Initiation Train. This is a means by which, once the safety features have been switched off or removed, a chain reaction occurs through the weapon. Starting within the fusing system as a small ignition or spark, causing a detonator to explode, which in turn causes the booster charge to detonate with a greater energy and ending in the full detonation of the main explosive filling. Each part of the process has in-built safety features to prevent an unintended detonation. A failure in any of the components within the Initiation Train can result in a UXO. In the case of a UXB; the chain reaction has broken down and the Initiation Train is brought to a halt, albeit, a temporary one. There are a number of ways that sufficient energy could be introduced to the otherwise stable UXB / UXO that may allow the Initiation Train to set off once more, overcoming the initial reason for failure. In addition to subjecting the weapon to excessive heat, such as a fire, the most common methods to bring about an explosive detonation in such items are considered to be:

Direct impact onto the main body of the bomb by mechanical excavation or pile driving: Such an occurrence can cause the bomb to detonate, should the point of impact be on the bomb fuze; less force would be required to bring about a full or partial explosive detonation.

Re-starting the clock timer in the bomb fuze. Only a small percentage of bombs were fitted with clockwork fuzes. It is likely that corrosion has taken place within the fuze that may prevent the clockwork mechanism from functioning. However, the restarting of the clock is by no means a scenario that can be completely ruled out. This is considered to be one of the two most credible mechanisms by which sufficient energy could be introduced to the bomb and result in a detonation.

Induction of a static charge or exposure to an external power source (Electrical Services), causing a current in an electrical fuze. The majority of German bombs employed an electrical component within the fuzes, it is likely that corrosion would have taken place within the fuze mechanism and that it would no longer contain, or conduct sufficient electrical charge to initiate the bomb.

Friction initiating the sensitive fuze explosive. Some chemical constituents may have deteriorated, due to oxidisation. Components designed with a high degree of stability at the time of manufacture may no longer be as safe. **This is considered to be the most likely mechanism by which sufficient energy could be introduced to the bomb and result in a detonation.**

Annex F

Risk Assessment Tables

Table 1: Summary of Potential Contamination Sources

Source	Applicable	Not Applicable
Enemy Attack & Counter Measures		
Bombing WW1		☒
Manned Aircraft Bombing WW2	☒	
Unmanned V1 & V2 Rocket Attack		☒
Shelling		☒
Anti-Shipping Mines & Depth Charges		☒
Anti-Aircraft Shells & Rockets		☒
Beach Mines & Coastal Defences.		☒
Airfield/Key Point Defensive Mines/Charges		☒
Abandoned Unexploded Bomb (A/UXB)		☒
Migration of UXO		
UXO Migration in Rubble & Infill		☒
UXO Migration by Tide & River Current		☒
UXO Migration by Marine Dredging		☒
Ship Wrecks		☒
Dispersal by Explosion, Fire & Accident		☒
Aeroplane Crash		☒
Private Collections		☒
MOD Facilities		
Bombing Range		☒
Artillery, Mortar & Tank Range		☒
Grenade Range		☒
Small Arms Firing Range		☒
Weapon Research & Development Facilities		☒
Ammunition Burial Grounds		☒
Docks & Harbour Facilities		☒
Offshore Ammunition Dumping Grounds		☒
Ammunition Storage & Manufacture Sites		☒
Airfields & Air Stations		☒
Bombing Decoy Site		☒
Army Barracks & Camps		☒
MOD Training / Concentration Areas		☒
Home Guard & SOE Weapon Caches		☒

Table 2: Baseline Bomb Penetration Assessment

	Bomb Weights			
Sub Soil Type	50kg	250kg	500kg	1000kg
Soft Rock	**2.442**	**5.016**	**6.006**	**7.062**
Gravel	2.442	5.016	6.006	7.062
Sand	**2.442**	5.016	6.006	7.062
Chalk	3.7	7.6	9.1	10.7
Shingle	3.7	7.6	9.1	10.7
Dry Clay	3.7	7.6	9.1	10.7
Wet Sand	5.55	11.4	13.65	16.05
Wet Clay	5.55	11.4	13.65	16.05
Average Offset (m)	0.8-1.6	1.6-3.7	3-4.5	3.4-5.3

Table 3: Site Specific Bomb Penetration Assessment

Input Figures			
Bomb Weight	Release Height	Velocity on Impact	Angle of Strike
500 kg	5000 m	340 $m.s^{-1}$	10º to vertical

Geological Unit Description	Anticipated Thickness (m)	Anticipated Depth (m bgl)
Top Soil	0.2	0.2
Sand	1.2	1.4
Sandstone	8.6	10 end of log

Output Figures	
Maximum Penetration Depth	Maximum Offset
8m	**5.3m**
The maximum threat depth from airdropped weapons is considered to be:	**Bombs 8m**
The maximum threat depth for smaller shells is considered to be:	**AA Shells 3m**

Input figures based on the most common bombing methods and largest common bomb type Figures derived from computer simulation. All depths based on 1939 levels.

Table 4: Airdropped Weapon Strike Indicators (UK)

Item	Increasing Potential level ⇨			
Site Location	Rural	**Small Town**	Brown Field Large Towns	Cities
Site Description and Use	**Greenfield or Agricultural Land**	Near Strategic Target	Adjacent to Strategic Target	Strategic Target
Site History	No history of Attack	Near area of Attack	Immediate Area Attacked	**Direct Attack**

Strategic Target: Military Installation, Industrial or Munitions Manufacturer, Power Station, Gas or Water Works, Port, Dock, Railway Yard, Decoy Site.

Table 5: Weapon Strike Records (UK)

Source	Availability			
Archive	None	Non specific	**Specific**	Extensive
In-house	None	Non specific	**Specific**	Extensive
Anecdotal	**None**	Non specific	Specific	Confirmed

Table 6: Anti-Aircraft Weapon Strike Indicators (UK)

Item	Increasing Potential level ⇨			
Site Location	Rural	**Town**	City	Military Site
Fixed Battery Location	None	**General Area**	Nearby	Onsite
Mobile Battery	Rural	**Town**	City	Military Site
Military Site: Airfield, Port, Radar, Barracks, Depots, Arsenal or Similar.				

Table 7: Abandoned Bomb Records (UK)

Item	Increasing Potential level ⇨		
In-house	**None**	Yes	On-site
Other	**None**	Yes	On-site

Table 8: Bomb Strike Density Assessment

Bombs & Mines	**Bomb density placed at Medium.**

Table 9: Opportunity to have detected Bomb or Shell Strikes (UK)

Increasing Potential level ⇨
No recorded bombs or damage
Good ARP cover
Significant development
No significant ground cover
Light bombing or damage
Moderate ARP cover
Moderate development
Frequent public access
Little ground cover
Significant bombing or damage
Poor ARP cover
Minimal development limited to shallow excavations
Infrequent public access
Moderate ground cover
Heavy bombing or damage
No ARP cover
Development limited to site clearance
Controlled private access
Heavy ground cover, vegetation, ploughing or body of water

Table 10: Post Contamination Development Indicators (UK)

Nature of Post Contamination Development	Increasing Potential level ⇨
	100% excavations of the entire site to below contamination depth.
	Significant development
	Moderate development
	Minimal development
	No development

Table 11: Construction Activities Encounter Indicators

Activities	Increasing Potential level ⇨
	Borehole Drilling
	Dynamic Sampling
	Shallow Trial Pit
	Services Trenching
	Bored (CFA) Piling
	Sheet Piling
	Shallow Excavations over extended area
	Deep Excavations over a limited area
	High Density Piles
	Deep Excavations over extended area
	Bulk Excavations

Annex G

Sip Grenades

Aftermath of Demolition

The Beach https://www.thebeach.co.uk/news/local-news/bomb-squad-called-after-dozens-of-second-world-war-grenades-discovered/

28 May 2019

Army bomb disposal teams have detonated 24 grenades found in a field in East Suffolk.

The 'SIP grenades' - which stands for 'self-igniting phosphorus' - were discovered in the village of Sibton, which is near Yoxford, yesterday.

The bombs, which were designed during the 1940s, were glass bottles filled with phoshorus and petrol. Unlike traditional Molotov cocktails, they would ignite spontaneously when the glass shattered, and the phosphorus became exposed to air.

The grenades were issued to Home Guard units in the event of a German invasion; as that never happened crates of them have been left buried in unregistered hiding places.

BBC News https://www.bbc.com/news/uk-england-hampshire-48327618

19 May 2019

A suspected German wartime bomb which was caught in a fishing net off the coast of the Isle of Wight has been detonated.

A fishing vessel reported picking up the 7ft-long sea mine, which was “most likely an old German wartime sea mine”, about a mile from the Needles at around 8am on Saturday, the Maritime and Coastguard Agency (MCA) said.

Bomb disposal experts from the Royal Navy’s Portsmouth base were called in to detonate the device, while warnings were issued to ships and public in the area.

Divers placed the mine back on the sea bed and blew up the bomb – found to contain 2,000lb of explosives – at 10.51am on Sunday, the Ministry of Defence said.

Source:	**Birmingham Live**
Date:	**25th March 2019**
Description:	Stechford Retail Park and homes evacuated after 'unexploded bomb' found Police have cordoned off the area at the Retail Park, off Flaxley Road, following reports an unexploded bomb. The discovery was made Stechford Retail Park just after midday. A number of homes have been evacuated along with part of the retail park. West Midlands Police say they believe it's from World War Two. A section of the A4040 closed, with bus routes also affected.

Source:	**The Guardian**
Date:	**3 March 2017**
Description:	A second world war bomb that forced schools and homes in London to be evacuated has been defused. The device, weighing 500lb (227kg), was found by builders working on a development in Brondesbury Park, north-west London, late on Thursday morning, on The Avenue, near the junction of Willesden Lane. The Metropolitan police, London fire brigade and an army bomb-disposal team were scrambled to the scene, where a cordon was erected and homes were evacuated.

Source:	**BBC News**
Date:	**13th February 2018**
Description:	**London City Airport has reopened after an unexploded 500kg World War Two bomb was safely moved from the area.** The device was discovered at the King George V Dock on Sunday during planned work at the east London airport. All flights were cancelled on Monday after an exclusion zone was put in place, **with the closure affecting up to 16,000 passengers and nearby residents being evacuated from their homes.** The bomb is due to be detonated in a controlled explosion in Shoeburyness. Royal Navy divers worked through the night to move the 1.5m-long German bomb down the Thames. Divers took the device - which was found in a bed of silt, 15m underwater - along with military explosives out to sea. Commander Del McKnight said it had been taken to the sea bed, a mile away from the coast, before military explosives were placed on it. He added the bomb would be exploded in due course, weather permitting.

Source:	**BBC**
Date:	**16th May 2017**
Description:	**Bomb disposal experts in Birmingham are taking part in a "major, delicate operation" to make a wartime bomb safe.** A major route into the city remains closed for a second day, rail services are affected and people have been evacuated from their homes. The bomb disposal team said 13 lorry loads of sand had been brought in to create a "sizeable igloo" around the 250kg (551lb) bomb. Junctions four to seven of the M6 have been closed ahead of detonation. West Midlands Police, who has praised the bravery of the team at the scene, said the motorway between junction four near Coleshill and seven at Great Barr will shut in both directions while a controlled explosion is carried out.

Discovery: the unexploded German SD 50kg bomb was dropped by an aircraft during the second world war.

Source:	**Evening Standard**
Date:	**20th January 2017**
Description:	**This is the World War Two bomb which caused chaos after it was found in the Thames near the Houses of Parliament on Thursday evening.** Waterloo and Westminster bridges were both closed for several hours, Westminster underground station was closed and river traffic was halted after the device was dredged up near the Victoria Embankment. Scores of police carried out safety checks in the area and the riverfront remained closed until around 3am on Friday morning. The Royal Navy operation to dispose of the unexploded bomb involved towing it along the river to Tilbury where a controlled detonation was carried out.

The device was destroyed in a controlled explosion at about 15:00 BST

Source:	**BBC**
Date:	**8th August 2017**
Description:	**A bomb believed to be from World War Two has been found in the Bristol Channel near Hinkley Point nuclear power station.** The 500lb device was discovered 2.5 nautical miles from the coast, about 8m below the surface. Divers conducting a survey for the construction of the new power station found the ordnance on Monday. It was destroyed in a controlled explosion at about 15:00 BST on Tuesday. The "unusual" ordnance was found off Lilstock Range, just west from Steart point and Bridgwater in Somerset.

