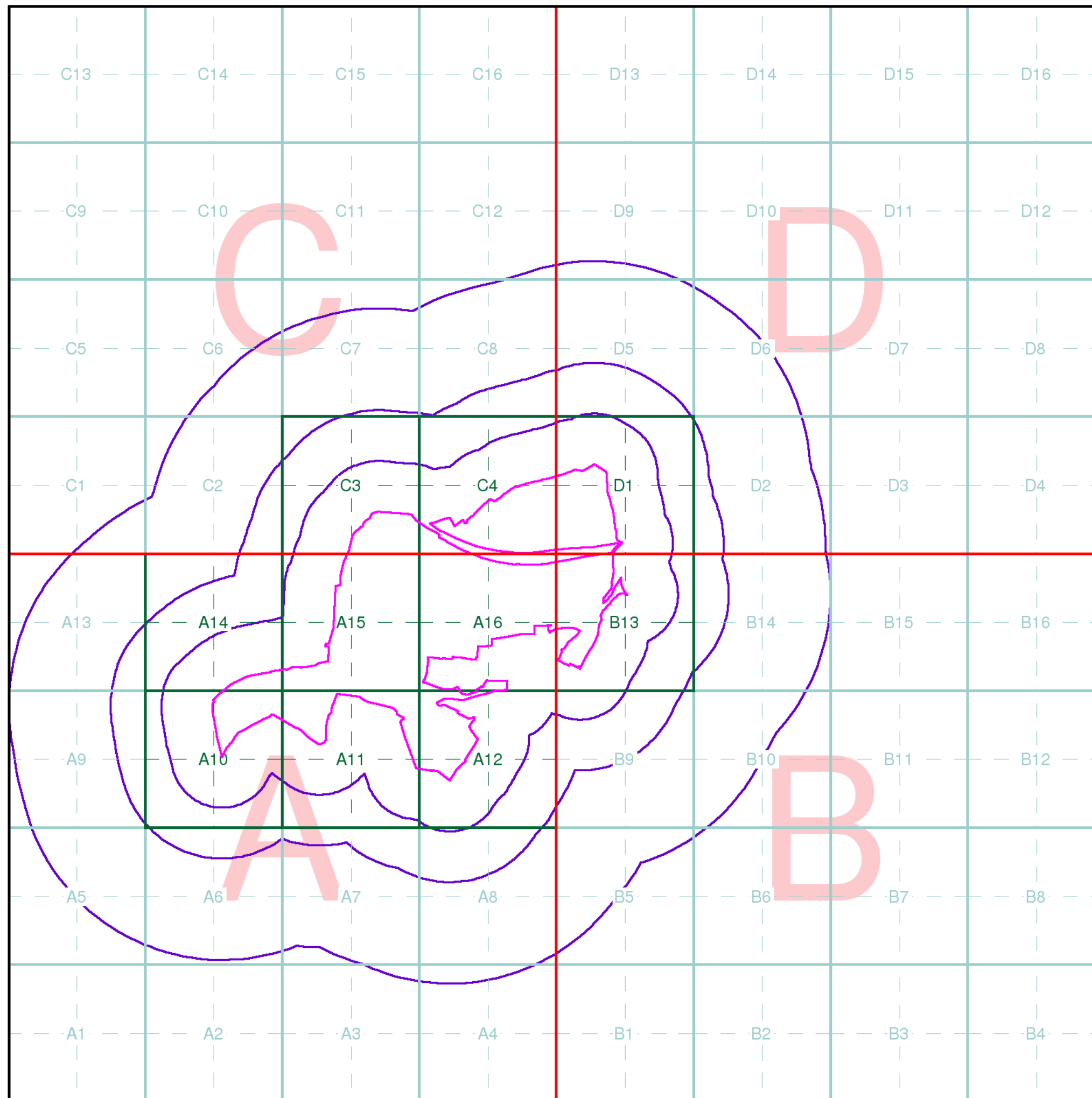




Index Map

For ease of identification, your site and buffer have been split into Slices, Segments and Quadrants. These are illustrated on the Index Map opposite and explained further below.

Slice

Each slice represents a 1:10,000 plot area (2.7km x 2.7km) for your site and buffer. A large site and buffer may be made up of several slices (represented by a red outline), that are referenced by letters of the alphabet, starting from the bottom left corner of the slice "grid". This grid does not relate to National Grid lines but is designed to give best fit over the site and buffer.

Segment

A segment represents a 1:2,500 plot area. Segments that have plot files associated with them are shown in dark green, others in light blue. These are numbered from the bottom left hand corner within each slice.

Quadrant

A quadrant is a quarter of a segment. These are labelled as NW, NE, SW, SE and are referenced in the datasheet to allow features to be quickly located on plots. Therefore a feature that has a quadrant reference of A7NW will be in Slice A, Segment 7 and the NW Quadrant.

A selection of organisations who provide data within this report:



Envirocheck reports are compiled from 136 different sources of data.

Client Details

Mr L Clark, PJA Civil Engineering Ltd, Seven House, High Street, Longbridge, Birmingham, B31 2UQ

Order Details

Order Number: 283848248_1_1
Customer Ref: 05474 - Coed Darcy
National Grid Reference: 271190, 195910
Site Area (Ha): 131.44
Search Buffer (m): 1000

Site Details

Site at 271220, 195880

Full Terms and Conditions can be found on the following link:
<http://www.landmarkinfo.co.uk/Terms/Show/515>

Appendix C Explosive Ordnance Threat Assessment

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Explosive Ordnance Threat Assessment

in respect of

Coed Darcy Urban Village, Swansea

for

Atkins Limited

9741TA

16/01/2009

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Date of Issue: 16th January 2009

Electronic Copy

Originator: CC

This Report has been produced in compliance with the Construction Industry Research and Information Association guidelines (Report CIRIA 681, dated December 2008) for the preparation of Detailed Risk Assessments in the management of UXO risks in the construction industry.

Glossary of Terms

AAA	Anti-Aircraft Artillery
ARP	Air-raid Precautions
BDO	Bomb Disposal Officer
EOD	Explosive Ordnance Disposal (current term for “bomb” disposal)
HE	High Explosive
HG	Home Guard
IB	Incendiary Bomb
kg	Kilogram
LCC	London County Council
LM	Land Mine
LSA	Land Service Ammunition (includes grenades, mortars, etc.)
Luftwaffe	German Air Force
m bgl	Metres Below Ground Level
MoD	Ministry of Defence
OB	Oil Bomb
PM	Parachute Mine
RAF	Royal Air Force
SI	Site Investigation
SSA	Small Arms Ammunition (small calibre cartridges used in rifles & machine guns)
UP	Unrotating Projectile (Rocket)
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
V-1	“Doodlebug” the first cruise type missile, used against London from June 1944. Also known as ‘Flying Bomb’.
V-2	The first ballistic missile, used against London from September 1944
WWI	First World War (1914 -1918)
WWII	Second World War (1939 – 1945)

Executive Summary

The Site: The Coed Darcy Urban Village development site is located in southern Wales, to the east of Swansea. The M4 motorway is situated to the east of the site, with the River Neath running to the south-east. Much of the southern part of the site fronts on to Swansea Bay. The site is centred on the approximate OS Grid Reference: SS 70289 94395.

Proposed Works: Coed Darcy Urban Village is a proposed development of the former BP oil refinery, comprising 4000 homes, employment areas and open space covering 1,300 acres.

Risk Assessment Methodology: In accordance with CIRIA 681 guidelines this assessment has carried out research, analysed the evidence and considered the risks that the site has been contaminated with unexploded ordnance; that such items remained on site; that they could be encountered during the proposed works and the consequences that could result. Appropriate risk mitigation measures have been proposed.

Quality of the Historical Record: The research has located and evaluated WWII-era Cassini maps, Luftwaffe aerial photography and target maps, and records of ground defences. The majority of written WWII ARP records and bomb census maps for the Swansea and Neath areas have not survived and it is therefore impossible to plot the exact locations and quantity of ordnance dropped in the region. Similarly, detailed post-war aerial photography of the site, which may have highlighted areas of significant damage, was not available. As a consequence, the analysis and conclusions drawn from the accessible evidence are necessarily general in nature.

