BAE SYSTEMS Environmental

Factual Report

Stage 2 Site Investigation, Bishopton

BAE Systems Property Investments Ltd

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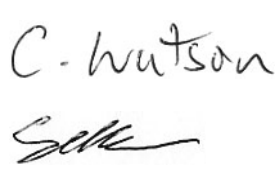		
Craig Watson BSc (Hons.) AIEMA **Senior Geo-Environmental Consultant** Sharon O'Brien BSc (Hons.) FGS **Geo-Environmental Consultant**	David Croke BSc MSc CGeol FGS **Principal Consultant**	Graham Vincent MCIOB **Business Manager**

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BAE Systems Environmental, Station Road, Bishopton, Renfrewshire. PA7 5NJ. United Kingdom.
Telephone: +44 (0) 1505 832025 Fax: +44 (0) 01505 832052 http://www.baesystems.com/propertyandenvironmental

Registered in England & Wales No 2863702. Registered Office BAE SYSTEMS Properties Limited Warwick House PO Box 87 Farnborough Aerospace Centre Farnborough Hampshire GU14 6YU

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1. INTRODUCTION

1.1. Commission

BAE Systems Environmental were commissioned by BAE Systems Property Investments Limited to undertake Stage 2 investigation works at the Bishopton Site, as outlined in our proposal reference, ENQS0003-P1, dated 28th August 2008.

The scope of the commission was to undertake additional intrusive site works and to enable a more detailed risk assessment to be undertaken in support of the planning applications for site remediation and construction of a non-hazardous landfill. Both planning applications will be re-submitted to Renfrewshire Council in July 2009.

This report contains the factual findings of the recent Stage 2 investigations, with the results and findings of previous investigations referenced in Appendix 1.

1.2. Background

As part of the overall regeneration of the former Royal Ordnance factory at Bishopton, BAE Systems currently have outline planning consent (reference number 06/0602/PP) for the development of the site and a planning consent (reference number 06/1065/PP) for the construction of a new M8 motorway junction.

The regeneration of the Royal Ordnance factory at Bishopton will take the form of a mixed use development; with residential, commercial, employment, community and open space uses planned for specified areas of the existing site, as identified by the original master plan. The Core Development Area (CDA), which will be located in the north-east of the existing Site, occupies a quarter of the total site (233 Ha) and will be the main focus for the proposed residential and commercial end uses. The recreational open space areas (ROS) Which is located to the west of the CDA and covers an area of 588 Ha will be utilised for recreational purposes, including a woodland park area.

An existing area of the Site, known as the Environmental Testing Facility (ETF) will remain in commercial use by BAE Systems, and as such will not be developed as part of the overall regeneration plans.

The investigation strategy was based on a phased approach (Stage 1, 2006 and Stage 2, 2009). It was anticipated that Stage 2 (main works) would be progressed once outline planning consent was gained (March 2009).

In December 2007, Renfrewshire Council's advisors reviewed the outline proposals for the Stage 2 investigations and considered them to be reasonable and suitable for further characterisation of the Site.

The regulator provided comment on the Stage 1 investigations in 2008, and indicated that planning approval for the detailed remediation strategy and the construction of a non- hazardous landfill on site would not be granted as there was a requirement for more detailed information to be obtained in support of these applications.

As a result, the opportunity was taken by BAE Systems to bring the Stage 2 works forward to October 2008 to facilitate the earlier construction of the landfill; which

could potentially maximise the opportunity to make full use of the landfill tax exemption by 2012.

1.3. Scope & Objectives

The Stage 2 Site Investigation Strategy, Report Ref: B0014-0G-R4-2 October 2008 (Appendix 2) was initially developed by BAE Systems following the Stage 1 investigation and outlines the rationale adopted for the Stage 2 investigation works. This document was submitted to Renfrewshire Council and the Scottish Environment Protection Agency (SEPA) for comment.

The principal objectives of the Stage 2 site works were:

- to provide sufficient information to develop a remediation strategy to meet the approval of the regulator, and
- to provide sufficient detail for the re-submission of the planning application for the proposed site remediation and construction of a non-hazardous landfill site.