Source:	**The Telegraph**
Date:	**31st March 2017**
Description:	**A World War Two bouncing bomb which was trailed prior to the Dambusters raid has been discovered on a beach in Kent.** The May 1943 raid is one of the most memorable British war victories - and now a piece of one of the iconic explosives washed ashore on a picturesque beach. Beach cafe owner Lisa Clayton has owned her business on Reculver Beach near Herne Bay, Kent, for 11 years, and spotted the bomb on Wednesday morning around 10am. The 49-year-old said: "We saw the police, coastguard and bomb disposal people on the beach so we went to have a look. "We were really surprised - we've been here 11 years and had never seen a bomb here before. "It's only one end of it but it's quite big, it's a lot bigger than I thought. "There have been other little mine-type things on the beach before, but nothing like this. "It's right by the sea wall, it's a busy area, but at that time it's really quiet and there was this sudden commotion.

BRIMSTONE
SITE INVESTIGATION

NON-INTRUSIVE UXO SURVEY REPORT

INTEGRITY | PROFESSIONALISM | KNOWLEDGE

BRIMSTONE
SITE INVESTIGATION

NON-INTRUSIVE UXO SURVEY REPORT

Client:	Campbell Reith
Project Location:	Brislington, Bristol
Project Ref:	CAMP11
Report Ref:	20210421-NIREP-CAMP11
Revision:	1
Status:	Final
Date:	29th April 2021

Data Processing By:	Dr Sumana Basu PhD.	Geophysicist	sumana.basu@brimstoneuxo.com
Written By:	Shaib Ahmed	Technical Executive	shaib.ahmed@brimstoneuxo.com
Reviewed By:	Andrew Lane	Operations Manager	andrew.lane@brimstoneuxo.com
Authorised By:	Aaron Florence	Managing Director	

QUALITY MANAGEMENT

Brimstone Site Investigation 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 Site Investigation Ltd 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 Site Investigation Ltd.

CONTENTS

Quality Management i
Contents i
Executive Summary 6
1 What is UXO? 6
2 Why is Land Contamintaed by UXO? 6
3 The Regulatory Environment 6
3.1 Construction (Design Management) Regulations (2015) 6
3.2 Health and Safety at Work Act (1974) 6
3.3 Management of Health and Safety at Work (1999) 7
4 CIRIA C681 guidelines 7
5 ALARP 7
6 Maximum Bomb Penetration Depths 8
7 Land Service Ammunition 8
8 How Does This Survey Work? 8
9 Other Possible Mitigation Strategies 9
10 Survey Details 9
10.1 Location 9
10.2 Survey Dates 10
10.3 Survey Limitations 10
11 Survey Equipment 11
12 Data Interpretation 11
13 Target Selection 11
14 Recommendations 12
15 Annexes 6

EXECUTIVE SUMMARY

- Brimstone Site Investigation (BSI) has completed a non-intrusive UXO Survey for Campbell Reith from the 14th of April 2021 to the 16th of April 2021, using push-cart methodology (Annex B).
- The aim of the survey was to identify any possible buried UXO ahead of ground-intrusive works proposed by the client.
- The output of this survey is a coordinated list of targets (Annex D) with estimated mass and depth.
- The follow-up activity to this report is a 'target investigation' of suspect buried objects.
- Buried ferrous targets have been identified. These targets are not necessarily UXO, but through analysis are comparable with known magnetic signatures of UXO.
- In total, 281 targets were modelled because of the survey. These targets have been reduced to 196 to achieve reduce risk to a reasonably practicable level. Discounted targets are inconsistent with UXO.

Area Surveyed (ha)	Total No. of Targets Modelled	Discounted Targets	Targets to Investigate	Est. Duration of Investigation (two-man team)
5.68	281	85	196	8 days

1 WHAT IS UXO?

UXO is an abbreviation for unexploded ordnance. It is a term that refers to explosive ordnance which has been primed, armed, fused, or otherwise prepared for use, and has been dropped, fired, launched, projected, thrown, or placed and remains unexploded either by malfunction or by design.

UXO is a catch-all term used in the UK to refer to explosive hazard contamination. Although, not all explosive hazards are correctly described as UXO. Abandoned explosive ordnance, or AXO, is ordnance, which is in a safe state, has not been prepared for use or has not been fire, projected, thrown, or otherwise used. Instead, AXO has been buried or hidden, either as a means of disposal or as a cache in anticipation of invasion.

An example of UXO would be an anti-aircraft projectile having been fired at an aircraft, failing to function and the falling back to land, unexploded. An example of AXO would be a 'bomb dump' of expired ordnance, whereby an excavation is filled with unwanted ordnance and backfilled. This was frequently used by the MoD up until the 1980s as a recognised means of disposal.

2 WHY IS LAND CONTAMINTAED BY UXO?

There are four sources of UXO contamination in the UK. These are: enemy action, allied action, military activity or munitions manufacturing and storage locations. Enemy action refers primarily to artillery bombardment and strategic bombing campaign of the Second World War. Allied action refers to defensive activities, again primarily in relation to the Second World War, which includes land and sea mining, anti-aircraft batteries and rocket batteries.

Military training is a significant source of UXO contamination. In former and current military training areas, the risk of encountering UXO is significant, ranging from projectiles, mortars, and grenades. The MoD is the second-largest landowner in the UK, and as such large parts of the UK have historically been used or requisitioned by the military for training our armed forces and allied armed forces.

Finally, munitions manufacturing and storage sites also present a UXO risk, although the risk is generally localised and in small specific parts of the UK.

3 THE REGULATORY ENVIRONMENT

There are no specific regulations that manage how UXO is dealt with on UK construction sites, and similar operations. However, there are pieces of legislation that must be considered when companies choose how to approach UXO risk, these include those listed below. The CIRIA guidelines are a set of guiding principles that offer a framework to the UK UXO risk mitigation sector, these are explained in the subsequent section.

- Construction (Design Management) Regulation (2015)
- Health and Safety at Work Act (1974)
- Management of Health and Safety at Work (1999)

3.1 Construction (Design Management) Regulations (2015)

CDM 2015 replaces CDM 2007. These regulations define the responsibilities of roles within construction projects. The Principal Designer is responsible for managing health and safety, in that role they must exercise identification, elimination and control of foreseeable risks. UXO is a significant potential hazard and must be considered at the design phase.

3.2 Health and Safety at Work Act (1974)

Employers must ensure as far as is reasonably practicable the health and safety of their employees. They must also ensure the health and safety of others affected by their work activity. When working on a site which is thought to have a UXO

contamination risk, employers have a responsibility to provide a safe system of work that addresses the assessed UXO risk.

3.3 Management of Health and Safety at Work (1999)

This adds on to the Health and Safety at Work Act (1974). The act sets out the general duties which employers have towards employees and members of the public, and those which employees have to themselves and each other. In relation to UXO, the act applied that duty holders are to ensure that proper assessments of foreseeable risks are completed and that necessary measures are taken to control risks to an acceptable level.

4 CIRIA C681 GUIDELINES

CIRIA is the Construction Industry Research and Information Association. Two sets of guidelines provide a framework to the UXO risk mitigation sector in the UK. They are not legally binding, and are optional to follow, but they form the accepted best-practice standards to which the industry operates.

CIRIA C681: Unexploded Ordnance: A Guide for the Construction Industry (2009)

This is the overarching document which provides the four stage UXO risk mitigation framework. Stages are:

1. Preliminary UXO risk assessment – a qualitative screening exercise to assess the likelihood of finding UXO on a site. This can be completed by a non-UXO specialist or a UXO specialist.

2. Detailed UXO risk assessment – A wider and deeper assessment of the site, using bomb damage amps, penetration assessments and other historical information.

3. Recommendations – A proposal of risk mitigation strategies determined in coordination with the client.

4. Implementations – the on-site UXO risk mitigation measures being put in place.

CIRIA C785: Unexploded Ordnance Risk Management Guide for Land-Based Projects (2019)

This guidance document adds on to C681. It provides additional details and structure to the risk assessment process. Both documents are available to purchase on the CIRIA website.

5 ALARP

The ALARP (as low as reasonably practicable) principle is about 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, BSI aims to reduce client costs by recommending strategies that are proportionate to the assessed risks.

Page Continued Overleaf

6 MAXIMUM BOMB PENETRATION DEPTHS

Using data gathered during WWII by the Ministry of Home Security, estimates can be made about how deep a bomb is likely to penetrate the ground. Over one thousand incidents were reported by the bomb disposal units to support this research. Further tests were carried out, dropping bombs of different sizes into chalk and measuring the depths they reached. This research is held at the National Archives. The estimates are:

Bomb weight (kg)	Ground Type (m)							
	Sand		Gravel		Chalk		Clay	
	Average	Max.	Average	Max.	Average	Max.	Average	Max.
50	2.8	7.8	2.8	7.8	3.5	7.7	4.0	9.1
250	4.8	13.7	4.8	13.7	6.0	13.1	6.8	15.8
500	6.0	17.3	6.0	17.3	7.6	16.4	8.7	19.8
1,000	7.6	21.9	7.6	21.9	9.6	20.7	10.9	24.9

Different layers of geology affect penetration depths, for example 1m of made ground, then 1m of gravel before reaching clay – as is many areas of London – is not easily calculated from the data above.

When calculating how deep a bomb could have reached, we must make three assumptions:

a) **Impact velocity.** German bombing raids were carried out at altitudes more than 5,000m. The velocity of impact is roughly 313ms^{-1} (not accounting for resistance). It is the same velocity regardless of mass.

b) **Impact angle.** Strike angles of 10 to 15 degrees to the vertical. It must be assumed that the bomb was stable at the moment of ground penetration.

c) **Bomb design.** Some larger German bombs were occasionally fitted with 'kopfrings' - a metal ring, triangular in cross section, fitted around the nose of the bomb to help prevent penetration. It must be assumed that no 'kopfrings' were fitted.

7 LAND SERVICE AMMUNITION

Land service ammunition (LSA) includes mortars, grenades, rockets, and projectiles. These types of ordnance can contaminate land in the UK due to prior and current training of the UK's armed forces, as well as the activities of other allied nations on British soil. Training areas, airfields, barracks, and camps are areas which may have a heightened risk of encountering LSA. During WWII anti-aircraft weaponry was deployed across much of the UK, and as a result contamination from anti-aircraft projectiles can occur in cities as well as in the open countryside.

LSA is typically found within the first 0.5m of WWII level ground. Non-intrusive UXO surveying is an effective method of targeting LSA due to these shallow depths and high iron content. Objects, even large objects, which lay deeper than 4m below the surveyed ground level are difficult for this equipment to detect.

8 HOW DOES THIS SURVEY WORK?

In coordination with the client Brimstone recommended the completion of a non-intrusive magnetometry survey. The output of this survey is false colour maps of 'hotspots' overlain satellite imagery of the site. A non-intrusive survey is a survey style which does not require any manipulation or 'intrusions' into the ground. This means that specialist technical equipment is methodically moved across the surface of a given area without disturbing any possible buried objects. The benefit of this type of survey is wide area coverage, as consistent with the requirements for this project.

The data collected is GPS information joined with magnetometry information. Magnetometry is a type of technical sensing technology. Essentially, a magnetometer is an instrument which detects the Earth's natural magnetic field by sending signals between two sensors - contained within an aluminium tube called a probe. These sensors are known as

fluxgate gradiometers. Deviations within the Earth's magnetic field indicates the presence of a buried object containing iron. The more iron, the stronger the magnetic signal. The diagrams below illustrate this effect.