Explosive Ordnance Risk Assessment: BACTEC believes that there is a risk of encountering explosive ordnance associated with proposed works at the Coed Darcy Urban Village site. This assessment is based on the following facts:

- Coed Darcy: The largest single section of the site incorporated the Llandarcy Oil Refinery, which would have been the primary Luftwaffe target in the immediate region. Sources indicate that at least two significant bombing raids occurred in this area, with a number of UXBs dropped. Serious damage was caused to part of the refinery during one of these raids and there is a risk that UXO may have gone unnoticed and unrecorded in bomb damaged areas. It should be noted however that the refinery would have been in constant use during the war and likely subject to stringent post-raid checks for UXBs. However, more peripheral and open areas of this section may not have been subject to the same levels of access; such areas are at a greater risk of UXO contamination. The reservoir (in the northern part of this site) was an area of open water during WWII and is also considered to be at an elevated risk.
- Nature Reserve/Eco Dwellings: These areas lay close to a number of Luftwaffe targets including factories and railway tracks; three HAA batteries were also located close to these sections. WWII-era aerial photography indicates that factories close to these areas suffered severe bomb damage during the war. As open agricultural ground, it is unlikely that such areas were accessed frequently or subject to post-raid checks and it is therefore possible that UXO fell unobserved on this part of the site.
- SSSI/Transit Site: These large sections of the site lay to the south of railway sidings, a steelworks and two HAA batteries. During WWII, this area consisted of the open foreshore, which was unlikely to have been of high priority for ARP personnel carrying out post-raid checks; indeed the beach may not have been accessible at all for security reasons. As a consequence there is a risk that air-delivered UXO fell unnoticed and unrecorded. Although unlikely, the possibility that anti-invasion defences (such as pillboxes and gun emplacements) were located in this section resulting in ordnance contamination cannot be totally discounted.
- ABP Freehold: This section was occupied by fuel tanks and areas of hard standing during WWII, with at least one tank suffering bomb damage. Whilst the possibility cannot be discounted that evidence of UXO may have been obscured by such damage, the fact that this area would have been frequently accessed and checked for UXO indicates that it is unlikely any such evidence would have been overlooked.
- Queens Dock: The docks to the south-east of Swansea were bombed on a number of occasions. It is considered unlikely that UXO could have gone unnoticed and unrecorded on areas of hardstanding on the dockside. Parts of this section which encompass open water are thought to be of elevated risk however, as any UXO falling in this area during the war is less likely to have been observed.
- Pipeline Routes: Any intrusive works to remove pipeline routes laid in the post-war period are considered at reduced risk¹. At elevated risk however, are pipeline routes constructed in the pre-war period, particularly where these routes ran through areas that were open ground or subject to significant damage during the war.

¹ It should be noted however, that BACTEC has provided support on a site where a live incendiary bomb was found in the fill of a post-war pipeline route (an example of a 1kg incendiary bomb is presented in Annex F-3). Therefore although unlikely, the possibility cannot be discounted that items of UXO may have gone unnoticed and unrecorded in the fill of post-war pipeline routes along parts of the Coed Darcy Urban Village site.

Bomb Penetration Assessment: Given the size of the proposed development area and consequently the varied nature of geology underlying the site, it is not possible to provide bomb penetration depths at this time. Assessments can be made for individual areas once details of underlying geology become available.

Risk Mitigation Measures: Once construction plans are made available it is recommended that a meeting with BACTEC is held in order to determine the most appropriate and cost-effective risk mitigation strategy, considering areas of the site subject to post-war redevelopment and the location and extent of the proposed intrusive works. Proactive measures may be appropriate for certain works.

Reactive risk mitigation measures comprise:

- Explosive Ordnance Safety and Awareness Briefings to all personnel conducting intrusive works.
- The Provision of Unexploded Ordnance Site Safety Instructions.
- Explosive Ordnance Disposal (EOD) Engineer Presence on site.

Potential proactive mitigation measures comprise:

- Down-hole Intrusive Magnetometer Survey of all pile/borehole locations and Target Investigation, if necessary.
- Non-Intrusive Advanced Geophysical System (AGS) Survey and target investigation ahead of any intrusive works.
- Search and Clearance by qualified EOD Engineers.

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Explosive Ordnance Threat Assessment

in respect of

Coed Darcy Urban Village, Swansea

1. Introduction

1.1. Background

Atkins Limited has commissioned BACTEC International Limited to conduct an Explosive Ordnance Threat Assessment for the proposed redevelopment works at the Coed Darcy Urban Village site.

Unexploded Ordnance presents a significant threat to construction projects in parts of the UK as a result of enemy actions during the two 20th Century World Wars and historic British and Allied military activity.

The city of Swansea, surrounded by areas of heavy industry, suffered a number of significant bombing raids throughout WWII. Whilst Swansea was subject to less bombing than comparable cities in England, it sustained more casualties and material damage than anywhere else in Wales. Over 27,000 properties in the County Borough of Swansea were damaged during WWII, with nearly 400 people killed.

One of the legacies of this conflict is buried unexploded air-dropped bombs or anti-aircraft projectiles resulting from the failure of a proportion of the weapons to function as designed. It is commonly accepted that the failure rate of these munitions was approximately 10%, and depending on their shape, weight, velocity and ground conditions many penetrated the ground and came to rest at depth. Intensive efforts were made during and after the war to locate and render safe all UXOs but, unsurprisingly, not all were found and dealt with. This is evidenced by the regular, ongoing discoveries of unexploded ordnance during construction-related intrusive ground works.

The UK was also bombed, though to a much lesser extent, during WWI and it is thought that a similar proportion of these weapons also malfunctioned. There have been occasional finds of unexploded WWI bombs in recent years but the risk of encountering them today is mostly very low.

As a result of a generally increased risk awareness amongst professionals involved in ground engineering works and proactive health and safety measures the threat to life and limb from unexploded ordnance has been minimised. However even the simple discovery of a suspected device during ongoing works can cause considerable disruption to production and cause unwanted delays and expense.

Such risks can be more fully controlled by a better understanding of the site-specific threat and the implementation of appropriate risk mitigation measures.

2. Construction Industry Duties and Responsibilities

2.1. The UK Regulatory Environment

There is no specific legislation covering the management and control of the UXO risk in the UK construction industry but issues regarding health and safety are addressed under a number of regulatory instruments, as outlined below.

In practice the regulations impose a responsibility on the construction industry to ensure that they discharge their obligations to protect those engaged in ground-intrusive operations (such as archaeology, site investigation, drilling, piling or excavations) from any reasonably foreseeable UXO risk.

2.2. The Health and Safety at Work Act, 1974

The Act places a duty of care on an employer to put in place safe systems of work to address, as far as is reasonably practicable, all risks (to employees and the general public) that are reasonably foreseeable.

2.3. Construction (Design and Management) Regulations 2007

This legislation defines the responsibilities of all parties (primarily the Client, the CDM Co-ordinator, the Designer and the Principal Contractor) involved with works.

Although UXO issues are not specifically addressed the regulations effectively place obligations on all these parties to:

- Ensure that any potential UXO risk is properly assessed
- Put in place appropriate risk mitigation measures if necessary
- Keep all parties affected by the risk fully informed
- Prepare a suitably robust emergency response plan

2.4. Other Legislation

Other relevant legislation includes the "Management of Health and Safety at Work Regulations 1999" and "The Corporate Manslaughter and Corporate Homicide Act 2007".

3. The Role of the Authorities and Commercial Contractors

3.1. The Authorities

The Police have the responsibilities for co-ordinating the emergency services in the case of an ordnance-related incident on a construction site. They will make an initial assessment (i.e. is there a risk that the find is ordnance or not?) and if they judge necessary impose a safety cordon and/or evacuation and call the military authorities (JSEOD - Joint Services Explosive Ordnance Disposal Operations centre) to arrange for investigation and/or disposal. In the absence of an EOD specialist on site many Police Officers will use the precautionary principle, impose cordon(s)/evacuation and await advice from the JSEOD.

The priority given to the request by JSEOD will depend on their judgement of the nature of the threat (ordnance, location, people and assets at risk) and the availability of resources. They may respond immediately or as resources are freed up. Depending on the on-site risk assessment the item of ordnance may be removed or demolished (by controlled explosion) in-situ. In the latter case additional cordons and/or evacuations may be necessary.

Note that the military authorities will only carry out further investigations or clearances in very high profile or high risk situations. If there are regular ordnance finds on a site the JSEOD may not treat each occurrence as an emergency and will encourage the construction company to put in place alternative procedures (i.e the appointment of a commercial contractor) to manage the situation and relieve pressure from the JSEOD disposal teams.

3.2. Commercial Contractors

In addition to pre-construction site surveys and clearances a commercial contractor is able to provide a reactive service on construction sites. The presence of a qualified EOD Engineer with ordnance recognition skills will avoid unnecessary call-outs to the authorities

and the Contractor will be able to arrange for the removal and disposal of low risk ordnance. If high risk ordnance is discovered actions will be co-ordinated with the authorities with the objective of causing the minimum possible disruption to site operations whilst putting immediate, safe and appropriate measures in place.