The works required to meet these objectives are described below:

- further delineation of contamination identified in Stage 1, as requiring remediation, following the establishment of significant pollutant linkages.
- to provide information on data gaps identified in the Stage 1 Site Investigation, in relation to previously inaccessible areas.
- to undertake more detailed quantitative risk assessments (DQRA) to determine if any identified pollutant linkages are significant,
- to increase confidence that unexpected or unknown contamination sources are not present, and
- provide more detailed information to finalise a detailed remediation design.

1.4. Reporting

This document details the factual findings of the Stage 2 site investigation. A detailed assessment and interpretation of this information in conjunction with the Stage 1 investigation and previous assessments will be undertaken in the interpretative report. The interpretative report along with this report will support the remediation and landfill planning applications.

More detail on the investigation rationale and methodology for the Stage 2 investigation are described in Section 3 of this report.

This report should be read in conjunction with the following documents:

- Preliminary Risk Assessment for Land Contamination, Desk Study, Bishopton, (BAE Systems Environmental 2005)
- Stage 1 Site Investigation Outline Strategy, (BAE Systems Environmental, 2005)

- Stage 1 Site Investigation, Factual Report Bishopton, (BAE Systems Environmental 2006)
- Generic Quantitative Risk Assessment, (BAE Systems Environmental, 2006)
- Outline Remediation Strategy, (BAE Systems Environmental, 2006)
- Stage 2 Site Investigation Strategy, (BAE Systems Environmental, 2008).

1.5. Definitions

The term 'Site' refers to land owned by BAE Systems, encompassing the former Royal Ordnance factory, as shown in Figures 1 and 2.

The terms 'CDA', 'ROS' and 'RL' refer to Core Development Area, Recreational Open Space and Retained Land as defined in the Masterplan Statement (Cass Associates, 2006). The location and extent of the three key development areas are shown in Figure 3.

Within the CDA there are three development areas relating to residential, commercial and open-space end uses. The ROS relates to the open space areas to the north and west of the CDA. Retained land relates to the existing ETF facility.

1.6. Reporting Conditions

This report has been prepared by BAE Systems Environmental within the scope of work, terms of contract and resources as agreed with the client. It has been specifically prepared without the benefit of knowing the exact intentions of third parties and therefore should not be used by such organisations without prior consultation with BAE Systems Environmental. Any such party relies on this report and any information contained therein at their own risk.

The report refers to the conditions present at the Site at the time of the study and no liability can be accepted by BAE Systems Environmental for any future changes of Site conditions. It should be noted that BAE Systems Environmental has relied on the accuracy of the information contained in any documents consulted or supplied by the client and is in no circumstances responsible for the accuracy of such information or data supplied.

It should be noted that exploratory points such as trial pits and boreholes only provide information on a relatively limited volume of soil or groundwater. In general, the ground conditions encountered may be considered representative but the possibility exists for variations in ground conditions between exploratory points that have not been disclosed by the investigation and could not therefore be taken into account in this report. Groundwater levels are particularly susceptible to seasonal and other variations.

For reasons of explosive safety, areas of the Site beneath existing buildings, selected lagoons and ponds have not been investigated; therefore not all areas of the Site have been fully investigated.

Any conclusions and recommendations represent our professional opinions and have been determined in accordance with accepted industry good practice at the time of writing; BAE Systems Environmental cannot accept responsibility for future

changes in legislation or good practice guidance that may affect any opinions expressed in this report.

2. SITE CHARACTERISTICS

2.1. General

This section of the report provides a brief summary of the Site's history and physical setting, and reference should be made to the Preliminary Risk Assessment for Land Contamination (PRALC), (BAE Systems Environmental, 2005) and the Stage 1 Site investigation Factual Report (BAE Systems Environmental 2006).

2.2. Location

The Site is located to the south-west of Bishopton Village in Renfrewshire, Scotland, approximately 15 km west of Glasgow city centre and is centred on National Grid Reference (NGR) NS 433 691.