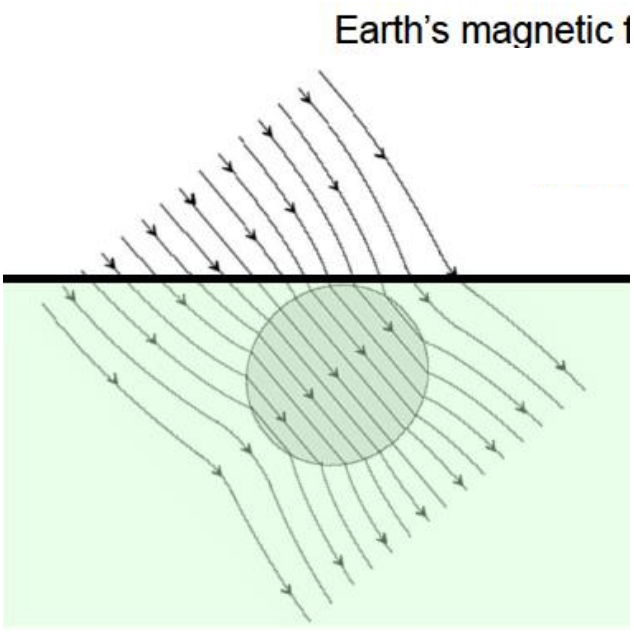


Figure 2. Earth's magnetic field interrupted by a buried iron (ferrous) object

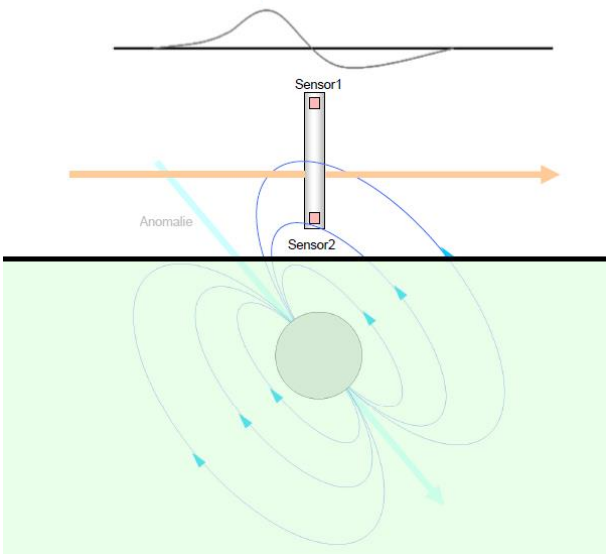


Figure 1 A description of how the sensor locate targets and the sinusoidal information received.

By analysing the wavelength and amplitude of the signal measured by the magnetometers, we can estimate the likely depth and size of a buried object. Whilst the depth of the object is quite accurate, the estimated mass is harder to determine and is known for a greater degree of inaccuracy.

Magnetometry technology is a so-called passive system. A simple way to think about passive systems is that the object looks at the sensor, rather than the sensor looking at the object – as is the case with active systems. Therefore, with the type of system used in this survey, the maximum depth the equipment can sense to is dependent on the mass of the item and its surrounding geology.

9 OTHER POSSIBLE MITIGATION STRATEGIES

Other options of mitigation for the project could include a long-term watching brief. This involves a suitably qualified and experienced UXO engineer to be present on site to provide supervision of all excavations. They would use technical search equipment to identify buried items ahead of the excavator. This process is generally slow and long-term and is suitable where UXO surveys cannot be used.

10 SURVEY DETAILS

10.1 Location

The project address is: Brislington Meadows, Brislington, Bristol, BS4 4FJ. The site boundaries are indicated in red below, and in further detail contained in Annex A.

Page Continued Overleaf

10.2 Survey Dates

The survey was completed on the 14th of April 2021 to the 16th of April 2021, using pushcart methodology (Annex B).

10.3 Survey Limitations

At times, not all the proposed area can be surveyed. This can be for one or several reasons, including:

a) Vegetation too tall or impassable for the equipment,

b) Too soft ground for the operator,

c) Man-made or natural obstacles, and

d) Deep furrows or ditches on farmers' fields.

During analysis, the survey data quality can be limited by environmental factors including:

a) Made ground,

b) Heras or chain-link type fencing,

c) Overhead high-voltage power cables, and

d) Heavily mineralised geology.

Additionally, the survey is subject to the following limitations:

a) Detection of UXO is dependent contrast between UXO and its host materials. There is an extremely remote likelihood that ferrous items can be missed by the equipment if its magnetic field is in the same orientation as local magnetic declination.

b) The survey task specifically targets the anticipated risk of ordnance (mortars, grenades, bombs, and alike) within the limits of the equipment capability.

c) As with all UXO survey tasks, 100% clearance certificates cannot be issued. This document certifies that work has been undertaken to mitigate against the risk of UXO, using the ALARP principle. However unlikely, encountering UXO cannot wholly be discounted.

11 SURVEY EQUIPMENT

Our survey equipment comprises of a GPS system and a magnetometry system. The GPS uses GNSS accurate to 1cm or less, with mobile data correction. The magnetometry equipment is designed, made, and manufactured at a single site in Germany to ISO 9001 quality standards. Specification sheets for the equipment used on this survey can be found annexed in this report.

12 DATA INTERPRETATION

Following field collection, the data is processed in house by our geophysics team. The data undergoes several steps to reduce noise and improve the survey quality. In the later stages of data processing, we use a specialist computer model to look at the signals measured by the equipment. These signals are then compared against a bank of known UXO signals. This is a semi-automated process.

The data processing software then presents a list of possible UXO targets. Estimation in depth and mass are made, and their locations are offered in coordinates accurate to 1cm. Additional survey data services are available including CAD drawings banded by depth to offer a more granular application to the project scope, possibly reducing time and costs further down the pipeline.

13 TARGET SELECTION

Based on our experience as an organisation and through guidance from the manufacturer of our equipment, we can reduce the overall number of targets required for investigation. We reduce the targets to the following criteria:

- All targets with a mass greater than 1kg.
- 25% selection of targets with a mass less than 1kg.

We reduce these targets due to the level of sensitivity the equipment offers, and the perceived risk of encountering certain types of UXO. The equipment we use is used within archaeological investigations and as such it can measure the smallest iron objects, down to the head of a rusty nail. We need to filter out these smaller targets, inconsistent with UXO, so we do not add unnecessary time and costs to the project. We aim to achieve ALARP, whereby any further reduction is risk is disproportionate to the additional cost, time, and effort to achieve the reduction.

Figure 3. No. 36 Mills Grenade, source: IWM

A No.36 grenade, which is one of the smallest mass items we could find, has an overall mass of around 750g, and approximately 500-600g of iron. If UXO is found however, a 100% investigation of all targets would be recommended, to satisfy CIRIA C681 guidelines and the ALARP principle.

Total Targets:

The table below describes all targets that have been measured in the field and have been modelled through our data processing.

Total Targets	Total Targets < 1kg	Total Targets > 1kg	Depth Range
281	206	75	0.5 – 1.6m

Selected Targets:

The table below describes all targets, less those which have been filtered out according to the criteria as above.

Total Targets	Selected Targets < 1kg	Selected Targets > 1kg	Depth Range
196	121	75	0.55 – 1.6m

14 RECOMMENDATIONS

We recommend an investigation of the targets as outlined above. Intrusive works should not continue or be started within the surveyed areas until this process has been completed. Usually a two-person team is deployed to site, for larger areas, higher number of targets, or for tighter timelines, we can deploy extra teams as required. Examples of intrusive works are:

a) Trenching/excavations

b) Installing or moving buried services

c) Land drilling/geotechnical investigations

d) Archaeology

e) Profiling

For those areas that have not been possible to survey or to select targets, further mitigations may be necessary. Please contact the operations or technical team to discuss your project needs. The additional recommended activities could be a safety brief, a watching brief, or a search and clear. Further data analysis and interpretation can be completed on agreement.

15 ANNEXES

Annex A – Site Boundaries

Annex B – Equipment Specification Sheets

Sheets specifying the equipment used and their technical capabilities.