4. This Report

4.1. Aims and Objectives

The aim of this report is to examine the possibility of encountering any explosive ordnance during the proposed works at the Coed Darcy Urban Village site. The site comprises several large sections of land and numerous pipeline routes; details of final construction methodologies were not provided at the time of writing this report.

The scope of this assessment will therefore reflect the scale of such a development and will provide a broad overview of the available historical evidence including any post-war intrusive works. It will recommend a risk mitigation approach aimed at reducing the threat from explosive ordnance during the envisaged works. The report follows the CIRIA 681 Guidelines.

4.2. Risk Assessment Methodology

The following issues will be addressed in the report:

- The risk that the site was contaminated with unexploded ordnance
- The risk that unexploded ordnance remains on site
- The risk that ordnance may be encountered during the proposed Works
- The risk that ordnance may be initiated
- The consequences of initiating or encountering ordnance

Risk mitigation measures, appropriate to the assessed level of risk and site conditions, will be recommended if required.

4.3. Approach

In preparing this Explosive Ordnance Threat Assessment Report BACTEC has considered general and, as far as possible site specific, factors including:

- Evidence of German bombing and delivery of UXBs
- Site history, occupancy and conditions during WWII
- The legacy of allied military activity
- Details of any known EOD clearance activity
- The extent of any post war redevelopment
- Scope of the current proposed works.

4.4. Sources of Information

BACTEC has carried out detailed historical research for this Explosive Ordnance Threat Assessment including accessing military records and archived material held in the public domain and in the MoD.

Material from the following sources has been consulted:

- The National Archives, Kew
- West Glamorgan Archive Service, Swansea
- Landmark Maps
- English Heritage National Monuments Record
- Relevant information supplied by Atkins Limited
- Available material from 33 Engineer Regiment (EOD) Archive

- BACTEC's extensive archives built up over many years of research and hands-on Explosive Ordnance Disposal activities in the UK
- Open sources such as published books, local historical records and the internet

Research involved visits to the National Archives and the West Glamorgan Archive Service, Swansea.

4.5. Reliability of Historical Records

4.5.1 General Considerations

This report is based upon research of historical evidence. Whilst every effort has been made to locate all relevant material BACTEC cannot be held responsible for any changes to the assessed level of risk or risk mitigation measures based on documentation or other information that may come to light at a later date.

The accuracy and comprehensiveness of wartime records is frequently difficult or impossible to verify. As a result conclusions as to the exact location, quantity and nature of the ordnance threat can never be definitive but must be based on the accumulation and careful analysis of all accessible evidence. BACTEC cannot be held responsible for inaccuracies or gaps in the available historical record.

4.5.2 Bombing records

During WWII considerable efforts were expended in recording enemy air raids. Air Raid Precautions (ARP) wardens were responsible for making records of bomb strikes either through direct observation or by post-raid surveys. However their immediate priority was to deal with casualties and limit damage, so it is to be expected that records are often incomplete and sometimes contradictory. Record keeping in the early days of bombing was not comprehensive and details of bombing in the early part of the war were sometimes destroyed in subsequent attacks. Some reports may cover a single attack, others a period of months or the entire war.

Records of raids that took place on sparsely or uninhabited areas were often based upon third party or hearsay information and are not always reliable; records of attacks on military or strategic targets were often maintained separately from the general records and have not always survived.

5. The Site

5.1. Site Location

The Coed Darcy Urban Village development site is located in southern Wales, to the east of Swansea. The M4 motorway is situated to the east of the site, with the River Neath running to the south-east. Much of the southern part of the site fronts on to Swansea Bay. The site is centred on the approximate OS Grid Reference: SS 70289 94395.

Site location maps are presented in Annex A.

5.2. Site Description

The site currently comprises several parcels of land, with a number of pipeline routes running through outlying areas.

Development Areas:

Coed Darcy: This large section of the development encompasses much of the area of the former Llandarcy Oil Refinery. A reservoir is located on the north of this area, whilst much of the remaining parts of the development is occupied by infrastructure associated with the Refinery including offices, tanks and access roads. There are also substantial areas of landscaped open ground, woodland and fields in this section. The southern area comprises a narrow corridor of land either side of a roadway.

Nature Reserve: This area comprises a triangular section of open land, with a stream running along the eastern boundary.

Eco Dwellings: Located adjacent to the Nature Reserve, much of the area of the planned Eco Dwellings is currently heavily wooded. A railway line lies to the west of this section.

SSSI: The SSSI area is a large section of vegetated land on the southern part of the development site, extending along the foreshore of Swansea Bay, close to the mouth of the River Neath.

Transit Site/ABP Freehold: Located to the west of the SSSI area, the Transit Site is currently occupied by a storage area to the east. A number of storage tanks (now removed) were situated on the western part of this area.

Queens Dock: This area encompasses the southern part of the Queens Dock, situated to the south-east of Swansea. The eastern extent of this section comprises areas of hardstanding, whilst the western area extends into the dock basin.

Pipeline Routes:

Thirteen existing pipeline routes extend across and between the development areas.

A recent aerial photograph showing the development site areas and approximate existing pipeline routes is presented in Annex B.

6. Scope of the Proposed Works

6.1. General

Coed Darcy Urban Village is a proposed development of the former BP oil refinery, comprising 4000 homes, employment areas and open space covering 1,300 acres.

A proposed site plan is presented in Annex C.

6.2. Intrusive Ground Works

The proposed intrusive works have not yet been defined but are likely to include site investigation trial pits and boreholes both into and through bedrock and demolition of any remaining redundant structures followed by construction related activities. These are expected to include piled and shallow foundations, shallow excavations for foundations and pipelines (including the removal of redundant lines) and more extensive earthworks for landscaping or basement levels.

7. Ground Conditions

The British Geological Survey Map 1:50,000 Sheet 247 for the Swansea region indicates the general geological sequence of the development site to be variable, comprising mainly of Mudstone, Siltstone and Sandstone. An extract of this map, indicating the combined "surface geology" of the region is presented in Annex D.

No site specific geotechnical data was available for the site at the time of the production of this report.

8. Site History

8.1. General

A WWII-era map of the site, based on the Cassini Grid, is presented in Annex E. The map shows the site to be surrounded by a number of villages however; the area of the site itself is shown to be relatively rural in character. Much of the northern boundary encompasses open ground and woodland, with a railway line running across the site and a number of *Pipelines* extending southwards. Note that the Llandarcy Oil Refinery (see section 8.2 below) was located on this part of the site during the war but has been excluded from the map, presumably for security reasons.

The southern sections of the site are occupied by rail, canal and dock infrastructure (labelled *Port Tennant*), with part of the southern boundary of the site lying within the foreshore of Swansea Bay. A *Steel Works* is labelled close to the southern part of the site; further heavy industry works are located to the west.

8.2. Llandarcy Oil Refinery

Located on the northern part of the site, the Llandarcy Oil Refinery began operating in the early 1920s. The first major refinery to be constructed in Britain, the large facility was a significant source of local employment in the Neath area and when fully operational was able to supply one third of the total UK consumption of petrol. As a consequence, the refinery became a vital facility during WWII and was targeted a number of times by the Luftwaffe. Despite a period of expansion during the 1960s and 70s, the formal closure of the refinery was announced in 1997. Whilst some of the refinery infrastructure has been removed (for example the tank farm storage on the western part of the site), many buildings, concrete foundations and pipelines remain in place.

9. The Threat from Aerial bombing

9.1. General Bombing History of West Glamorgan

9.1.1 First World War

London and Eastern England suffered aerial bombardment during WWI, beginning with indiscriminate night raids by Zeppelin airships. However as British defensive measures became more effective and aircraft development progressed, the German military switched to daylight raids by fixed wing aircraft in June 1917.

There is no evidence to indicate that Wales suffered aerial bombardment during WWI.

9.1.2 Second World War

At the start of WWII, the Luftwaffe planned to destroy key military installations, including RAF airfields and Royal Navy bases, during a series of daylight bombing raids. After the Battle of Britain these tactics were modified to include both economic and industrial sites. Targets included dock facilities, railway infrastructure, power stations, weapon manufacturing plants and gas works. As a result of aircraft losses daylight raids were reduced, in favour of attacking targets under the cover of darkness.

From mid-1944 the "V-weapon" (for Vengeance) campaign, using unmanned cruise missiles and rockets, represented Hitler's final attempt to reverse Germany's imminent defeat. There are no available records of these weapons reaching southern Wales.

9.2. Aerial Delivered Ordnance in the Second World War

9.2.1 Generic Types of WWII German Air-delivered Ordnance

The nature and characteristics of the ordnance used by the Luftwaffe allows an informed assessment of the hazards posed by any unexploded items that may remain today. Detailed illustrations of German air delivered ordnance are presented at Annex F.