2.3. Description

The Site is roughly rectangular in shape and occupies an area of approximately 1005 hectares (ha). The land surrounding the Site is predominantly agricultural, with a mix of arable, pasture and woodland uses.

Some 766 ha of the Site is fenced and contains the former Royal Ordnance factory, which can be accessed via Station Road. The 230 ha of land located between the factory fence and the Site boundary is noted to be predominantly arable and pasture land, except for Barochan Moss.

There is a general decline in elevation from the north to south across the Site, with ground elevations recorded at approximately 60 metres above Ordnance Datum (m AOD), in the north-west . Both the centre and south of the Site are generally flat lying at levels between 15 and 5 metres above Ordnance Datum (mAOD), respectively.

2.4. Brief History

Prior to the development of the Bishopton site, the land was predominantly used for agricultural purposes.

The industrial development of the Site can be divided into two eras, the first being the Scottish Filling Factory ('Georgetown') operational during the First World War, the second being the development of The Royal Ordnance factory prior to the Second World War.

Georgetown, an ordnance filling factory, occupied approximately 194 ha in the southern part of the Site, within the factory fence. Buildings associated with the Georgetown factory were demolished shortly after the Second World War (WWII) and the area is now predominantly wooded.

The Royal Ordnance factory was built from 1937 over much of the remainder of the Site and also occupies the northern part of Georgetown. The major function of the factory was the production of gun and rocket propellant for the armed services, and was in production until 2002.

The Royal Ordnance factory was conceived as three self-sufficient propellant factories (I, II and III), each having its own boiler house, nitroglycerine, nitrocellulose

and acids production sections. The manufacture of tetryl was undertaken in factories II and III.

Although the layout of the factory has remained largely unchanged since it was built, the range in activities carried out has varied over the years. Of particular note were the manufacture of picrite and the breakdown of surplus ammunition. Other processes included the manufacture of Research Development Explosive (RDX), Ball Powder, ammonium perchlorate and Combustible Charge Containers (CCCs), and the filling of ordnance with white phosphorus.

2.5. Geology

2.5.1. Made Ground Deposits

Given the industrial nature of the Site, involving the construction of factory areas and buildings, it is generally considered that made ground will be present across the majority of the Site.

It is known from previous investigations that the majority of made ground deposits appear to be less than 0.7m in thickness, with localised areas of thickening, e.g. waste tips.

The made ground deposits previously encountered were generally noted to consist of deposits of concrete and brick; reworked natural clay soils with brick and concrete; reworked clay deposits containing ash, clinker and blaes. Pulverised ash deposits have generally been found beneath existing haul roads located in the west and east of the Site.

2.5.2. Superficial Deposits

Glacial till of the Wilderness Till Formation directly overlies the local bedrock and is known to crop out on higher ground, particularly in the north of the Site. Map evidence indicates that this deposit is likely to be laterally continuous across the Site.

A single mound of sand and gravel in the centre of the Site, located to the south-east of Dargavel House, is attributed to the fluvio-glacial deposits of the Broomhouse Formation, which directly overly the glacial till.

In the lower-lying central and southern areas, the glacial till is overlain by glacio-marine silts and clays of the Paisley and Linwood Formations. These deposits are practically indistinguishable from each other in the field and therefore are referred to collectively in this document as the Linwood and Paisley Formation.

Both the glacial till and the Linwood and Paisley Formation are locally overlain by beach/deltaic sands and gravels of the Killearn Formation. These deposits have been generally represented by thin gravely sand deposits locally identified in the northern part of the Site.

Peat belonging to the Clippens Peat Formation has been previously recorded on low lying land in the east and west of the Site. Alluvium deposits of younger age and belonging to the Erskine Formation associated with the River Gryfe are likely to be present in the far south-western corner of the Site.

The general presence of these deposits has been confirmed by previous site investigations. From a review of available geological map information and the findings of previous investigations, a superficial geological outcrop plan generated from the Stage 1 site investigation data is presented in Figure 4A. A Revised Superficial Outcrop Plan, incorporating the Stage 2 site investigation findings is shown in Figure 4B. Further discussion will be provided in the Interpretative report.