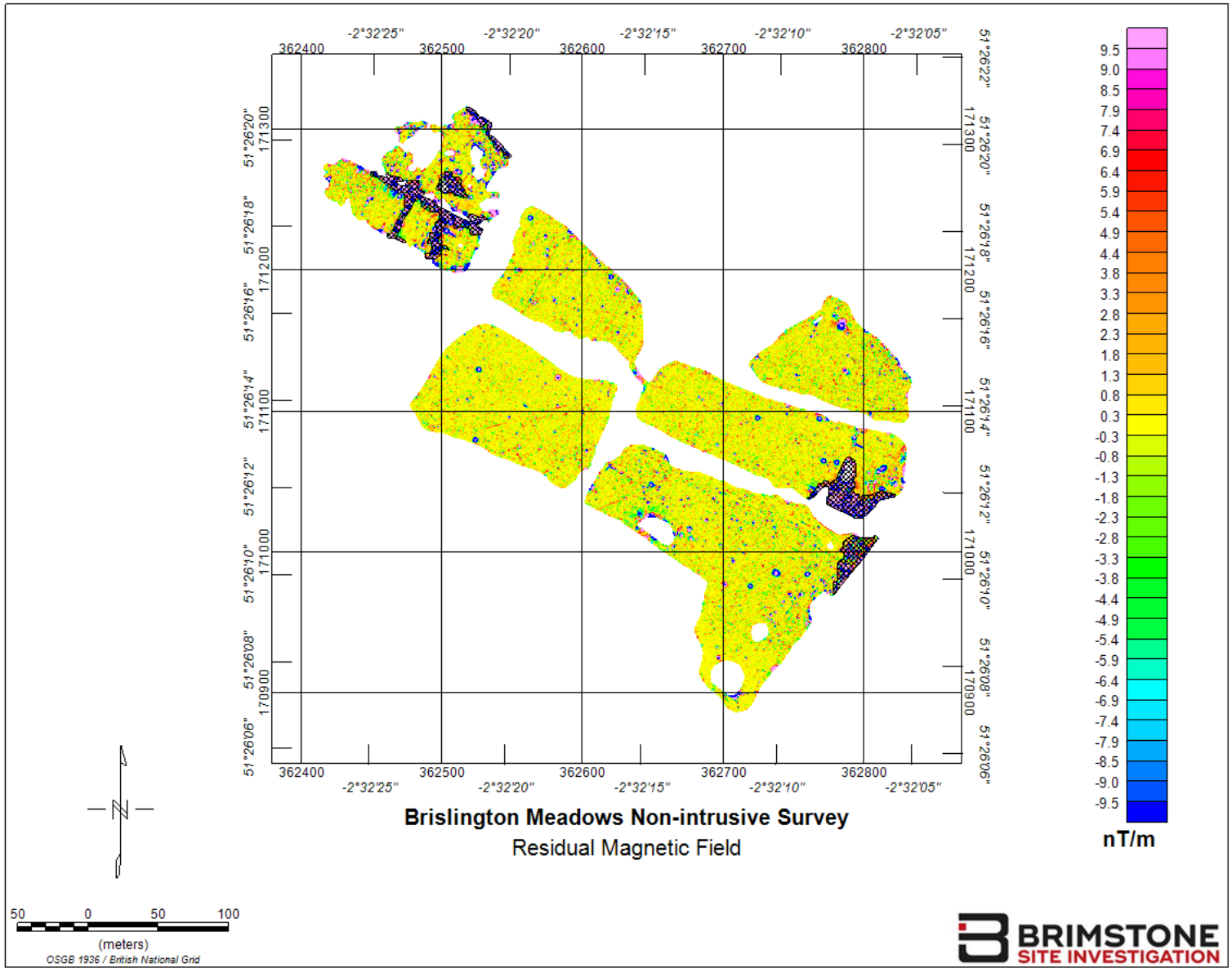
Annex C - Non-Intrusive Survey Maps

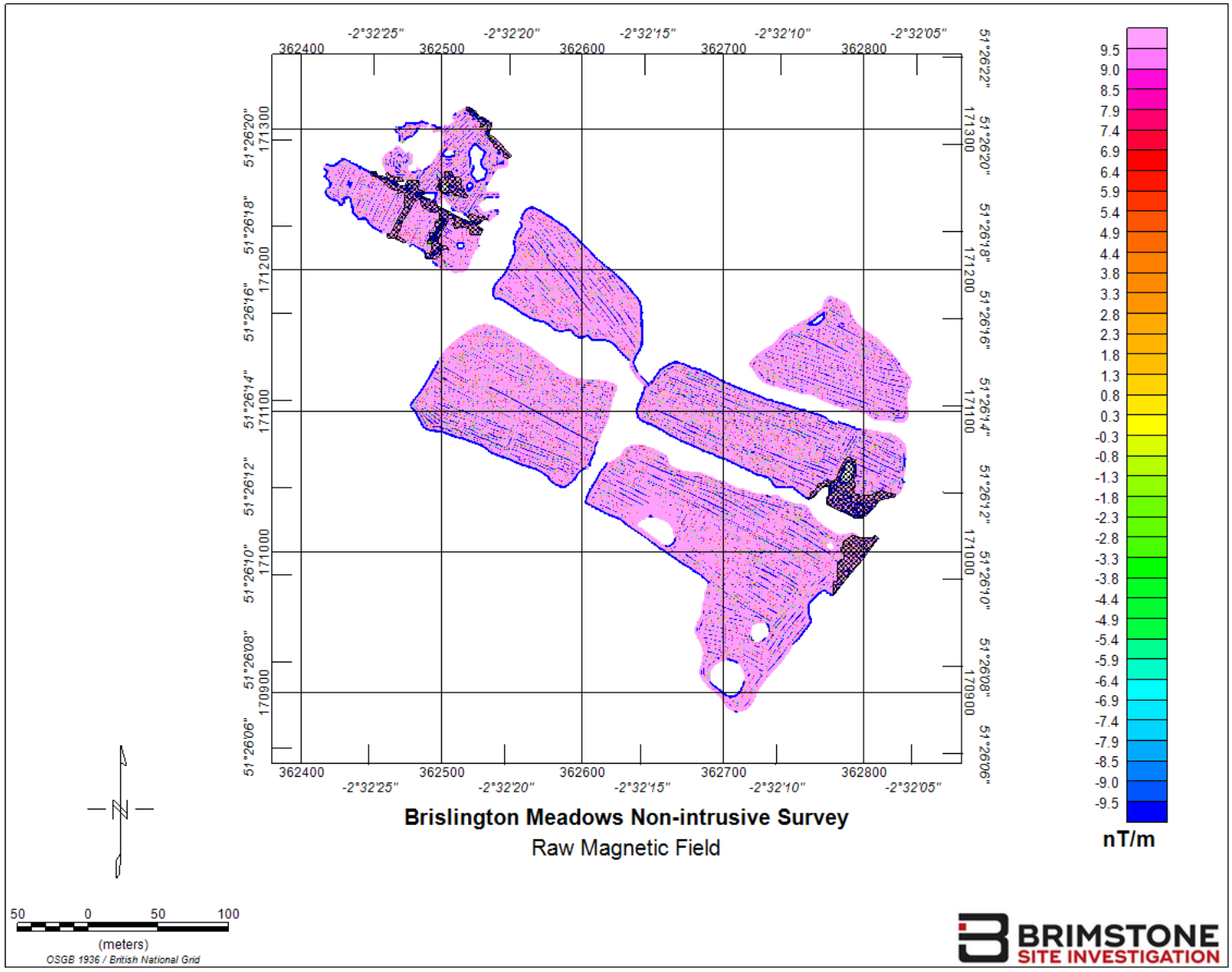
False colour maps showing geospatial hotspots, areas too noisy to interpret and location of targets.

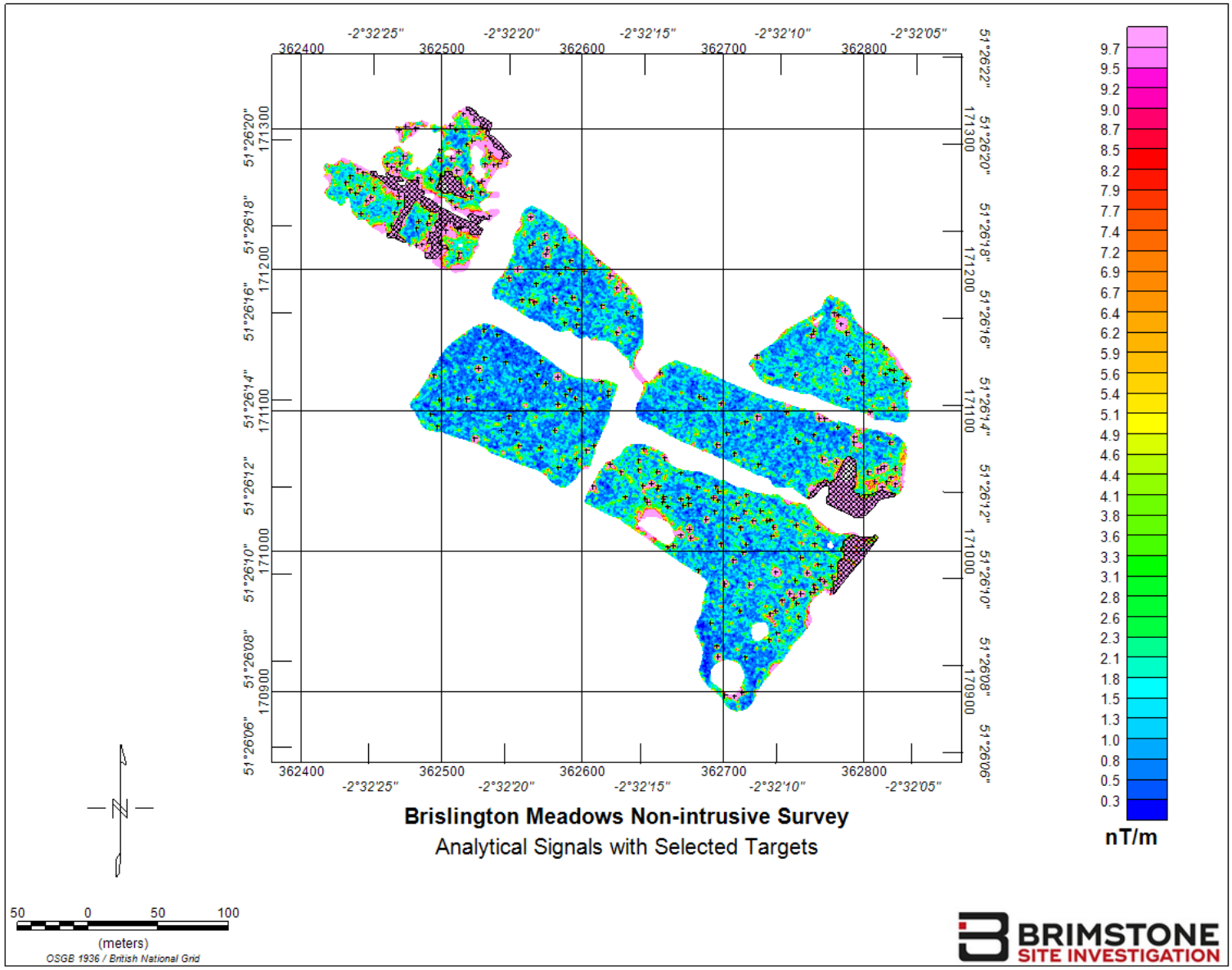
Annex D – Target List

A list of selected targets, along with attributes of mass, depth, depth error and OSGB coordinates.

Raw Magnetic Field


-2°32'25"
-2°32'20"
-2°32'15"
-2°32'10"
-2°32'05"
362400
362500
362600
362700
362800
51°26'22"
51°26'20"
51°26'18"
51°26'16"
51°26'14"
51°26'12"
51°26'10"
51°26'08"
51°26'06"
171300
171200
171100
171000
170900
9.5
9.0
8.5
7.9
7.4
6.9
6.4
5.9
5.4
4.9
4.4
3.8
3.3
2.8
2.3
1.8
1.3
0.8
0.3
-0.3
-0.8
-1.3
-1.8
-2.3
-2.8
-3.3
-3.8
-4.4
-4.9
-5.4
-5.9
-6.4
-6.9
-7.4
-7.9
-8.5
-9.0
-9.5
nT/m
Brislington Meadows Non-intrusive Survey
Residual Magnetic Field
50
0
50
100
(meters)
OSGB 1936 / British National Grid
BRIMSTONE
SITE INVESTIGATION


-2°32'25"
-2°32'20"
-2°32'15"
-2°32'10"
-2°32'05"
362400
362500
362600
362700
362800
51°26'22"
51°26'20"
51°26'18"
51°26'16"
51°26'14"
51°26'12"
51°26'10"
51°26'08"
51°26'06"
171300
171200
171100
171000
170900
9.5
9.0
8.5
7.9
7.4
6.9
6.4
5.9
5.4
4.9
4.4
3.8
3.3
2.8
2.3
1.8
1.3
0.8
0.3
-0.3
-0.8
-1.3
-1.8
-2.3
-2.8
-3.3
-3.8
-4.4
-4.9
-5.4
-5.9
-6.4
-6.9
-7.4
-7.9
-8.5
-9.0
-9.5
nT/m
Brislington Meadows Non-intrusive Survey
Raw Magnetic Field
N
50 0 50 100
(meters)
OSGB 1936 / British National Grid
BRIMSTONE
SITE INVESTIGATION


-2°32'25"
-2°32'20"
-2°32'15"
-2°32'10"
-2°32'05"
362400
362500
362600
362700
362800
51°26'22"
51°26'20"
51°26'18"
51°26'16"
51°26'14"
51°26'12"
51°26'10"
51°26'08"
51°26'06"
171300
171200
171100
171000
170900
9.7
9.5
9.2
9.0
8.7
8.5
8.2
7.9
7.7
7.4
7.2
6.9
6.7
6.4
6.2
5.9
5.6
5.4
5.1
4.9
4.6
4.4
4.1
3.8
3.6
3.3
3.1
2.8
2.6
2.3
2.1
1.8
1.5
1.3
1.0
0.8
0.5
0.3
nT/m
Brislington Meadows Non-intrusive Survey
Analytical Signals with Selected Targets
N
50 0 50 100
(meters)
OSGB 1936 / British National Grid
BRIMSTONE
SITE INVESTIGATION

BRIMSTONE
SITE INVESTIGATION

Target_ID	Estimated Mass (Kg)	Estimated Depth (m)
1	3.20	0.78
2	0.29	0.65
3	0.71	0.75
4	4.30	0.71
5	0.73	0.74
6	0.67	0.77
7	0.39	0.73
8	0.77	0.76
9	0.48	0.75
10	0.97	0.69
11	0.45	0.72
12	4.71	0.79
13	3.72	0.69
14	0.40	0.69
15	0.45	0.65
16	0.47	0.75
17	2.88	0.70
18	3.21	0.68
19	0.52	0.73
20	0.49	0.72
21	4.35	0.83
22	29.84	1.45
23	1.01	0.74
24	1.25	1.04
25	0.62	0.74
26	0.51	0.73
27	0.50	0.79
28	0.95	0.71
29	0.41	0.75
30	4.62	1.11
31	3.31	0.98
32	2.69	1.03
33	0.49	0.72
34	0.82	0.67
35	0.91	0.72
36	0.37	0.67
37	0.96	0.75
38	1.74	0.68
39	0.40	0.72
40	0.46	0.69
41	0.32	0.69
42	0.84	0.78
43	0.97	0.74
44	0.47	0.71
45	1.22	0.77

46	0.41	0.68
47	0.30	0.68
48	3.92	0.61
49	1.79	0.87
50	0.81	0.73
51	8.08	1.41
52	3.28	0.75
53	1.92	1.17
54	0.51	0.68
55	0.88	0.70
56	2.16	0.95
57	0.46	0.63
58	2.93	0.91
59	0.71	0.75
60	3.68	0.78
61	0.55	0.70
62	3.58	0.70
63	1.19	0.75
64	3.13	0.72
65	0.61	0.67
66	3.92	0.74
67	1.31	0.78
68	0.45	0.76
69	0.47	0.77
70	0.65	0.73
71	1.84	0.89
72	1.64	0.69
73	0.74	0.72
74	3.67	0.71
75	3.23	0.78
76	0.78	0.71
77	1.39	0.74
78	4.39	0.75
79	0.37	0.69
80	3.56	0.71
81	0.69	0.80
82	1.10	0.71
83	0.57	0.72
84	0.46	0.68
85	1.33	0.69
86	1.21	0.64
87	0.46	0.68
88	0.93	0.94
89	0.61	0.78
90	8.17	0.77
91	0.70	0.86
92	0.55	0.73
93	0.72	0.81
94	0.40	0.68
95	8.50	0.92