- HE Bombs: In terms of weight of ordnance dropped, HE bombs were the most frequent weapon deployed. Most bombs² were 50kg, 250kg or 500kg (overall weight, about half of which was the high explosive) though large bombs of up to 2000kg were also used. HE bombs had the weight, velocity and shape to easily penetrate the ground intact if they failed to explode. Post-raid surveys would not always have spotted the entry hole or other indications that a bomb penetrated the ground and failed to explode and contemporary ARP documents describe the danger of assuming that damage, actually caused by a large UXB, was due to an exploded 50kg bomb. Unexploded HE bombs therefore present the greatest risk to present-day intrusive works.
- Blast Bombs/Parachute Mines: Blast bombs generally had a slow rate of descent and were extremely unlikely to have penetrated the ground. Non-retarded mines would have shattered on most ground types, if they had failed to explode. There have been extreme cases when these items have been found unexploded, but this was where the ground was either very soft or where standing water had reduced the impact. BACTEC does not consider there to be a significant threat from this type of munition on land.

² Some 2/3 of the numbers of bombs dropped were 50kg and less than 1 in 20 were 1000kg or larger

- Large incendiary bombs: This type of bomb ranged in size from 36kg to 255kg and had a number of inflammable fill materials (including oil and white phosphorus), and a small explosive charge. They were designed to explode and burn close to the surface but their shape and weight meant that they did have penetration capability. If they penetrated the ground complete combustion did not always occur and in such cases they remain a risk to intrusive works.
- 1 kg Incendiary Bombs (IB): These bombs, which were jettisoned from air-dropped containers, were unlikely to penetrate the ground and in urban areas would usually have been located in post-raid surveys. However, if bombs did not initiate and fell in water or dense vegetation, or became mixed with rubble in bomb damaged areas they could have been overlooked. Some variants had explosive heads and these present a risk of detonation during intrusive works.
- Anti-personnel (AP) Bomblets: AP bombs had little ground penetration ability and should have been located by the post-raid survey unless they fell into water, dense vegetation or bomb rubble.
- Specialist Bombs (smoke, flare, etc): These types do not contain high explosive and therefore a detonation consequence is unlikely. They were not designed to penetrate the ground.

9.2.2 German Air-delivered Ordnance Failure Rate

It has been estimated that 10% of the German HE bombs dropped during WWII failed to explode as designed. This estimate is probably based on the statistics of wartime recovered UXBs and therefore will not have taken account of the unknown numbers of UXBs that were not recorded at the time, and is probably an underestimate.

The reasons for failures include:

- Fuze or gaine malfunction due to manufacturing fault, sabotage (by forced labour) or faulty installation.
- Clockwork mechanism failure in delayed action bombs.
- Failure of the bomber aircraft to arm the bombs (charge the electrical condensers which supplied the energy to initiate the detonation sequence) due to human error or equipment defect
- Jettison of the bomb before it was armed or from a very low altitude. Most likely if the bomber was under attack or crashing.

War Office Statistics document that a daily average of 84 bombs which failed to function were dropped on civilian targets in Great Britain between 21st September 1940 and 5th July 1941. 1 in 12 of these (probably mostly fitted with time delay fuzes) exploded some time after they fell - the remainder were unintentional failures.

From 1940 to 1945 bomb disposal teams dealt with a total of 50,000 explosive items of 50 kg and over (i.e. German bombs), 7000 AAA shells and 300,000 beach mines. These operations resulted in the deaths of 394 officers and men.

9.2.3 UXB Ground Penetration

9.2.3.1 General Considerations

The actual penetration depth of aerial delivered bombs into the ground will have been determined by the mass and shape of the bomb, the velocity and angle of the bomb on impact (dependant on the height of release) and the nature of the ground and ground cover; the softer the ground, the greater the potential penetration. Peat, alluvium and soft clays are easier to penetrate than gravel and sand. Bombs are brought to rest or are commonly deflected by bedrock or large boulders.

9.2.3.2 The "j" Curve effect

An air-dropped bomb falling from normal bombing altitude (say 5000m) into homogeneous ground will continue its line of flight but turn in an upwards curve towards the surface as it comes to rest. This offset from vertical is generally

thought to be about one third of the penetration depth, but can be up to 15m depending on ground conditions or the bomb's angle of impact.

9.2.3.3 Second World War Bomb Penetration Studies

During WWII the Ministry of Home Security undertook a major study on actual bomb penetration depths, carrying out statistical analysis on the measured depths of 1328 bombs as reported by Bomb Disposal, mostly in the London area. They then came to conclusions as to the likely average and maximum depths of penetration of different sized bombs in different geological strata.

The median penetration of 430 x 50kg German bombs in London Clay was 4.6m and the maximum penetration observed for the SC50 bomb was 9m.

They concluded that the largest common German bomb, 500kg, had a likely penetration depth of 6m in sand or gravel but 8.7m in clay. The maximum observed depth for a 500kg bomb was 10.2m and for a 1000kg bomb 12.7m. Theoretical calculations suggested that significantly greater penetration depths were probable.

9.2.4 Initiation of Unexploded bombs

Unexploded bombs do not spontaneously explode. All high explosive requires significant energy to create the conditions for detonation to occur. In the case of unexploded German bombs discovered within the construction site environment, there are a number of potential initiation mechanisms:

- Direct impact onto the main body of the bomb: Unless the fuze or fuze pocket is struck, there needs to be a significant impact (e.g. from piling or large and violent mechanical excavation) to initiate a buried iron bomb. Such violent action can cause the bomb to detonate.
- Re-starting the clock timer in the fuze: Only a small proportion of German WWII bombs employed clockwork fuzes. It is probable that significant corrosion has taken place within the fuze mechanism over the last 60 years that would prevent clockwork mechanisms from functioning. Nevertheless it was reported that the fuze in a UXB dealt with by 33 EOD Regiment in Surrey in 2002 did re-commence.
- Induction of a static charge, causing a current in an electric fuze: The majority of German WWII bombs employed electric fuzes. It is probable that significant corrosion has taken place within the fuze mechanism over the last 60 years such that the fuze circuit could not be activated.
- Friction impact initiating the (shock-sensitive) fuze explosive: This is the most likely scenario resulting in the bomb detonating.

Annex G details UXB incidents where intrusive works have caused UXBs to detonate, resulting in death or injury and damage to plant.

9.3. Bombing of Swansea and Neath

9.3.1. Second World War Overview

Situated in an ideal location for military-based industries and munitions manufacture, with the docks providing transportation for weapons and troops, the Swansea area was vital to the war effort. The city was a major industrial centre, housing metal refineries, coal depots and the Llandarcy Oil Refinery. An important rail network, linking London and West Wales also lay close to the city.

Two Luftwaffe maps (presented in Annex H) demonstrate the high number of targets in the Swansea region. The first map, presented in Annex H-1, shows the wider south Wales region; coal mines, metal works and the Llandarcy Oil Refinery are amongst the many strategic targets clearly marked in the vicinity of the site. A more detailed map of the eastern Swansea area (Annex H-2) shows the Kings Dock, a Fuel Depot, Train Repair Works and a Chemical Works on or close to the south-west of the development site. Numerous targets have been highlighted by German military intelligence to the north-west.

The city experienced around forty air-raids, with six major "blitzes". However, the most severe damage to Swansea was caused during the "Three Nights' Blitz" of the 19th – 21st

February 1941, when forty-one acres of the city was destroyed. Generally, much of the docks and industrial areas escaped the majority of air-raids, with residential and commercial parts of the city suffering more substantial damage.

Records of bombing incidents in the Swansea area were collected by the Air Raid Precautions wardens and collated by the Civil Defence Office.

Records would be in the form of typed or hand written incident notes, maps and statistics. Bombing data was carefully analysed, not only due to the requirement to identify those parts of the capital most needing assistance, but also in an attempt to find patterns in the Germans' bombing strategy in order to predict where future raids might take place. A small number of typed Swansea ARP records were located in West Glamorgan Archive, visited on January 8th 2009; however, it is understood that the majority of such records were destroyed when the Civil Defence organisation was wound up in the 1960s³.

These various types of available records of bombing incidents for Swansea and Neath are presented in the following sections.