2.5.3. Bedrock

The higher ground of the northern part of the Site is represented by the Clyde Plateau Volcanic Formation of Upper Carboniferous age, which is represented by sequences of 'basaltic type rocks'.

The Clyde Plateau volcanic formation is in turn overlain by sequences of sedimentary rocks of Carboniferous age, including the Lawmuir Formation and the Lower Limestone Formation. The Lawmuir Formation consists mainly of sandstones with siltstones, mudstones, coals and thin limestones. The Lower Limestone Formation consists mainly of limestone, mudstone and sandstones with siltstones, marine limestones, thin coals and ironstones.

Generally, these sedimentary rocks appear to be dipping in an easterly direction and have been faulted by east-west trending normal faults.

Both the igneous and sedimentary rocks appear to have been dissected by two quartz-dolerite dykes, which cut the bedrock in a general west-east direction across the central portion of the Site.

Previous site investigations conducted by BAE Systems Environmental have encountered shallow igneous and sedimentary bedrock in the northern area of the site. The Stage 2 investigation has improved our understanding of the bedrock profile across the Site. An extract of the British Geological Survey solid geology map is given in Figure 5. Further details will be provided in the interpretative report.

2.6. Hydrogeology and Hydrology

2.6.1. Superficial Hydrogeology

Previous investigations have confirmed that groundwater levels have been recorded within the made ground and natural superficial deposits at shallow depths across the Site, with localised groundwater flow towards the local surface watercourses. Shallow groundwater is generally encountered within the low permeability silt and clay deposits of the Linwood and Paisley Formation.

It is not considered that there are any significant shallow drift aquifers located on Site as the granular sand and gravel deposits encountered have been noted to be localised and of limited thickness.

2.6.2. Bedrock Hydrogeology

Groundwater Occurrence in Bedrock

In previous investigations, groundwater has been encountered within the basalt and sedimentary rocks encountered at the site. As anticipated, groundwater strikes are limited to preferential pathways, including fractures and joints within the bedrock. Groundwater strikes in the bedrock aquifers were generally noted to be under

pressure, i.e. confined. Locally, groundwater in the bedrock has been recorded to be artesian (i.e. groundwater level above ground level)

Though locally controlled by rock types and structural features such as faults and igneous intrusions within the bedrock, it is generally considered that groundwater flow will be in an easterly to south –easterly direction. Recharge to the bedrock aquifer will be from the north and west from areas of higher ground, with deeper groundwater flow to the east. An extract of the British Geological Survey Hydrogeological map is given in Figure 6A.

2.6.3. Groundwater Vulnerability (Susceptibility to contamination)

Given the variation in superficial deposits across the Site, with a general thickening of deposits to the south, it is considered that the vulnerability of the groundwater within the bedrock will be correspondingly low where superficial deposits are thick.

Where the superficial cover is reduced, the vulnerability of groundwater within the bedrock aquifer will be greater, (though still considered to be low to moderate given the low permeability nature of the overlying soils). Recent information supplied from SEPA indicates a high groundwater vulnerability class of 4b in the north of the site, with a low groundwater vulnerability classification of 1 in the south of the Site.

2.6.4. Aquifer Productivity

Within the basalts of the Clyde Plateau Volcanic Formation, it is considered that aquifer productivity will be low to moderate, with groundwater arising predominantly from fracture flow.

It is considered that the Carboniferous sedimentary rocks will be moderately productive, with both fracture and inter-granular groundwater flow.

2.6.5. Groundwater Abstractions

Shallow groundwater

A review of groundwater abstraction information supplied from SEPA, do not indicate the presence of shallow groundwater abstractions in the **immediate** vicinity of the site.

SEPA provided details of three groundwater licences for abstractions (up to approximately 50 m^3/day). The locations of these abstractions are show in Figure 6C. One abstraction is located to the north and up hydraulic gradient of the Site at NS 4384 7217. Two additional abstractions are located to the south of the site, on the southern bank of the River Gryfe. These abstractions are located at NS 4582 6669 and NS 4560 6629. No specific details of response zones or actual recorded flow rates were provided for these groundwater abstractions.

