record set, obtained from the National Archives, provides specific details pertaining to air raids across Wales. These details include the place, assumed target, number of bombs, and the specifics regarding damage caused. One record was found related to the Site, see below for details.

Place	Assumed Target	No. of Bombs	Details
Port Talbot	Morgam Steel Works	9	Most of the nine bombs appear to have affect residential areas, although bombs 7 and 8 were dropped on 'waste ground (G.W.R)' and bomb 9 was dropped 'on railway siding'.

5.2.5 Luftwaffe Attacks On South Wales And Surrounding Bridgend Area¹

This online source provides a timeline of air raids in south Wales, providing specific details where possible. See below for relevant incidents pertaining to the Site.

Date	Bomb(s)	Location (<i>relevant to the Site</i>)
29/06/1940	1 x UXB	Port Talbot. <i>Precise location unknown.</i>
29/06/1940	1 x HE	Near the Grand Hotel. <i>Located approximately 710m to the north-west of Site C.</i>
29/06/1940	1 x HE	In the station approach. <i>Located approximately 710m to the north-west of Site C.</i>
29/06/1940	1 x HE	On the railway sidings near Port Talbot Steelworks. <i>Precise location unknown, railway sidings were located immediately to the west of Site C and within Site B; however, the bomb could have affected railway sidings on the eastern side of the works.</i>
29/06/1940	1 x HE	Between Margam Coke Ovens and Richard Thomas Steelworks. <i>Precise location unclear, likely within either the Margam Steel Works, in close proximity to Site C, or the Port Talbot Steel Works, approximately 550m to the north of Site A.</i>
29/06/1940	1 x HE	Talbot House. <i>Precise location unknown.</i>
29/06/1940	1 x HE	Between the Steelworks and Dock Ferry. <i>Precise location unknown, potentially near the Site.</i>
29/07/1940	3 x HE	Port Talbot harbour gates. <i>Located approximately 470m to the west of Site A.</i>
20/08/1940	HEs (number unspecified)	Port Talbot Docks. <i>Precise location unknown, potentially on/near Site A & B.</i>

¹ http://www.islandfarm.wales/Luftwaffe_Attacks_On_South_Wales.htm