9.3.2. Second World War Bombing Statistics

The following table summarises the quantity of German bombs (excluding 1kg incendiaries and anti-personnel bombs) falling on the boroughs of Swansea and Neath between 1940 and 1945:

Record of German Ordnance Dropped on the County Borough of Swansea	
Area Acreage	21600
High Explosive Bombs (all types)	1496
Parachute Mines	4
Oil Bombs	0
Phosphorus Bombs	5
Pilotless Aircraft (V1)	0
Fire Pot	12
Long Range Rocket (V2)	0
Total	1517
Items Per 1000 Acres	70.2

Record of German Ordnance Dropped on the Rural District of Neath	
Area Acreage	52039
High Explosive Bombs (all types)	202
Parachute Mines	0
Oil Bombs	3
Phosphorus Bombs	0
Pilotless Aircraft (V1)	0
Fire Pot	0
Long Range Rocket (V2)	0
Total	205
Items Per 1000 Acres	3.9

Source: Home Office Records

³ Alban, J R, The 'Three Nights' Blitz'

Detailed records of the quantity and locations of the 1kg incendiary and anti-personnel bombs were not routinely maintained by the authorities as they were frequently too numerous to record. Although the incendiaries are not particularly significant in the threat they pose, they nevertheless are items of ordnance that were designed to cause damage and inflict injury and should not be overlooked in assessing the general risk to personnel and equipment. The anti-personnel bombs were used in much smaller quantities and are rarely found today but are potentially more dangerous.

This table does not include UXO found during or after WWII.

9.4. Site Specific WWII Bombing Records

9.4.1. Bombing Incident Records`

Few written bombing records for the Swansea area have survived to the present day; no records of the Neath region (in which most of the development site was historically located) were available in West Glamorgan Archives. References in secondary sources (primarily, 'Llandarcy Remembered' by V Griffiths and 'A History of Llandarcy' by V L Barnes) were found to only a handful of incidents; these are described below:

- 10th July 1940 – An aircraft dropped four HE bombs over the Kings Dock area, damaging sheds and warehouses.
- The Llandarcy Oil Refinery, situated to the east of the city, was targeted on a number of occasions throughout the war (although the majority of these raids occurred during the summer of 1940). Fourteen UXBs were dropped over the refinery on the 10th July 1940, causing damage to the roof of one of the storage tanks. The following day, four HE bombs (one of which failed to explode) were dropped on the refinery. A heavy raid was recorded on the 1/2nd September 1940, when HE and incendiary bombs caused damage to parts of the Tank Farm area of the refinery; photographs taken after this raid are presented in Annex I. Several of the tanks were set on fire; efforts to extinguish the flames were hampered by a number of unexploded bombs over the facility. The following night, Llandarcy village was attacked, with several houses suffering damage.
- 13th January 1941 – A lone aircraft dropped two HE bombs on Kings Dock.
- 28/29th November 1941 – A parachute mine fell in the canal at the Kings Dock entrance.
- 16/17th February 1943 – Two 500kg HE bombs were recorded on Swansea Docks. An incendiary bomb container was also found in this area. The location of the two HE bomb strikes is shown on an ARP map, presented in Annex J.

9.4.2. Second World War Era Aerial Photographs

WWII-era aerial photography of much of the site area was obtained from the publication 'Eye of the Eagle: The Luftwaffe Aerial Photographs of Swansea'. A copy of the original images is presented in Annex K-1.

Taken in the days before a heavy raid on Swansea, the second image (presented in Annex K-2) shows the southern extent of the Llandarcy Oil Refinery. Bombing targets such as the oil storage tanks and railway sidings have been highlighted by German military intelligence (outlined in green); bomb craters and damage caused to these targets has been highlighted in red. Serious damage is noted to storage tanks on part of the refinery along with a number of bomb craters; further damage has been highlighted to the south-west.

A number of defences, including anti-aircraft batteries and barrage balloons are situated in the vicinity of the site and have been circled in blue and yellow respectively.

Similarly, the third image shows a number of targets close to the south-western part of the site including the docks to the south and a power station, ammunition and metal working factories to the west, defended by barrage balloons. Numerous bomb craters (indicated by red circles) have been highlighted by Luftwaffe photograph interpreters across the open ground in the centre of the photograph.

RAF aerial photography of the southern extent of the site (Annex K-4) was obtained from the Royal Commission on the Ancient and Historical Monuments of Wales⁴. Many of these images were found to be of poorer quality than Luftwaffe images with the available photographs obscured by cloud cover; however, a post-war photograph of the eastern part of the site does appear to show significant damage (most likely as a result of bombing) to factories adjacent to the Nature Reserve area.

An oblique post-war aerial photograph of the northern part of Llandarcy Oil Refinery (not shown on the Luftwaffe images) is presented in Annex K-5. Note the heavy industrialisation of this part of the site during the war, with only isolated pockets of open, undeveloped land.

9.4.3. Abandoned Bombs

A post-air raid survey of buildings, facilities and installations would have included a search for evidence of bomb entry holes. If evidence were encountered, Bomb Disposal Officer teams would normally have been requested to attempt to locate, render safe and dispose of the bomb. Occasionally evidence of UXBs was discovered but due to a relatively benign position, access problems or a shortage of resources the UXB could not be exposed and rendered safe. Such an incident may have been recorded and noted as an Abandoned Bomb.

Given the inaccuracy of WWII records and the fact that these bombs were 'abandoned', their locations cannot be considered definitive, nor the lists exhaustive. The MoD states that 'action to make the devices safe would be taken only if it was thought they were unstable'. It should be noted that other than the 'officially' abandoned bombs, there will inevitably be UXBs that were never recorded.

BACTEC holds no records of officially registered abandoned bombs at or near the site of the proposed works.

9.4.4. EOD Bomb Disposal and Clearance Tasks

The information service from the Explosive Ordnance Disposal (EOD) Archive Information Office at 33 Engineer Regiment (EOD) is currently facing considerable delay. It has therefore not been possible to include any official information regarding bomb disposal/clearance tasks on this site. If any relevant information is received at a later date Atkins Limited will be advised.

9.4.5 Site Specific Bomb Penetration Considerations

Given the size of the proposed development area and consequently the varied nature of geology underlying the site, it is not possible to provide bomb penetration depths at this time. Assessments can be made for individual areas once details of underlying geology become available.

9.5. Likelihood of Post-raid UXO Detection

Utilising the above information, it is possible to make an assessment of the likelihood that evidence of unexploded ordnance would have been noted on a site during the war and the incident dealt with or recorded at the time. Factors such as bombing density, frequency of access, ground cover, damage and failure rate have been taken into consideration.

9.5.1. Density of Bombing

Bombing density is an important consideration for assessing the possibility that UXBs remain in an area. A very high density of bombs can for example result in increased levels of damage sustained to structures, greater likelihood of errors in record keeping and a higher risk that UXBs fell over the area.

Llandarcy Oil Refinery, associated railway infrastructure, steelworks and docks, all located within or adjacent to the site boundary, were specific Luftwaffe bombing targets. Further targets (including the city of Swansea itself) were located close to the site to the west. Secondary historical sources indicate that the docks and oil refinery were subject to bombing raids; adjacent rural areas were also hit, evidenced by the significant number of

⁴ No photographs of the northern areas of the site were available.

HE bomb craters visible on WWII-era aerial photography to open ground to the west of the site.

The majority of the proposed area of development lies outside of the County Borough of Swansea in the Neath region. Very few contemporary sources, such as written ARP records or bomb census maps which may have indicated the specific location and number of bombs dropped, have survived to the present day. Home Office bombing statistics record a very low bombing density over the Neath area as a whole (3.9 items of UXO per 1000 acres) when compared to the Swansea region (70.2 items per 1000 acres) however the Neath area was large and mostly rural. It is probable that most of the bombs recorded for Neath actually fell on or around the study site. It is also possible that bomb strikes on the refinery – as a strategic installation – were excluded from the civilian statistics.

9.5.2. Frequency of Access

Unexploded ordnance at sites where human access was infrequent would have a higher chance of being overlooked than at those sites which were subject to greater occupancy. The importance of a site or facility to the war effort is also an important consideration as such sites are likely to have been both frequently accessed and are also likely to have been subject to post-raid checks for evidence of UXO.

Much of the site, comprising the former oil refinery, railway tracks and industrial structures, would have been in constant use during the war. Furthermore, Llandarcy Oil Refinery had its own dedicated ARP personnel and bomb disposal squad; given that the facility was vital to the war effort, it is highly likely that it would have been subject to post-raid checks for UXBs. This high level of access in certain areas of the site would have significantly increased the likelihood of UXBs being noticed in undamaged areas. It is therefore less likely that evidence of a UXB could have been overlooked in such areas.

Other parts of the site were more rural in nature during WWII and it is probable that such areas would have been less frequently accessed. Comparatively unimportant, it is also less likely that areas consisting of open ground were subject to post-raid checks for UXBs.

9.5.3. Ground Cover

The degree and type of groundcover present during WWII would have a significant effect on the visual evidence at ground level which may have indicated the presence of buried UXO.

Evidence of a UXB would have been more obvious on parts of the proposed development site occupied by oil storage tanks, factories, roads or railway lines. Where the ground cover was more open in nature, evidence of a UXB may have been less visible (note that the entry hole of a 50kg HE UXB may have been as small as 20cm in diameter). In areas of the site which encompass open water (such as the reservoir to the north), there would have been no signs of UXB entry.