Given to location of these shallow abstractions, it is considered that they are not in hydraulic connection with any potential groundwater flow emanating from the Site.

Bedrock abstractions

SEPA previously advised that according to available BGS records, Messrs J. Craig, Barr and Cook own a disused borehole located on Old Bishopton Estate.(The location of this borehole is not known). This borehole tapped the Carboniferous,

Calciferous Sandstone Measures, however no additional information was made available concerning yield or water quality. It is acknowledged that the presence of this former borehole indicates that the sedimentary bedrock aquifer is important as a potential groundwater resource.

No information regarding current bedrock groundwater abstractions within the immediate vicinity of the Site was available from either SEPA or the British Geological Survey (BGS).

2.6.6. Bedrock Water Bodies

SEPA informed BAE Systems Environmental that the site is underlain by the Kilmacolm, and Paisley and Rutherglen water bodies, and that these bedrock water bodies are likely to be subject to pressures, including past industrial activities and groundwater abstractions.

It is also known that these bedrock water bodies are designated as drinking water protected zones.

2.6.7. Hydrology

The Dargavel Burn is the main surface watercourse on Site, which flows in a south-easterly direction through the centre of the Site, before entering the River Gryfe located to the south. Along its length, the Dargavel Burn is joined by numerous ditches, drainage pipes, former process water drains and small streams, some of which originate from outside the factory boundary. The locations of principal surface watercourses are shown on the Site plan (Figure 2).

Craigton Burn enters the Site at the eastern boundary just south of Bishopton Village and flows in a north-east to south-westerly direction. In turn, it is joined by the Cordite Burn, which flows from the northern boundary of the site, before joining the Dargavel Burn in the centre of the Site.

A recent biological assessment of surface water quality in the form of an ecological survey (2008) undertaken by SEPA, indicates that the general water quality of the Dargavel Burn and its tributaries is good to excellent.

3. INVESTIGATION DESIGN AND METHODS

3.1. General

The Stage 1 works were reported in July 2006 and included a site wide intrusive investigation and Generic Quantitative Risk Assessment (GQRA). The investigation was designed to inform the Outline Remediation Strategy and the Stage 1 Detailed Remediation Strategy, which were prepared in support of various planning applications. The Stage 1 Site Investigation design was largely based on confirming the existence of the various sources that were previously identified in the desk study.

The Stage 2 works were undertaken between 20 October 2008 and 23 March 2009 to focus on areas of potential concern, and to provide a greater degree of confidence on the status of identified potential contamination sources, particularly in the Core Development Area (CDA). The objectives of this phase of work are as outlined in Section 1 of this report, with the key aim of confirming the existence of significant pollutant linkages.

The recent Stage 2 investigations were also undertaken by BAE Systems Environmental using approved subcontractors, under the supervision of BAE Systems Environmental personnel.

These works were notified under the Construction (Design and Management) Regulations 2007, and were carried out in accordance with BAE Systems Environmental's Construction Phase Safety, Health and Environment (SHE) Plan, (BAE Systems Environmental, 2008).

The site investigation design was outlined in The Stage 2 Site Investigation Strategy (Appendix 2), under broad categories including delineation; addressing data gaps; reducing uncertainties, unexplained contamination and further risk assessment.

A number of potential contamination sources were assessed separately, including the presence of asbestos beneath steam mains; explosives residues around buildings; explosive fragments around the narrow-gauge rail lines, explosives within process drains; potential buried devices in Factory III, Georgetown and the proposed footprint of the proposed non-hazardous landfill area. Additional groundwater investigations were also undertaken around the picrite lagoons within retained land areas (RL). The details of the findings are presented in the following sections.

Following detailed design, minor adjustments were made to the position and numbers of exploratory points outlined in the investigation strategy, as well as during the site works to allow for access issues and to avoid underground services.

Exploratory point and sample location points are shown on Figures 7 to 13. Detailed descriptions of the materials encountered at each exploratory point and a record of the type and frequency of samples types recovered are given on the exploratory point records (trial pit, hand auger, borehole and window sample logs) in Appendices 3 to 6.