96	3.15	0.69
97	1.10	0.80
98	0.36	0.67
99	0.93	0.74
100	0.80	0.71
101	1.49	0.78
102	0.38	0.73
103	153.86	1.12
104	2.27	0.71
105	0.47	0.73
106	0.42	0.68
107	0.52	0.70
108	0.90	0.79
109	0.47	0.74
110	0.77	0.71
111	2.26	0.72
112	0.78	0.76
113	2.20	0.70
114	0.51	0.77
115	6.93	0.87
116	0.50	0.72
117	1.15	0.79
118	3.47	0.76
119	0.47	0.65
120	1.41	0.75
121	0.33	0.66
122	2.84	0.89
123	3.58	0.89
124	0.40	0.67
125	3.09	0.75
126	1.84	0.81
127	9.01	0.78
128	0.88	0.74
129	0.66	0.71
130	0.85	0.74
131	9.70	0.76
132	3.97	0.73
133	0.55	0.64
134	0.44	0.64
135	0.70	0.79
136	3.32	0.96
137	1.14	0.72
138	0.32	0.68
139	2.56	0.90
140	1.77	0.76
141	2.21	0.72
142	0.35	0.71
143	0.37	0.70
144	0.62	0.78
145	0.30	0.66

146	0.41	0.74
147	0.55	0.73
148	5.14	0.77
149	0.35	0.70
150	0.81	0.77
151	17.25	0.97
152	1.65	0.80
153	5.20	0.76
154	0.47	0.60
155	2.52	0.75
156	0.57	0.70
157	0.47	0.69
158	0.47	0.73
159	0.55	0.70
160	0.58	0.71
161	4.75	0.83
162	0.29	0.66
163	1.17	0.74
165	0.65	0.68
166	1.81	0.74
167	1.20	0.70
168	0.46	0.72
169	2.88	0.73
170	29.54	1.28
171	4.10	0.76
174	0.34	0.74
176	0.43	0.78
181	0.47	0.67
184	0.30	0.66
193	0.31	0.70
195	0.35	0.73
199	0.39	0.77
202	0.29	0.74
214	0.33	0.74
218	0.37	0.78
221	0.33	0.83
223	0.29	0.75
224	0.36	0.76
228	0.30	0.78
230	0.36	0.88
232	0.42	0.99
239	0.72	0.80
240	0.32	0.75
243	0.31	0.70
250	0.29	0.79
254	0.30	0.84
257	0.35	0.84
258	0.84	0.72
268	0.45	0.82
271	0.45	0.84

278	0.32	0.74

BRIMSTONE
SITE INVESTIGATION

SUITE 6, DELTA HOUSE, LASER QUAY, CULPEPER CLOSE, ROCHESTER, ME2 4HU

BRIMSTONE SITE INVESTIGATION LTD, REGISTERED IN ENGLAND AND WALES UNDER COMPANY NUMBER 10253758

WWW.BRIMSTONEUXO.COM | TEL: 0207 117 2492 | ENQUIRE@BRIMSTONEUXO.COM

BRIMSTONE
SITE INVESTIGATION

UXO TARGET INVESTIGATION REPORT

INTEGRITY | PROFESSIONALISM | KNOWLEDGE

BRIMSTONE
SITE INVESTIGATION

TARGET INVESTIGATION REPORT

Client:	Campbell Reith
Project Location:	Brislington, Bristol
Project Ref:	CAMP13
Report Ref:	20211206-TIREP-CAMP13
Revision:	1
Status:	Final
Date:	6th December 2021

Data Processing By:	Dr Sumana Basu PhD.	Geophysicist	sumana.basu@brimstoneuxo.com
Written By:	Shaib Ahmed	Technical Executive	josh.pattinson@brimstoneuxo.com
Reviewed By:	Andrew Lane	Operations Manager	andrew.lane@brimstoneuxo.com
Authorised By:	Aaron Florence	Managing Director	

QUALITY MANAGEMENT

Brimstone Site Investigation 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 Site Investigation Ltd 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 Site Investigation Ltd.

CONTENTS

Quality Management i
Contents i
Executive Summary 5
1 What is UXO? 6
2 Why is Land Contamintaed by UXO? 6
3 The Regulatory Environment 6
3.1 Construction (Design Management) Regulations (2015) 6
3.2 Health and Safety at Work Act (1974) 6
3.3 Management of Health and Safety at Work (1999) 7
4 CIRIA C681 guidelines 7
5 ALARP 7
6 Maximum Bomb Penetration Depths 7
7 Land Service Ammunition 8
8 How Does This Survey Work? 8
9 Other Possible Mitigation Strategies 9
10 Survey Details 10
10.1 Location 10
10.2 Survey Dates 10
10.3 Survey Limitations 10
11 Survey Equipment 11
12 Data Interpretation 11
13 Target Selection 12
14 Target Investigation 12
15 Recommendations 13
16 Annexes 14

EXECUTIVE SUMMARY

- Brimstone Site Investigation (BSI) has completed a 'Target Investigation' for Campbell Reith from the 15th of November 2021 to the 24th of November 2021, using push-cart methodology (Annex A).
- A survey was completed to identify any possible buried UXO ahead of ground-intrusive works proposed by the client.
- The output of this survey was a coordinated list of targets (Annex C) with estimated mass and depth.
- The follow-up activity to that survey was a 'Target Investigation' of the suspected buried objects.
- In total, 281 targets were modelled because of the survey. The targets were reduced to 196 to reduce the risk to a reasonably practicable level. Discounted targets are inconsistent with UXO.
- Out of the 196 targets, 145 targets were investigated. This was due to 51 targets falling in field 6, which BSI were unable to gain access to. The inaccessible targets have been labelled as 'F6'. (Annex C)
- The remaining targets will be investigated with a revisit to site.
- 145 targets were investigated and no items of UXO were found. Therefore, the site has been given clearance with the exception of field 6. Clearance (up to a depth of 4m) is **only** given to those areas where the targets have been investigated and no items of UXO have been found.

Area Surveyed (ha)	Total No. of Targets Modelled	Discounted Targets	Targets to Investigate	Est. Duration of Investigation (two-man team)
5.68	281	85	196	8 days

1 WHAT IS UXO?

UXO is an abbreviation for unexploded ordnance. It is a term that refers to explosive ordnance which has been primed, armed, fused, or otherwise prepared for use, and has been dropped, fired, launched, projected, thrown, or placed and remains unexploded either by malfunction or by design.

UXO is a catch-all term used in the UK to refer to explosive hazard contamination. Although, not all explosive hazards are correctly described as UXO. Abandoned explosive ordnance, or AXO, is ordnance, which is in a safe state, has not been prepared for use or has not been fire, projected, thrown, or otherwise used. Instead, AXO has been buried or hidden, either as a means of disposal or as a cache in anticipation of invasion.

An example of UXO would be an anti-aircraft projectile having been fired at an aircraft, failing to function and the falling back to land, unexploded. An example of AXO would be a 'bomb dump' of expired ordnance, whereby an excavation is filled with unwanted ordnance and backfilled. This was frequently used by the MoD up until the 1980s as a recognised means of disposal.

2 WHY IS LAND CONTAMINTAED BY UXO?

There are four sources of UXO contamination in the UK. These are: enemy action, allied action, military activity or munitions manufacturing and storage locations. Enemy action refers primarily to artillery bombardment and strategic bombing campaign of the Second World War. Allied action refers to defensive activities, again primarily in relation to the Second World War, which includes land and sea mining, anti-aircraft batteries and rocket batteries.

Military training is a significant source of UXO contamination. In former and current military training areas, the risk of encountering UXO is significant, ranging from projectiles, mortars, and grenades. The MoD is the second-largest landowner in the UK, and as such large parts of the UK have historically been used or requisitioned by the military for training our armed forces and allied armed forces.

Finally, munitions manufacturing and storage sites also present a UXO risk, although the risk is generally localised and in small specific parts of the UK.

3 THE REGULATORY ENVIRONMENT

There are no specific regulations that manage how UXO is dealt with on UK construction sites, and similar operations. However, there are pieces of legislation that must be considered when companies choose how to approach UXO risk, these include those listed below. The CIRIA guidelines are a set of guiding principles that offer a framework to the UK UXO risk mitigation sector, these are explained in the subsequent section.

- Construction (Design Management) Regulation (2015)
- Health and Safety at Work Act (1974)
- Management of Health and Safety at Work (1999)

3.1 Construction (Design Management) Regulations (2015)

CDM 2015 replaces CDM 2007. These regulations define the responsibilities of roles within construction projects. The Principal Designer is responsible for managing health and safety, in that role they must exercise identification, elimination and control of foreseeable risks. UXO is a significant potential hazard and must be considered at the design phase.

3.2 Health and Safety at Work Act (1974)

Employers must ensure as far as is reasonably practicable the health and safety of their employees. They must also ensure the health and safety of others affected by their work activity. When working on a site which is thought to have a UXO

contamination risk, employers have a responsibility to provide a safe system of work that addresses the assessed UXO risk.

3.3 Management of Health and Safety at Work (1999)

This adds on to the Health and Safety at Work Act (1974). The act sets out the general duties which employers have towards employees and members of the public, and those which employees have to themselves and each other. In relation to UXO, the act applied that duty holders are to ensure that proper assessments of foreseeable risks are completed and that necessary measures are taken to control risks to an acceptable level.

4 CIRIA C681 GUIDELINES

CIRIA is the Construction Industry Research and Information Association. Two sets of guidelines provide a framework to the UXO risk mitigation sector in the UK. They are not legally binding, and are optional to follow, but they form the accepted best-practice standards to which the industry operates.

CIRIA C681: Unexploded Ordnance: A Guide for the Construction Industry (2009)

This is the overarching document which provides the four stage UXO risk mitigation framework. Stages are:

1. Preliminary UXO risk assessment – a qualitative screening exercise to assess the likelihood of finding UXO on a site. This can be completed by a non-UXO specialist or a UXO specialist.

2. Detailed UXO risk assessment – A wider and deeper assessment of the site, using bomb damage amps, penetration assessments and other historical information.

3. Recommendations – A proposal of risk mitigation strategies determined in coordination with the client.

4. Implementations – the on-site UXO risk mitigation measures being put in place.

CIRIA C785: Unexploded Ordnance Risk Management Guide for Land-Based Projects (2019)

This guidance document adds on to C681. It provides additional details and structure to the risk assessment process. Both documents are available to purchase on the CIRIA website.

5 ALARP

The ALARP (as low as reasonably practicable) principle is about 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, BSI aims to reduce client costs by recommending strategies that are proportionate to the assessed risks.

6 MAXIMUM BOMB PENETRATION DEPTHS

Using data gathered during WWII by the Ministry of Home Security, estimates can be made about how deep a bomb is likely to penetrate the ground. Over one thousand incidents were reported by the bomb disposal units to support this research. Further tests were carried out, dropping bombs of different sizes into chalk and measuring the depths they reached. This research is held at the National Archives. The estimates are:

Bomb weight (kg)	Ground Type (m)							
	Sand		Gravel		Chalk		Clay	
	Average	Max.	Average	Max.	Average	Max.	Average	Max.
50	2.8	7.8	2.8	7.8	3.5	7.7	4.0	9.1
250	4.8	13.7	4.8	13.7	6.0	13.1	6.8	15.8
500	6.0	17.3	6.0	17.3	7.6	16.4	8.7	19.8
1,000	7.6	21.9	7.6	21.9	9.6	20.7	10.9	24.9

Different layers of geology affect penetration depths, for example 1m of made ground, then 1m of gravel before reaching clay – as is many areas of London – is not easily calculated from the data above.

When calculating how deep a bomb could have reached, we must make three assumptions:

a) **Impact velocity.** German bombing raids were carried out at altitudes more than 5,000m. The velocity of impact is roughly 313ms^{-1} (not accounting for resistance). It is the same velocity regardless of mass.

b) **Impact angle.** Strike angles of 10 to 15 degrees to the vertical. It must be assumed that the bomb was stable at the moment of ground penetration.

c) **Bomb design.** Some larger German bombs were occasionally fitted with 'kopfrings' - a metal ring, triangular in cross section, fitted around the nose of the bomb to help prevent penetration. It must be assumed that no 'kopfrings' were fitted.