9.5.4. Damage

If structures on a site have been subject to significant bomb or fire damage, rubble and debris are likely to have been present. Under such conditions there is a greater risk of the entry holes of unexploded bombs dropped during subsequent raids being obscured and going unnoticed. A UXB entry hole is considerably less likely to have been overlooked on an undamaged property. There is also the risk that damage from a 1000kg bomb was inadvertently recorded as a detonated 50Kg bomb.

Sources indicate that parts of Llandarcy Oil Refinery suffered serious damage during the early part of the war and HE bombs were also recorded to the Kings Dock area on the south-western part of the site. There is a risk that a UXB could have fallen unnoticed and unrecorded into the rubble and debris of bomb damaged areas following a heavy air raid. However, it must be considered that, given its importance, any damage caused to infrastructure occupying much of the site would have been repaired in a timely fashion.

9.5.5. Bomb Failure Rate

There is no specific evidence to suggest that the bomb failure rate in the vicinity of the site would have been different from the “approximately 10%” figure normally used, although available reports on the bombing of the refinery do make the point that there were many UXBs.

10. The Threat from Allied Military Activity

10.1. General

BACTEC has found no evidence to suggest that the site itself had any former military use which could have led to ordnance contamination.

The following potential military uses have been considered:

- Anti-Aircraft Defences
- Home Guard
- Training or firing ranges or the storage of ammunition
- Military bases
- Defensive minefields (including pipemines)
- Defensive Positions
- Manufacture of explosives or ordnance

The most likely source of allied ordnance is from anti-aircraft fire and anti-invasion defences situated in the vicinity of the site.

10.2. Defending Swansea and Neath from Aerial Attack

Both passive and active defences were deployed against enemy bombers attacking the Swansea area.

Passive defences included measures to hinder the identification of targets (such as a lighting blackout at night and the camouflaging of strategic installations); to mislead bomber pilots into attacking decoy sites located away from the city and to force attacking aircraft to higher altitudes with the use of barrage balloons.

Active air defence relied on a coordinated combination of fighter aircraft to act as interceptors, heavy and light anti-aircraft gun batteries and later the use of rockets and missiles, in order to actively engage and oppose attacking aircraft.

10.2.1. Anti-Aircraft Artillery and Projectiles

At the start of the war two types of AAA weapons were deployed: Heavy Anti-Aircraft Artillery (HAA), using large calibre weapons such as the 3.7" QF (Quick Firing) gun and Light Anti-Aircraft Artillery (LAA) using smaller calibre weapons such as 40mm Bofors gun.

Initially there was a serious shortage of AAA defences and some WWI 3" and modified naval 4.5" guns were also deployed. As the war progressed improved variants of the 3.7 Inch gun and, from 1942, large 5.25 inch weapons, were introduced. Ceiling heights of fire were around 11,000m for the early HAA guns but reached over 18,000m for the later variants.

The LAA batteries were intended to engage fast low flying aircraft and were typically deployed around airfields or strategic installations. These batteries were mobile and could be moved to new positions when required. The 40mm Bofors gun could fire up to 120 x 40mm HE shells per minute to over 1800m.

Six HAA batteries were situated within 4km of the centre of the development site, four of which were located within or close to the site boundary. No evidence of LAA could be found in the vicinity of the site, although the possibility that the oil refinery at Llandarcy may have been defended by such artillery cannot be discounted.

The HAA projectiles were high explosive shells, usually fitted with a time delay or barometric pressure fuze to make them explode at a pre-determined height. If they failed to explode or strike an aircraft, they would eventually fall back to earth. Details of the most common WWII AAA projectiles are shown below:

Gun type	Calibre	Shell Weight	Shell Dimensions
3.0 Inch	76mm	7.3kg	76mm x 356mm
3.7 Inch	94mm	12.7kg	94mm x 438mm
4.5 Inch	114mm	24.7kg	114 x 578mm
40mm	40mm	0.9kg	40mm x 311mm

Although the larger unexploded projectiles could enter the ground they did not have great penetration ability and are therefore likely to be found close to WWII ground level. They have been mistakenly identified as small German air-delivered bombs, but are differentiated by the copper driving band found in front of the base. With a high explosive fill and fragmentation hazard these items of UXO present a significant risk if encountered. The smaller 40mm projectiles are similar in appearance and effect to small arms ammunition and present a much lower risk.

Numerous unexploded AAA shells were recovered during and following WWII and are still occasionally encountered on sites today.

10.2.2. Rocket Projector "Z" Batteries

Initially developed as a naval AA defensive weapon these were deployed at sites around the UK from 1941 and proved to be an effective addition to AA defences. They comprised groups of multiple rocket launchers, laid out in a grid formation, which could project 2 or 3 Inch HE rockets, known as Unrotating Projectiles (U.P), to an altitude of 6000m and with a ground range of over 9000m.

The rockets were tubular in section, measuring 0.9m (2") or 1.8m (3") in length. with four fins. They were fitted with 3.5kg or 8.2kg high explosive warheads similar to artillery projectiles, with a time-delay fuze. The larger warhead was reputedly effective up to 20m. Some variants deployed a form of aerial mine described as a "small yellow bomb" which was designed to detach from the rocket at height and descend on a parachute with the objective of becoming snagged on target aircraft and then detonating

The rocket body from an unexploded missile would not have survived impact with the ground but the warhead could have survived and penetrated below ground level in soft geology or become lost in bomb damage rubble.

Illustrations of Anti-Aircraft artillery, projectiles and rockets are presented at Annex L.

10.3. Anti-Invasion Defences

The SSSI and Transit Site areas of the development site encompass the foreshore of Swansea Bay. It was anticipated at the beginning of the war that Germany would attempt to invade Britain. The coastal defences of Swansea Bay were therefore enhanced and a range of anti invasion measures was deployed around the area.

From 2002 – 2004 English Heritage undertook a study of the WWII anti invasion landscape of Britain, entitled 'The Defence of Britain', mapping the location and type of the known defences around the country. An aerial photograph showing the positions with these defensive measures in the vicinity of the site is presented in Annex M.

Anti-invasion defences known to be located along the shoreline in close proximity to the site include pillboxes and gun emplacements on the south-western part of the site. Located primarily on areas of hardstanding along the dockside, it is considered unlikely that a legacy of ordnance contamination remains from these defences. However, the possibility cannot be discounted that other, unrecorded defences were situated further along the coast on open ground on the southern part of the site. There is a remote possibility that items of Small Arms Ammunition (for example bullets) and Land Service Ammunition (such as grenades, mortars etc) may be encountered in these areas.

11. Ordnance Clearance and Post-WWII Ground Works

11.1. General

The extent to which any ordnance clearance activities have taken place on site or extensive ground works have occurred is relevant since on the one hand they may indicate previous ordnance contamination but also may have reduced the risk that ordnance remains undiscovered.

11.2. EOD Clearance

BACTEC has no evidence that any official ordnance clearance operations have taken place on site. Note however that we have not yet received confirmation of this fact from 33 EOD Regiment (see section 9.4.4.).

11.3. Post war Redevelopment

Exact details of the extent of post-war redevelopment in the region are not available. However, Llandarcy Oil Refinery did experience a period of expansion during the 1950s and 1960s, which is likely to have involved an amount of levelling and excavations for foundations and pipelines.

12. The Overall Explosive Ordnance Threat Assessment

12.1. General Considerations

Taking into account the quality of the historical evidence, the assessment of the overall threat to the proposed works from unexploded ordnance must evaluate the following risks:

- That the site was contaminated with unexploded ordnance
- That unexploded ordnance remains on site
- That such items will be encountered during the proposed works
- That ordnance may be activated by the works operations
- The consequences of encountering or initiating ordnance

12.2. Quality of the Historical Record

The research has located and evaluated WWII-era Cassini maps, Luftwaffe aerial photography and target maps, and records of ground defences. The majority of written WWII ARP records and bomb census maps for the Swansea and Neath areas have not survived and it is therefore impossible to plot the exact locations and quantity of ordnance dropped in the region. Similarly, detailed post-war aerial photography of the site, which may have highlighted areas of significant damage, was not available. As a consequence, the analysis and conclusions drawn from the accessible evidence are necessarily general in nature.

12.3. The Risk that the Site was Contaminated with Unexploded Ordnance

For the reasons discussed in section 9.5 BACTEC believes that there is a risk that unexploded high explosive bombs and/or anti-aircraft projectiles fell unnoticed and unrecorded within the site boundary.