3.2. Scope of Investigation

The Stage 2 investigation included the following works:

- Excavation of 1435 No. exploratory points comprising:
  - 717 No. trial pits;
  - 141 No. hand-auger holes;
  - 93 No. boreholes advanced by cable percussive and rotary techniques, installed with combined groundwater and gas monitoring standpipes;
  - 28 No. window sample boreholes;
  - 457 No. hand-dug positions.
- Total of 42 No. surface water samples collected comprising;
  - 23 No. Stage 1 sampling locations (one monitoring visit);
  - 19 No. Stage 2 sampling locations (one monitoring visit);
- Total of 310 No. groundwater samples collected including 8 No. duplicates comprising:
  - 29 No. Stage 1 boreholes (one monitoring visit);
  - 18 No. previous investigation boreholes (one monitoring visit);
  - 113 No. Stage 2 boreholes (two monitoring visits);
  - 6 No. burning ground boreholes (one monitoring visit);
  - 9 No. Stage 2 boreholes(one monitoring visit) for PCBs only;
  - 3 No. Stage 2 boreholes (one monitoring visit) for explosives only;
  - 11 No. bedrock boreholes (3 No. Stage 1 and 8 No. Stage 2) over one monitoring visit for explosives at lower reporting limits;
  - 44 No. boreholes (28 No. Stage 1 and 16 No. previous investigations) over one monitoring visit for explosives at lower reporting limits;
- Gas monitoring of 163 boreholes and window sample boreholes resulting in 395 No. gas analyses, from:
  - 39 No. Stage 2 CDA boreholes (5 No. rounds);
  - 12 No. baseline CDA boreholes (1 No. round);
  - 4 No. Burning Ground CDA boreholes (1 No. round);

  - 42 No. Stage 2 ROS boreholes (2 No. rounds);
  - 22 No. baseline ROS boreholes (1 No. round);
  - 2 No. Burning Ground ROS boreholes (1 No. round);
  - 34 No. Stage 2 RL boreholes (2 No. rounds);
  - 8 No. baseline RL boreholes (1 No. round); and,
- Survey of exploratory points to determine their location relative to National Grid and Ordnance Datum.
- Laboratory chemical analysis of 2529 No. soil samples and 352 No. water samples.
- Laboratory geotechnical testing.

The numbers of exploratory points are summarised below.

Element of Investigation	Trial Pits	Hand Augers	Bore-holes	Window sample boreholes	Hand Dug Samples	Total
Burning Grounds	41	4	0	8	0	53
Proof range	0	6	0	0	0	6
Explosive residues around lagoons/ponds	17	21	0	1	0	39
Electrical substations CDA	65	0	0	5	0	70
Hydrocarbon contamination	44	0	3	0	0	47
Metals salts storage	10	3	0	0	0	13
White phosphorus	9	0	0	0	0	9
Roads, rail, narrow gauge	26	0	0	0	0	26
Other uncontrolled waste tips	33	0	2	0	0	35
Vegetation tip/Boghall	1	6	0	0	0	7
Electrical substations ROS	34	6	0	0	0	40
Other storage areas	33	2	1	0	4	40
Other acids tanks/buildings, ASTs, USTs	57	2	8	0	0	67
Possible waste tips in Ammunition breakdown.	9	4	0	2	0	15
Possible asbestos tips	14	3	0	0	0	17
Suds ponds	25	0	0	0	0	25
Mound material	35	0	0	0	0	35
Flood compensation area	5	0	0	0	0	5
Ash	8	0	9	0	2	19
Laundry, boilerhouse No. 2 slab, apprentice hall, works department, area of made ground at 24/305C	24	3	0	0	0	27
Gaps	6	8	0	0	12	26
Carbamite	0	0	0	0	8	8
Additional soil testing from groundwater monitoring boreholes	0	0	64	0	0	64
Ammonium perchlorate	4	0	0	0	7	11
Explosives residues outside process buildings	146	22	0	0	257	425
Asbestos sampling beneath steam mains	0	0	0	0	150	150
Explosive fragments around narrow-gauge	10	0	0	0	0	10
Process drains and ditches	0	51	0	0	16	67
Potential buried devices/Ordnance walkovers	59	0	0	0	0	59
Picrite lagoons	0	0	6	12	0	18
Car Park	2	0	0	0	0	2
Total	717	141	93	28	456	1435

Table 1 – Summary numbers of exploratory methods

A more detailed description of the scope and methodology of the investigation are provided in the following sub-sections.