7 LAND SERVICE AMMUNITION

Land service ammunition (LSA) includes mortars, grenades, rockets, and projectiles. These types of ordnance can contaminate land in the UK due to prior and current training of the UK's armed forces, as well as the activities of other allied nations on British soil. Training areas, airfields, barracks, and camps are areas which may have a heightened risk of encountering LSA. During WWII anti-aircraft weaponry was deployed across much of the UK, and as a result contamination from anti-aircraft projectiles can occur in cities as well as in the open countryside.

LSA is typically found within the first 0.5m of WWII level ground. Non-intrusive UXO surveying is an effective method of targeting LSA due to these shallow depths and high iron content. Objects, even large objects, which lay deeper than 4m below the surveyed ground level are difficult for this equipment to detect.

8 HOW DOES THIS SURVEY WORK?

In coordination with the client Brimstone recommended the completion of a non-intrusive magnetometry survey. The output of this survey is false colour maps of 'hotspots' overlain satellite imagery of the site. A non-intrusive survey is a survey style which does not require any manipulation or 'intrusions' into the ground. This means that specialist technical equipment is methodically moved across the surface of a given area without disturbing any possible buried objects. The benefit of this type of survey is wide area coverage, as consistent with the requirements for this project.

The data collected is GPS information joined with magnetometry information. Magnetometry is a type of technical sensing technology. Essentially, a magnetometer is an instrument which detects the Earth's natural magnetic field by sending signals between two sensors - contained within an aluminium tube called a probe. These sensors are known as fluxgate gradiometers. Deviations within the Earth's magnetic field indicates the presence of a buried object containing iron. The more iron, the stronger the magnetic signal. The diagrams below illustrate this effect.

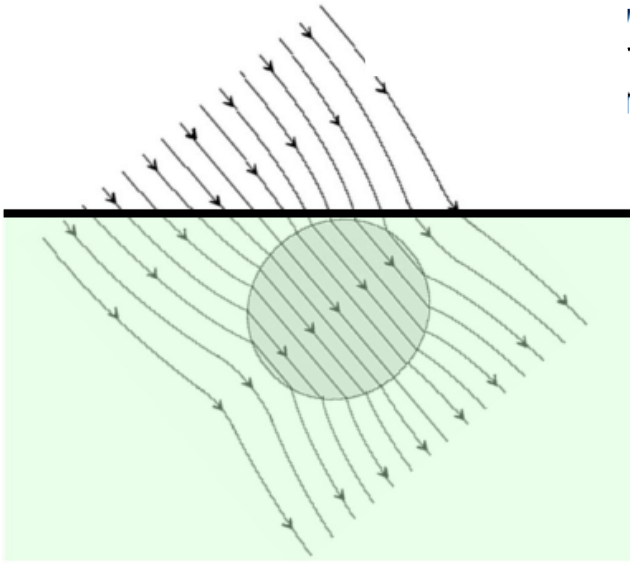


Figure 1: Earth's magnetic field interrupted by a buried iron (ferrous) object

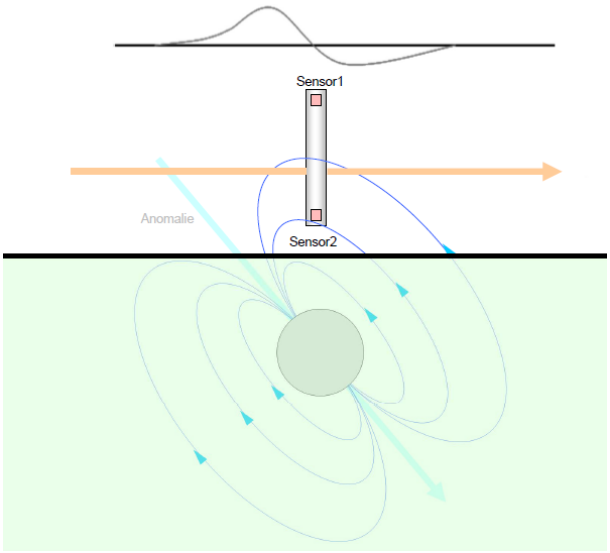


Figure 2: A description of how the sensor locate targets and the sinusoidal information received.

By analysing the wavelength and amplitude of the signal measured by the magnetometers, we can estimate the likely depth and size of a buried object. Whilst the depth of the object is quite accurate, the estimated mass is harder to determine and is known for a greater degree of inaccuracy.

Magnetometry technology is a so-called passive system. A simple way to think about passive systems is that the object looks at the sensor, rather than the sensor looking at the object – as is the case with active systems. Therefore, with the type of system used in this survey, the maximum depth the equipment can sense to is dependant on the mass of the item and its surrounding geology.

9 OTHER POSSIBLE MITIGATION STRATEGIES

Other options of mitigation for the project could include a long-term watching brief. This involves a suitably qualified and experienced UXO engineer to be present on site to provide supervision of all excavations. They would use technical search equipment to identify buried items ahead of the excavator. This process is generally slow and long-term and is suitable where UXO surveys cannot be used.

Page Continued Overleaf

10 SURVEY DETAILS

10.1 Location

The project address is: Brislington Meadows, Brislington, Bristol, BS4 4FJ. The site boundaries are indicated in red below.

Figure 3: Brislington Meadows, Brislington, Bristol, BS4 4FJ

10.2 Survey Dates

The survey was completed from the 15th of November 2021 to the 24th of November 2021, using push-cart methodology (Annex A).

10.3 Survey Limitations

At times, not all the proposed area can be surveyed. This can be for one or several reasons, including:

a) Vegetation too tall or impassable for the equipment,

b) Too soft ground for the operator,

c) Man-made or natural obstacles, and

d) Deep furrows or ditches on farmers' fields.

During analysis, the survey data quality can be limited by environmental factors including:

a) Made ground,

b) Heras or chain-link type fencing,

c) Overhead high-voltage power cables, and

d) Heavily mineralised geology.

Additionally, the survey is subject to the following limitations:

a) Detection of UXO is dependent contrast between UXO and its host materials. There is an extremely remote likelihood that ferrous items can be missed by the equipment if its magnetic field is in the same orientation as local magnetic declination.

b) The survey task specifically targets the anticipated risk of ordnance (mortars, grenades, bombs, and alike) within the limits of the equipment capability.

c) As with all UXO survey tasks, 100% clearance certificates cannot be issued. This document certifies that work has been undertaken to mitigate against the risk of UXO, using the ALARP principle. However unlikely, encountering UXO cannot wholly be discounted.

11 SURVEY EQUIPMENT

Our survey equipment comprises of a GPS system and a magnetometry system. The GPS uses GNSS accurate to 1cm or less, with mobile data correction. The magnetometry equipment is designed, made, and manufactured at a single site in Germany to ISO 9001 quality standards. Specification sheets for the equipment used on this survey can be found annexed in this report.

12 DATA INTERPRETATION

Following field collection, the data is processed in house by our geophysics team. The data undergoes several steps to reduce noise and improve the survey quality. In the later stages of data processing, we use a specialist computer model to look at the signals measured by the equipment. These signals are then compared against a bank of known UXO signals. This is a semi-automated process.

The data processing software then presents a list of possible UXO targets. Estimation in depth and mass are made, and their locations are offered in coordinates accurate to 1cm. Additional survey data services are available including CAD drawings banded by depth to offer a more granular application to the project scope, possibly reducing time and costs further down the pipeline.

13 TARGET SELECTION

Based on our experience as an organisation and through guidance from the manufacturer of our equipment, we can reduce the overall number of targets required for investigation. We reduce the targets to the following criteria:

- All targets with a mass greater than 1kg.
- 25% selection of targets with a mass less than 1kg.

We reduce these targets due to the level of sensitivity the equipment offers, and the perceived risk of encountering certain types of UXO. The equipment we use is used within archaeological investigations and as such it can measure the smallest iron objects, down to the head of a rusty nail. We need to filter out these smaller targets, inconsistent with UXO, so we do not add unnecessary time and costs to the project. We aim to achieve ALARP, whereby any further reduction is risk is disproportionate to the additional cost, time, and effort to achieve the reduction.

Figure 4: No. 36 Mills Grenade, source: IWM

A No.36 grenade, which is one of the smallest mass items we could find, has an overall mass of around 750g, and approximately 500-600g of iron. If UXO is found however, a 100% investigation of all targets would be recommended, to satisfy CIRIA C681 guidelines and the ALARP principle.

Total Targets:

The table below describes all targets that have been measured in the field and have been modelled through our data processing.

Total Targets	Total Targets < 1kg	Total Targets > 1kg	Depth Range
281	206	75	0.5 – 1.6m

Selected Targets:

The table below describes all targets, less those which have been filtered out according to the criteria as above.

Total Targets	Selected Targets < 1kg	Selected Targets > 1kg	Depth Range
196	121	75	0.55 – 1.6m

14 TARGET INVESTIGATION

Targets were set out using our RTK quality GPS and survey flags. Our engineers excavated, uncovered and identified buried ferrous targets. No targets were found to be UXO or items related to UXO.

A target investigation log was recorded and is annexed in this report, for your records.

Total Targets	Total Targets Found	No Observed Target*	UXO (and related) Targets
196	82	63	0

*No observed targets relate to a position in the survey area which modelled a buried ferrous object. Upon investigation, no target was observed. This is typically due to geology – certain types of ground are heavily magnetised, and pockets of such ground can model as a ferrous object.

15 RECOMMENDATIONS

Brimstone and the client have satisfied the criteria of CIRIA C681 and other standards in the completion of the survey and has successfully mitigated the risks posed by UXO to ALARP for all areas except field 6.

Clearance is given for the site as indicated in the annex to a depth of 4m below ground level. Any intrusion greater than this depth are not cleared and may require additional mitigation measures being put in place. This includes piling and drilling operations.

16 ANNEXES

Annex A – Equipment Specification Sheets

Sheets specifying the equipment used and their technical capabilities.

Annex B - Non-Intrusive Survey Maps

False colour maps showing geospatial hotspots, areas too noisy to interpret and location of targets.

Annex C – Target Investigation Log

A log of targets investigated during this project.

PASSIVE SYSTEM

Magnetometry Survey Pushcart

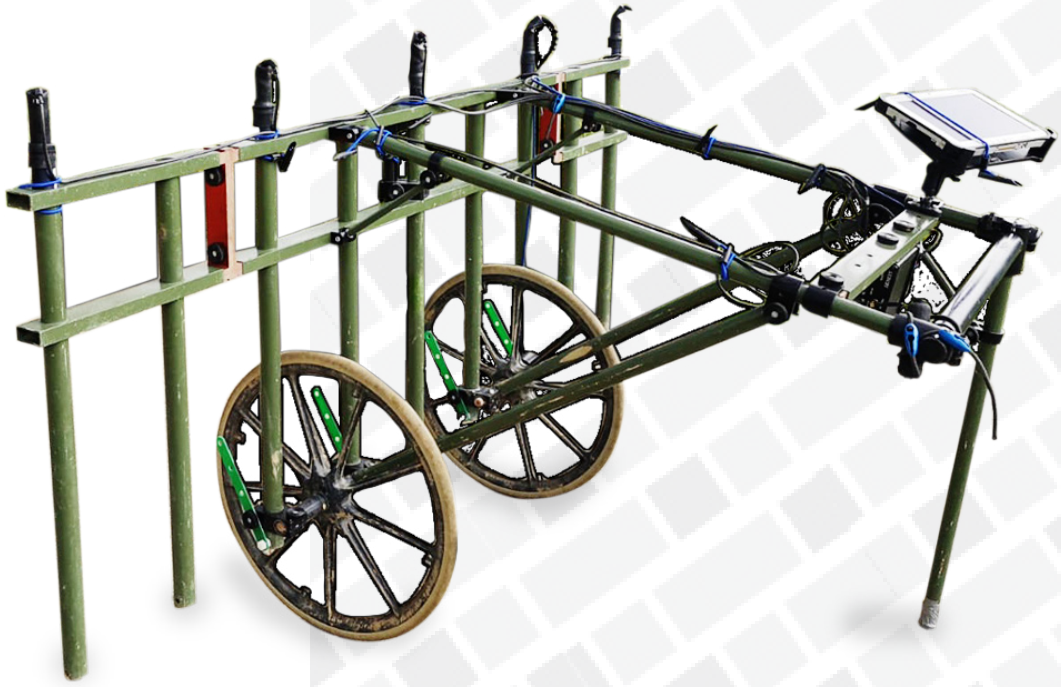
Ideal for small and medium-sized surveys on undeveloped land, our pushcart magnetometry system is an all-weather 5-channel magnetic surveying system used for UXO detection applications. The penetration capability for this system is up to 6m below ground level for a 50kg bomb. Smaller, near-surface items are readily detected too.