- Coed Darcy: The largest single section of the site incorporated the Llandarcy Oil Refinery, which would have been the primary Luftwaffe target in the immediate region. Sources indicate that at least two significant bombing raids occurred in this area, with a number of UXBs dropped. Serious damage was caused to part of the refinery during one of these raids and there is a risk that UXO may have gone unnoticed and unrecorded in bomb damaged areas. It should be noted however that the refinery would have been in constant use during the war and likely subject to stringent post-raid checks for UXBs. However, more peripheral and open areas of this section may not have been subject to the same levels of access; such areas are at a greater risk of UXO contamination. The reservoir (in the northern part of this site) was an area of open water during WWII and is also considered to be at an elevated risk.

- Nature Reserve/Eco Dwellings: These areas lay close to a number of Luftwaffe targets including factories and railway tracks; three HAA batteries were also located close to these sections. WWII-era aerial photography indicates that factories close to these areas suffered severe bomb damage during the war. As open agricultural ground, it is unlikely that such areas were accessed frequently or subject to post-raid checks and it is therefore possible that UXO fell unobserved on this part of the site.
- SSSI/Transit Site: These large sections of the site lay to the south of railway sidings, a steelworks and two HAA batteries. During WWII, this area consisted of the open foreshore, which was unlikely to have been of high priority for ARP personnel carrying out post-raid checks; indeed the beach may not have been accessible at all for security reasons. As a consequence there is a risk that air-delivered UXO fell unnoticed and unrecorded. Although unlikely, the possibility that anti-invasion defences (such as pillboxes and gun emplacements) were located in this section resulting in ordnance contamination cannot be totally discounted.
- ABP Freehold: This section was occupied by fuel tanks and areas of hard standing during WWII, with at least one tank suffering bomb damage. Whilst the possibility cannot be discounted that evidence of UXO may have been obscured by such damage, the fact that this area would have been frequently accessed and checked for UXO indicates that it is unlikely any such evidence would have been overlooked.
- Queens Dock: The docks to the south-east of Swansea were bombed on a number of occasions. It is considered unlikely that UXO could have gone unnoticed and unrecorded on areas of hardstanding on the dockside. Parts of this section which encompass open water are thought to be of elevated risk however, as any UXO falling in this area during the war is less likely to have been observed.
- Pipeline Routes: Any intrusive works to remove pipeline routes laid in the post-war period are considered at reduced risk⁵. At elevated risk however, are pipeline routes constructed in the pre-war period, particularly where these routes ran through areas that were open ground or subject to significant damage during the war.

There is no evidence that the site formerly had any military occupation or usage that could have led to contamination with other items of ordnance.

12.4. The Risk that Unexploded Ordnance Remains on Site

Parts of the site have been subject to redevelopment in the post war period, although the exact nature of the groundwork is unknown.

- The risk of encountering items of UXO will have been mitigated in the location of, and to the depth of any post-war foundations or pipeline routes, since any such items may have been discovered during excavations.
- Land reclamation appears to have taken place on the SSSI and Transit Site sections. Any items of UXO present in these areas are likely to remain a greater depth compared to other parts of the site.
- Parts of the development which have not been subject to any post-war intrusive works are at greatest risk from UXO remaining on site.

12.5. The Risk that Ordnance may be Encountered during the Works

The most likely scenarios under which a UXO could be encountered during the works is during bulk excavations for landscaping or basement levels or during piling or drilling. The overall risk will depend on the extent of the works (the volume of excavations, the numbers of piles) which is currently unknown.

Since an air-dropped bomb may come to rest at any depth between just below ground level and its maximum penetration depth there is also a chance that such an item could be

⁵ It should be noted however, that BACTEC has provided support on a site where a live incendiary bomb was found in the fill of a post-war pipeline route (an example of a 1kg incendiary bomb is presented in Annex F-3). Therefore although unlikely, the possibility cannot be discounted that items of UXO may have gone unnoticed and unrecorded in the fill of post-war pipeline routes along parts of the Coed Darcy Urban Village site.

encountered during shallow excavations (for services or site investigations) into the original WWII ground level.

12.6. The Risk that Ordnance may be Initiated

The risk that UXO could be initiated if encountered will depend on its condition, how it is found and the energy with which it is struck. The most violent activity on most construction sites is percussive piling.

As a result items that are shallow buried present a lower risk than those that are deep buried, since the force of impact is usually lower and they are more likely to be observed – when immediate mitigating actions can be taken.

12.7. The Consequences of Encountering or Initiating Ordnance

Clearly the consequences of an inadvertent detonation of UXO during construction operations would be catastrophic with a serious risk to life, damage to plant and a total site shutdown during follow-up investigations.

Since the risk of initiating ordnance is comparatively low if appropriate mitigation measures are undertaken, the most important consequence of the discovery of ordnance will be economic. This would be particularly so in the case of high profile locations and could involve the evacuation of the public. The unexpected discovery of ordnance may require the closing of the site for any time between a few hours and a week with a potentially significant cost in lost time. Note also that the suspected find of ordnance, if handled solely through the authorities, may also involve loss of production since the first action of the Police in most cases will be to isolate the locale whilst awaiting military assistance, even if this turns out to have been unnecessary.

12.8. BACTEC's Assessment

The Neath area was targeted by the Luftwaffe on numerous occasions, with both HE and incendiary bombs recorded in the region; in addition the locality was heavily defended by HAA batteries. There is therefore a risk of encountering both German aerially-delivered UXO and unexploded Allied anti-aircraft shells UXO over much of the site.

13. Proposed Risk Mitigation Methodology

13.1. General

Once construction plans are made available it is recommended that a meeting with BACTEC is held in order to determine the most appropriate and cost-effective risk mitigation strategy, considering areas of the site subject to post-war redevelopment and the location and extent of the proposed intrusive works. Proactive measures may be appropriate for certain works.

13.2. Recommended Reactive Risk Mitigation Measures

Reactive risk mitigation measures comprise:

- *EOD Engineer(s) Presence on Site* The role of the EOD Engineers would include: monitoring works using visual recognition and instrumentation and immediate response to reports of suspicious objects or suspected items of ordnance that have been recovered by the ground workers on site. Providing Explosive Ordnance Safety and Awareness briefings to any staff that have not received them earlier and advising staff of the need to modify working practices to take account of the ordnance threat. Finally, to aid Incident Management which would involve liaison with the local authorities and Police should ordnance be identified and present an explosive hazard.
- *Explosive Ordnance Safety and Awareness Briefings to all personnel conducting intrusive works:* A specialised briefing is always advisable when there is a possibility of explosive ordnance contamination. It is an essential component of the Health & Safety Plan for the site and conforms to requirements of CDM regulations 2007. All personnel working on the site should be instructed on the identification of UXB, actions to be taken to alert site management and to keep people and

equipment away from the hazard. Posters and information of a general nature on the UXB threat should be held in the site office for reference and as a reminder.

- *The Provision of Unexploded Ordnance Site Safety Instructions:* These written instructions contain information detailing actions to be taken in the event that unexploded ordnance is discovered. They are to be retained on site and will both assist in making a preliminary assessment of a suspect object and provide guidance on the immediate steps to be taken in the event that ordnance is believed to have been found.

13.3. Potential Proactive Risk Mitigation Measures

The two principal proactive risk mitigation measures available to detect the presence of unexploded ordnance are non-intrusive and intrusive magnetometry surveys. These surveys are designed to detect the variations in the earth's magnetic field produced by the presence of ferro-magnetic materials. Most ordnance has a high ferro-magnetic content.

- *Non-Intrusive Advanced Geophysical System (AGS) Survey and target investigation ahead of any intrusive works* – This survey is carried out using caesium vapour magnetometers to measure the total magnetic field. Data is interpreted using advanced proprietary software which is capable of modelling the magnetic anomalies for mass, depth and location, thus providing information which can be used to locate discrete buried objects that may be ordnance. Where there is a low magnetic background (greenfield sites) the system will typically locate buried ordnance to a depth of 4m for a 50kg bomb (the smallest HE bomb used by the Luftwaffe) and deeper for larger bombs. Additionally the survey will locate any buried services with a magnetic signature, and provide information on archaeological features. The technique is not appropriate in a brownfield or built environment.
- *Down-hole Intrusive Magnetometer Survey.* BACTEC can deploy a range of intrusive magnetometry techniques to clear ahead of pile or borehole locations. The appropriate technique is governed by a number of factors, but most importantly the site's ground conditions. Any anomalies highlighted during the intrusive survey which model as WWII-era air delivered bombs would be identified after investigation by EOD Engineers.

In some situations the preferred clearance methodology involves search and clearance by qualified Engineers:

- *Search and Clearance:* The works area is systematically searched by a team of Explosive Ordnance Disposal Engineers using hand-held magnetometry and pulse induction instruments. The magnetometry instrument will detect ferro-magnetic anomalies (for example airdropped bombs, land service ammunition and anti-aircraft projectiles). The pulse induction equipment will detect conducting (i.e. metallic) objects, including non-ferrous ordnance such as incendiary bombs or small arms ammunition. All such anomalies will be accessed and identified and if ordnance-related disposed of in an appropriate manner. The depth of clearance will depend on ground conditions and the type of ordnance involved.