3.3. Deviations from Investigation Strategy

The Stage 2 Site Investigation Outline Strategy (B0014-0G-R4-1) identified the required elements of investigation. Three of these elements were not carried out and details are given below;

- **Investigation under process buildings** using remote drilling techniques was not conducted due to health and safety concerns given the nature of process buildings. Ground conditions and chemical conditions beneath process buildings will be addressed as part of the remediation works.

- **Air monitoring for asbestos in Georgetown** was not carried out. Personal asbestos monitors were worn during hand sampling around steam mains. No asbestos was detected during monitoring. Analytical results from the personal monitors are included in Section 4.3.

- **Sediment sampling within NG ponds** was not carried out for health and safety reasons. This will be dealt with as part of the Remediation Strategy.

3.4. Trial Pits

A total of 717 No. trial pits were excavated to an approximate maximum depth of 4 m. Trial pits were excavated by JCB 3CXs owned and operated by AFP Construction (Bishopton) Ltd.

Following excavation, each trial pit was backfilled and the materials replaced as far as practicable in reverse order to which they had been excavated, so as to minimise mixing of made ground and natural strata.

The excavator bucket was decontaminated with Decon 90, followed by rinsing with water between exploratory positions.

Trial pits were logged in accordance with BS5930:1999 Incorporating Amendment No.1 December 2007 – Code of Practice for Site Investigations:- trial pit logs are provided in Appendix 3. A photographic record was made of each trial pit and a selection of trial pit photographs are included in Appendix 4.

Soil samples were generally collected at the following depths: 0.1, 0.3, 0.5 and 1.0 m, and each metre and/or change of strata.

In-situ measurements of shear strength were obtained using a hand vane in a selection of trial pits.

3.5. Boreholes

A total of 93 No. boreholes were drilled to depths of between 1.3 and 43.0 m by JB Site Investigations Ltd, by means of cable percussive and open hole drilling techniques. Drilling was preceded by hand-dug starter pits to a depth of 1.2 m.

Seventy-nine boreholes were formed by cable percussive techniques advanced to depths between 1.3 and 15.0 m within the superficial deposits.

Fourteen boreholes were formed by open-hole rotary (Symmetrix) techniques advanced from ground level to depths between 19.0 and 43.0 m. Eleven of these rotary boreholes were drilled into the bedrock.

The depths of groundwater strikes were noted and any changes in level observed for a minimum of 20 minutes.

Casing and tools were decontaminated with Decon 90 and clean water between borehole locations.

Soil samples were collected from starter pits and at approximate depths of 0.1, 0.3, 0.5 and 1.0 m, and in the cable percussive from within the top of natural deposits.

Samples from discrete horizons were not obtained during open-hole rotary drilling as this was not practical to do so.

Inspection pits, cable percussive and rotary boreholes were logged in accordance with BS5930:1999 Incorporating Amendment No. 1 December 2007. Borehole logs are given in Appendix 5.

3.6. Monitoring Installations

Upon completion, 93 No. boreholes were installed with 50 mm diameter HDPE standpipes for groundwater and gas monitoring. Response zones (slotted pipe) were positioned to intercept any observed groundwater strikes or, where groundwater was absent, to coincide with the main strata of interest in the borehole.

One-metre bentonite seals were placed above the slotted pipe sections. Bentonite seals were also installed below the slotted pipe to isolate the response zone from adjacent strata. A one-metre bentonite seal was placed at the top of each borehole to prevent entry of surface water. Surface reinstatement included the placement of an upstanding cover, set in concrete. Construction details are shown on the borehole logs in Appendix 5.