Our survey equipment tracks coverage in real-time, discounting the need for setting up 'boxes', significantly speeding up data collection. Additionally, a 2m wide survey track means we can cover double the area in the same amount of time, when compared to other systems.

Equipped with RTK GPS, we collect the data in field, process it using industry-leading software and acquire targets suspected to be UXO. Follow up activities include an investigation of targets which have modelled as UXO, and then final disposal and remediation of the explosive hazard.

The Stats

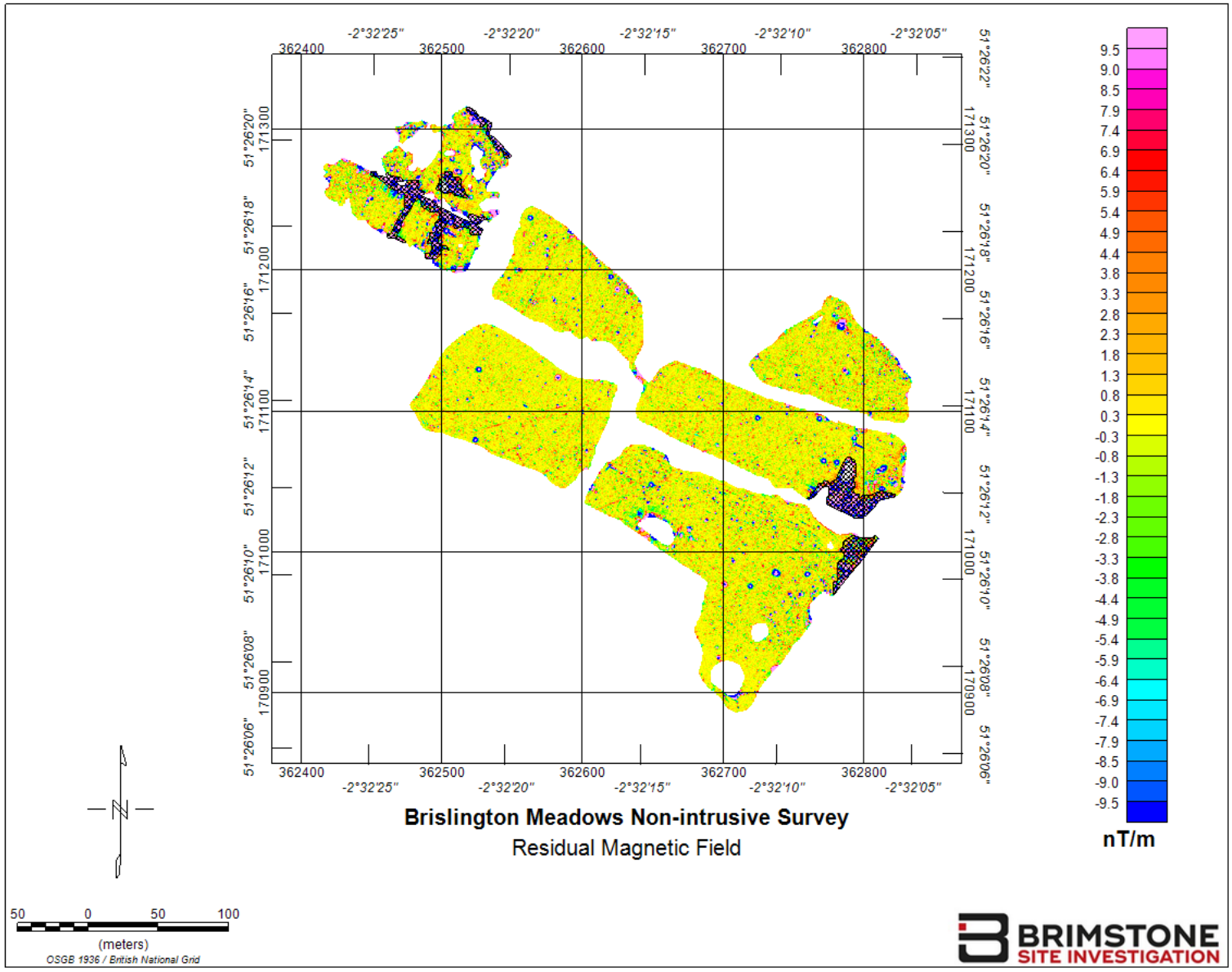
Coverage per day	2 hectares
Operating temperature	-20°C to +60°C
Mass	15kg
Sensors	5 x FGM650/10
Sensor Spacing	50cm
Measurement Range	± 10,000 nT
Dimension (LxWxH)	1.4 x 2.2 x 0.9
Construction	Fibreglass, nylon, stainless steel

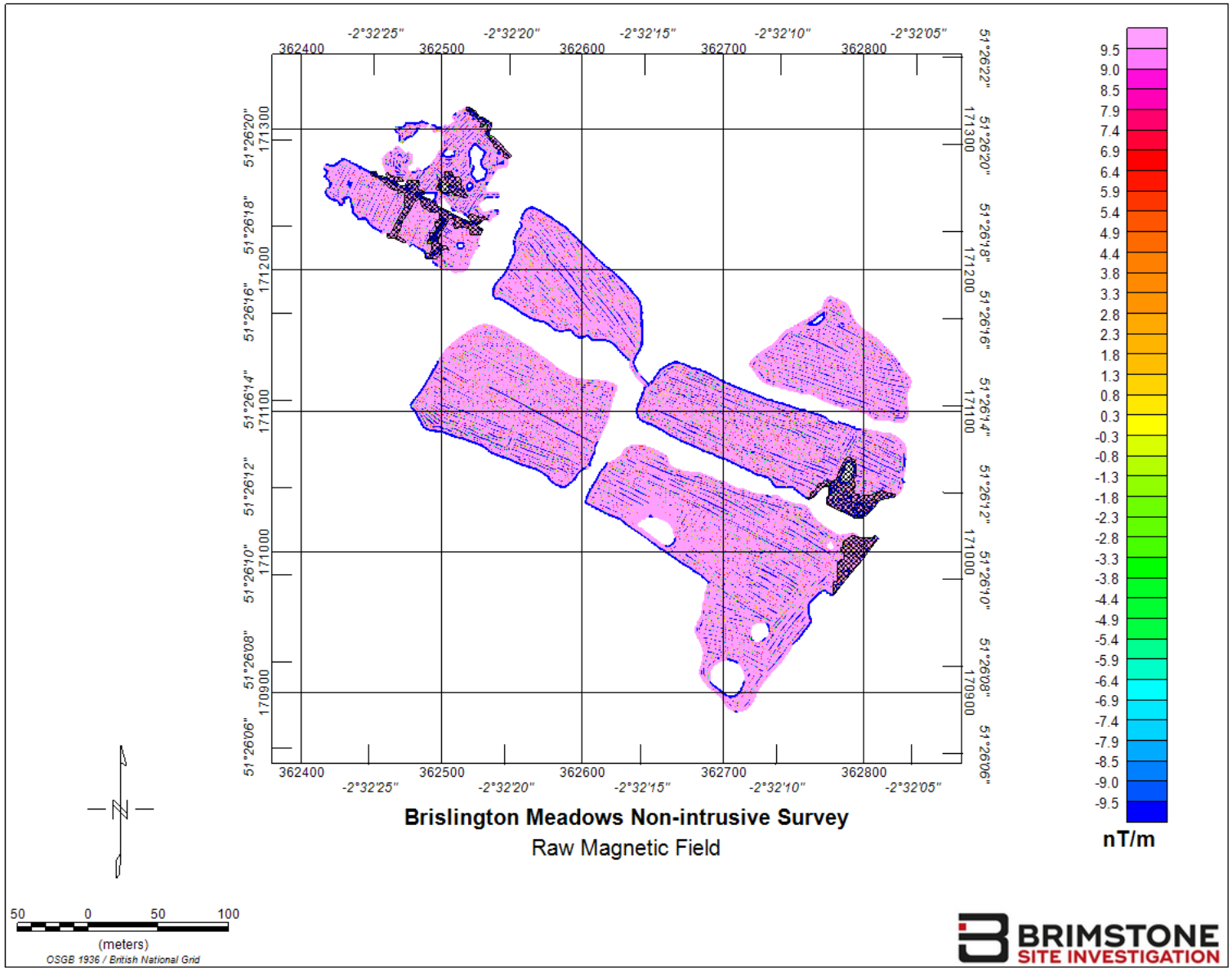


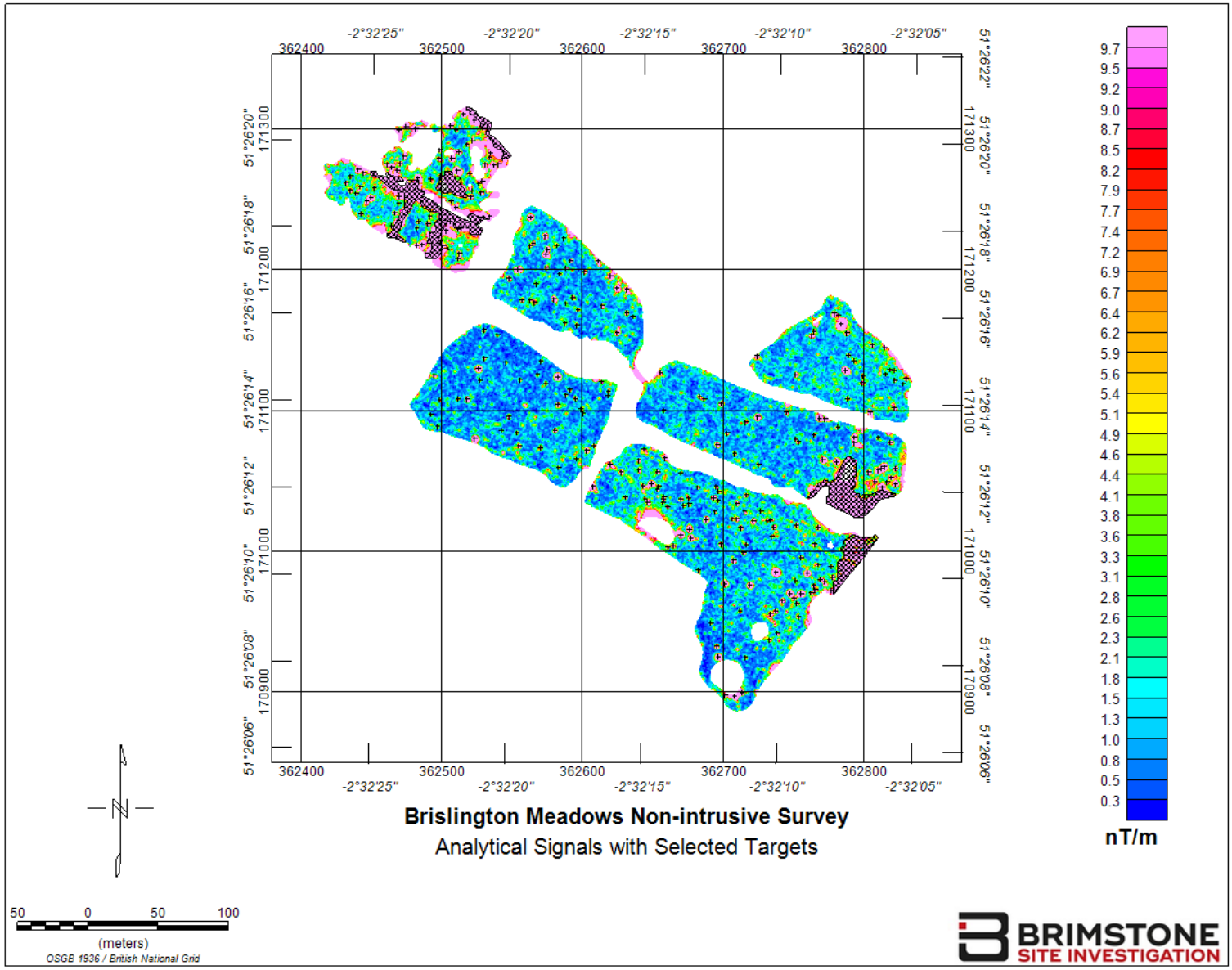
+44 (0)20 7117 2492
enquire@brimstoneuxo.com