15th January 2008

BACTEC International Limited

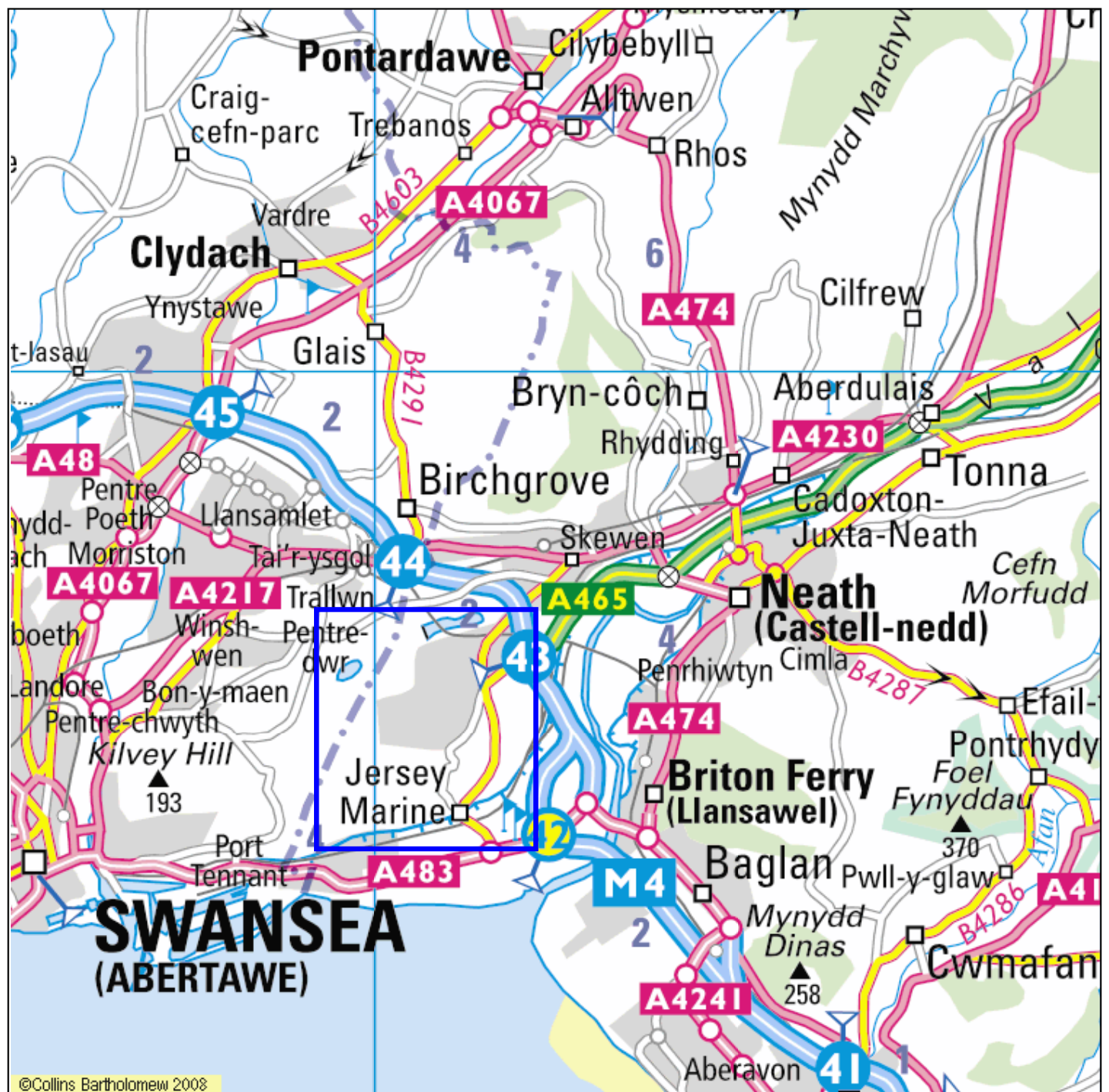
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Annex A: Site Location Map



— Approximate Site Location



37 Riverside, Sir Thomas
Longley Rd,
Rochester, Kent, ME2 4DP
Tel. +44 (0) 1634 296757
www.bacter.com

Report No:

9741 TA

Client:

Atkins Limited

Project:

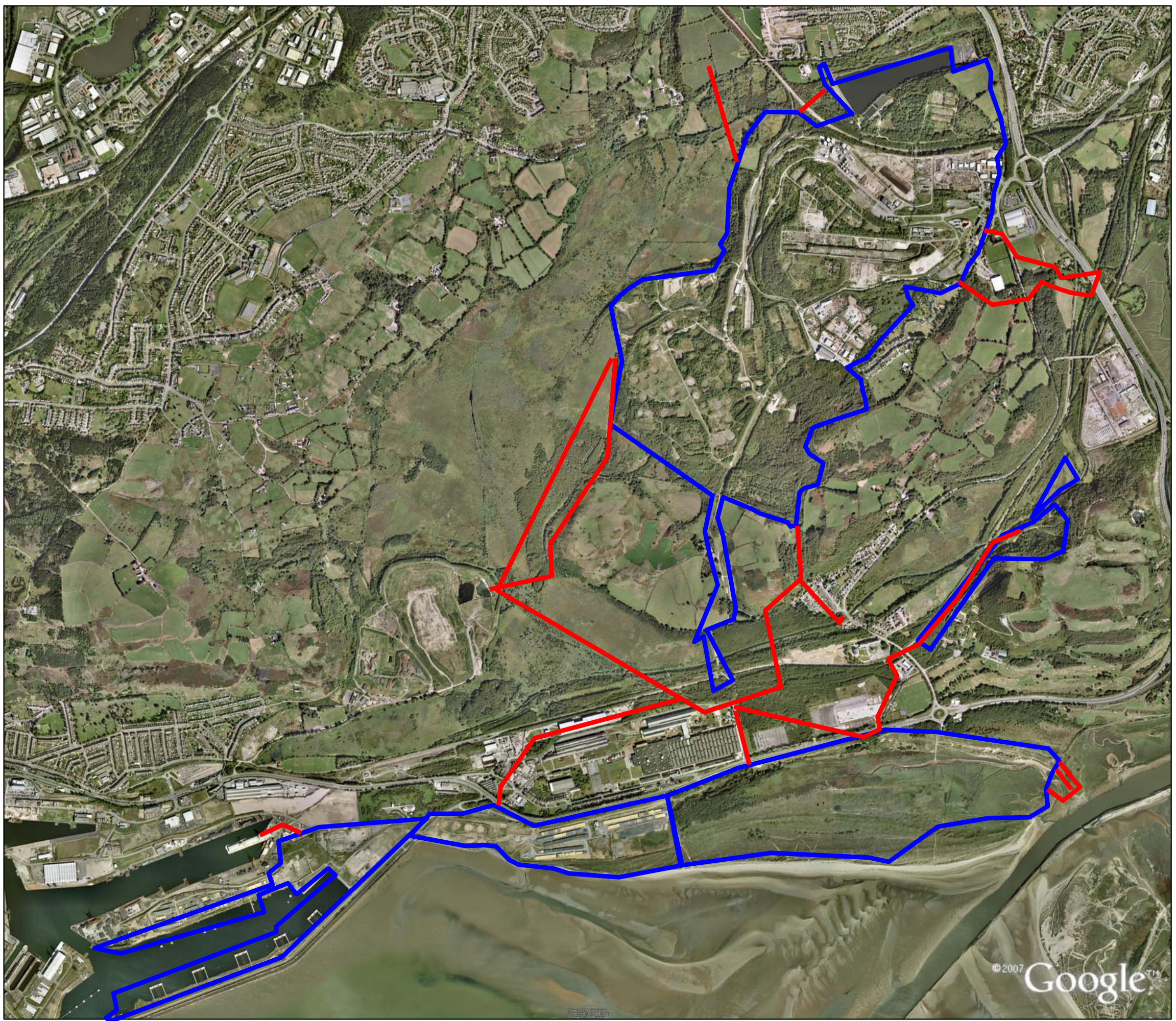
Coed Darcy Urban Village, Swansea

Source:

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Annex B: Recent Aerial Photograph of the Site



— Development Area — Pipeline Route

	Ref: 9741 TA	Client: Atkins Limited
	Source: Google Earth™ Mapping Services	Project: Coed Darcy Urban Village, Swansea

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Annex C: Proposed Site Plan