BRIMSTONE SITE INVESTIGATION

Raw Magnetic Field


-2°32'25"
-2°32'20"
-2°32'15"
-2°32'10"
-2°32'05"
362400
362500
362600
362700
362800
51°26'22"
51°26'20"
51°26'18"
51°26'16"
51°26'14"
51°26'12"
51°26'10"
51°26'08"
51°26'06"
171300
171200
171100
171000
170900
9.5
9.0
8.5
7.9
7.4
6.9
6.4
5.9
5.4
4.9
4.4
3.8
3.3
2.8
2.3
1.8
1.3
0.8
0.3
-0.3
-0.8
-1.3
-1.8
-2.3
-2.8
-3.3
-3.8
-4.4
-4.9
-5.4
-5.9
-6.4
-6.9
-7.4
-7.9
-8.5
-9.0
-9.5
nT/m
Brislington Meadows Non-intrusive Survey
Residual Magnetic Field
50
0
50
100
(meters)
OSGB 1936 / British National Grid
BRIMSTONE
SITE INVESTIGATION


-2°32'25"
-2°32'20"
-2°32'15"
-2°32'10"
-2°32'05"
362400
362500
362600
362700
362800
51°26'22"
51°26'20"
51°26'18"
51°26'16"
51°26'14"
51°26'12"
51°26'10"
51°26'08"
51°26'06"
171300
171200
171100
171000
170900
9.5
9.0
8.5
7.9
7.4
6.9
6.4
5.9
5.4
4.9
4.4
3.8
3.3
2.8
2.3
1.8
1.3
0.8
0.3
-0.3
-0.8
-1.3
-1.8
-2.3
-2.8
-3.3
-3.8
-4.4
-4.9
-5.4
-5.9
-6.4
-6.9
-7.4
-7.9
-8.5
-9.0
-9.5
nT/m
Brislington Meadows Non-intrusive Survey
Raw Magnetic Field
N
50 0 50 100
(meters)
OSGB 1936 / British National Grid
BRIMSTONE
SITE INVESTIGATION


-2°32'25"
-2°32'20"
-2°32'15"
-2°32'10"
-2°32'05"
362400
362500
362600
362700
362800
51°26'22"
51°26'20"
51°26'18"
51°26'16"
51°26'14"
51°26'12"
51°26'10"
51°26'08"
51°26'06"
171300
171200
171100
171000
170900
9.7
9.5
9.2
9.0
8.7
8.5
8.2
7.9
7.7
7.4
7.2
6.9
6.7
6.4
6.2
5.9
5.6
5.4
5.1
4.9
4.6
4.4
4.1
3.8
3.6
3.3
3.1
2.8
2.6
2.3
2.1
1.8
1.5
1.3
1.0
0.8
0.5
0.3
nT/m
Brislington Meadows Non-intrusive Survey
Analytical Signals with Selected Targets
N
50 0 50 100
(meters)
OSGB 1936 / British National Grid
BRIMSTONE
SITE INVESTIGATION

Target ID	Estimated Mass (Kg)	Estimated Depth (m)	Results
1	3.20	0.78	Scrap
2	0.29	0.65	Nothing Found
3	0.71	0.75	Scrap
4	4.30	0.71	Nothing Found
5	0.73	0.74	Nothing Found
6	0.67	0.77	Scrap
7	0.39	0.73	Nothing Found
8	0.77	0.76	Nothing Found
9	0.48	0.75	Nothing Found
10	0.97	0.69	Nothing Found
11	0.45	0.72	Scrap
12	4.71	0.79	Nothing Found
13	3.72	0.69	Nothing Found
14	0.40	0.69	Nothing Found
15	0.45	0.65	Nothing Found
16	0.47	0.75	Nothing Found
17	2.88	0.70	Nothing Found
18	3.21	0.68	Nothing Found
19	0.52	0.73	Nothing Found
20	0.49	0.72	Nothing Found
21	4.35	0.83	Nothing Found
22	29.84	1.45	Nothing Found
23	1.01	0.74	Scrap
24	1.25	1.04	Nothing Found
25	0.62	0.74	Nothing Found
26	0.51	0.73	Nothing Found
27	0.50	0.79	Nothing Found
28	0.95	0.71	Scrap
29	0.41	0.75	Nothing Found
30	4.62	1.11	Nothing Found
31	3.31	0.98	Nothing Found
32	2.69	1.03	Scrap
33	0.49	0.72	Nothing Found
34	0.82	0.67	Nothing Found
35	0.91	0.72	Nothing Found
36	0.37	0.67	Nothing Found

37	0.96	0.75	Scrap
38	1.74	0.68	Scrap
39	0.4	0.72	Scrap
40	0.46	0.69	Scrap
41	0.32	0.69	Scrap
42	0.84	0.78	Scrap
43	0.97	0.74	Nothing Found
44	0.47	0.71	Scrap
45	1.22	0.77	Scrap
46	0.41	0.68	Nothing Found
47	0.3	0.68	Scrap
48	3.92	0.61	Nothing Found
49	1.79	0.87	Nothing Found
50	0.81	0.73	Scrap
51	8.08	1.41	Slag
52	3.28	0.75	Instilation
53	1.92	1.17	Nothing Found
54	0.51	0.68	Scrap
55	0.88	0.7	Scrap
56	2.16	0.95	Nothing Found
57	0.46	0.63	Scrap
58	2.93	0.91	Scrap
59	0.71	0.75	Scrap
60	3.68	0.78	Scrap
61	0.55	0.70	Scrap
62	3.58	0.70	Scrap
63	1.19	0.75	Slag
64	3.13	0.72	Scrap
65	0.61	0.67	Scrap
66	3.92	0.74	Scrap
67	1.31	0.78	Magnetic rock
68	0.45	0.76	Scrap
69	0.47	0.77	Nothing found
70	0.65	0.73	Scrap
71	1.84	0.89	Nothing found
72	1.64	0.69	Scrap
73	0.74	0.72	Scrap
74	3.67	0.71	Scrap
75	3.23	0.78	Scrap
76	0.78	0.71	Nothing found
77	1.39	0.74	Nothing Found
78	4.39	0.75	Nothing Found
79	0.37	0.69	Scrap
80	3.56	0.71	Geo Instal
81	0.69	0.8	Scrap
82	1.10	0.71	Scrap
83	0.57	0.72	Scrap

84	0.46	0.68	Scrap
85	1.33	0.69	Scrap
86	1.21	0.64	Scrap
87	0.46	0.68	Nothing Found
88	0.93	0.94	Slag
89	0.61	0.78	Nothing Found
90	8.17	0.77	Nothing Found
91	0.70	0.86	Scrap
92	0.55	0.73	Slag
93	0.72	0.81	Nothing Found
94	0.40	0.68	Nothing Found
95	8.5	0.92	Scrap
96	3.15	0.69	Scrap
97	1.10	0.80	Scrap
98	0.36	0.67	Scrap
99	0.93	0.74	Scrap
100	0.80	0.71	Scrap
101	1.49	0.78	Scrap
102	0.38	0.73	Scrap
103	153.86	1.12	Nothing Found
104	2.27	0.71	Scrap
105	0.47	0.73	Scrap
106	0.42	0.68	Scrap
107	0.52	0.7	Scrap
108	0.90	0.79	Nothing Found
109	0.47	0.74	Scrap
110	0.77	0.71	Nothing Found
111	2.26	0.72	Scrap
112	0.78	0.76	Nothing Found
113	2.20	0.70	Scrap
114	0.51	0.77	Nothing Found
115	6.93	0.87	Nothing Found
116	0.50	0.72	Nothing Found
117	1.15	0.79	Nothing Found
118	3.47	0.76	Scrap
119	0.47	0.65	F6
120	1.41	0.75	Nothing Found
121	0.33	0.66	Scrap
122	2.84	0.89	F6
123	3.58	0.89	F6
124	0.40	0.67	Scrap
125	3.09	0.75	F6
126	1.84	0.81	Nothing Found
127	9.01	0.78	F6
128	0.88	0.74	F6
129	0.66	0.71	F6
130	0.85	0.74	F6

131	9.70	0.76	F6
132	3.97	0.73	Nothing Found
133	0.55	0.64	F6
134	0.44	0.64	F6
135	0.70	0.79	F6
136	3.32	0.96	F6
137	1.14	0.72	F6
138	0.32	0.68	F6
139	2.56	0.90	F6
140	1.77	0.76	F6
141	2.21	0.72	F6
142	0.35	0.71	F6
143	0.37	0.70	F6
144	0.62	0.78	F6
145	0.3	0.66	F6
146	0.41	0.74	F6
147	0.55	0.73	F6
148	5.14	0.77	F6
149	0.35	0.7	F6
150	0.81	0.77	F6
151	17.25	0.97	F6
152	1.65	0.80	F6
153	5.20	0.76	F6
154	0.47	0.60	F6
155	2.52	0.75	F6
156	0.57	0.70	F6
157	0.47	0.69	F6
158	0.47	0.73	F6
159	0.55	0.7	F6
160	0.58	0.71	F6
161	4.75	0.83	F6
162	0.29	0.66	F6
163	1.17	0.74	F6
165	0.65	0.68	F6
166	1.81	0.74	F6
167	1.20	0.70	F6
168	0.46	0.72	F6
169	2.88	0.73	F6
170	29.54	1.28	F6
171	4.10	0.76	F6
174	0.34	0.74	F6
176	0.43	0.78	F6
181	0.47	0.67	F6
184	0.30	0.66	F6
193	0.31	0.7	Scrap
195	0.35	0.73	Scrap
199	0.39	0.77	Scrap

202	0.29	0.74	Nothing Found
214	0.33	0.74	Scrap
218	0.37	0.78	Nothing Found
221	0.33	0.83	Scrap
223	0.29	0.75	Scrap
224	0.36	0.76	Nothing Found
228	0.30	0.78	Mag Rock
230	0.36	0.88	Scrap
232	0.42	0.99	Scrap
239	0.72	0.80	Scrap
240	0.32	0.75	Nothing Found
243	0.31	0.7	Scrap
250	0.29	0.79	Nothing Found
254	0.30	0.84	Scrap
257	0.35	0.84	Scrap
258	0.84	0.72	Nothing Found
268	0.45	0.82	Scrap
271	0.45	0.84	Nothing Found
278	0.32	0.74	Scrap

BRIMSTONE
SITE INVESTIGATION

SUITE 6, DELTA HOUSE, LASER QUAY, CULPEPER CLOSE, ROCHESTER, ME2 4HU

BRIMSTONE SITE INVESTIGATION LTD, REGISTERED IN ENGLAND AND WALES UNDER COMPANY NUMBER 10253758

WWW.BRIMSTONEUXO.COM | TEL: 0207 117 2492 | ENQUIRE@BRIMSTONEUXO.COM

London

15 Bermondsey Square
London
SE1 3UN

T: +44 (0)20 7340 1700
E: london@campbellreith.com

Birmingham

Chantry House
High Street, Coleshill
Birmingham B46 3BP

T: +44 (0)1675 467 484
E: birmingham@campbellreith.com

Surrey

Raven House
29 Linkfield Lane, Redhill
Surrey RH1 1SS

T: +44 (0)1737 784 500
E: surrey@campbellreith.com

Manchester

No. 1 Marsden Street
Manchester
M2 1HW

T: +44 (0)161 819 3060
E: manchester@campbellreith.com

Bristol

Unit 5.03,
HERE,
470 Bath Road,
Bristol BS4 3AP

T: +44 (0)117 916 1066
E: bristol@campbellreith.com