Following installation, monitoring wells were developed by over-pumping. Ten well volumes were pumped from each borehole. Where shallow wells readily dewatered; these were allowed to recharge overnight and pumped dry again the following day.

In general, monitoring boreholes screened within the superficial deposits were bailed dry, given the low permeability of the soils. It is estimated that these bores could only yield approximately 100-150 l/day. Continuous groundwater flow could not be sustained for the shallow wells screened across the low permeability soils.

Within the bedrock boreholes, ten well volumes (as a minimum) could easily be pumped from each well prior to sampling.

3.7. Window Sampling

Twenty one window sample boreholes (including 6 No. as part of the Burning Grounds Investigation) were advanced to depths between 2.8 and 7.0m using a Competitor window sampling rig, and installed with 50 mm diameter HDPE standpipes for groundwater and gas monitoring. Each hole was advanced by excavating a hand-dug starter pit to a depth of 1.2m.

Seven window sample boreholes were advanced to depths between 3.5 and 5.0m using a hand held window sample rig due to restricted access by way of very soft ground, thick vegetation and trees. These were installed with 33 mm HDPE standpipe to monitor groundwater levels and gas concentrations. Response zones were positioned to intercept any observed groundwater. Window sample logs are given in Appendix 5.

3.8. Hand Augers

Hand augers were used in place of trial pits where machine access was impractical, and a total of 14No hand augers were advanced to approximately 1.3m depth dependent on the ground conditions encountered. The equipment was decontaminated between exploratory points. Samples were generally taken at depth ranges of 0.0 to 0.2m, 0.3 to 0.5m, 0.6 to 0.9m and 1.0 to 1.2m, dependent on the strata encountered. Hand auger logs are given in Appendix 3.

3.9. Hand Dug Samples

A total of 456 No. hand dug samples were excavated to a maximum depth of 0.2m. Hand dug samples were taken in areas where near surface samples were required, such as sampling for asbestos underneath steam mains and sampling for explosives residues around process buildings. The equipment was cleaned with Decon 90 and water between exploratory points. Hand dug sample descriptions are given in Appendix 6.

3.10. Soil Sampling

Disturbed samples were obtained from all exploratory holes before being sent for chemical analysis and/or geotechnical testing.

Soil samples were collected to establish the nature and extent of the chemical profile of the underlying soil.

Soil samples were taken with stainless steel implements and/or disposable nitrile gloves. New gloves were used for each sample operation to minimise the potential for cross contamination. Samples collected from cable percussive boreholes were taken directly from the drilling tool.

Each sample consisted of a 500 ml amber glass jar with PTFE lined lid and a 1 litre plastic tub. The majority of analyses, including explosives, Poly Aromatic Hydrocarbons (PAHs) and Total Petroleum Hydrocarbons (TPHs) were carried out on the sample from the amber glass jar. Samples analysed for leachability, asbestos and Poly Chlorinated Biphenyls (PCBs) were taken from a tub.

Samples for Volatile Organic Compounds (VOCs) and Semi-Volatile Organic Compounds (SVOCs) analysis were collected in 60ml amber glass jars (phial) with PTFE lined lids.

All organic samples were stored in an on-site refrigerator at approximately 4 °C before being couriered to the laboratory. All soil samples were transported in cool boxes and kept in refrigerated conditions.

All samples were transported to laboratories with a completed chain of custody form.

3.11. Groundwater Sampling

Groundwater levels were determined using an electronic dip meter.

Where possible, each borehole was purged of 3 No. well volumes of groundwater prior to sampling using a dedicated inertial pump (Waterra™).

Measurements of pH, temperature, electrical conductivity, dissolved oxygen and redox potential were made during purging. Instruments used were calibrated prior to use in accordance with the manufacturer's instructions.

Samples were taken unfiltered from the Waterra™ pipe or from a dedicated HDPE bailer to minimise cross contamination. All samples were subsequently filtered at the receiving laboratory.

Following installation of monitoring boreholes BH2061 and BH2224, both were found to be dry or contained insufficient water to obtain a representative groundwater sample.

Water monitoring records are presented in Appendix 7.

3.12. Gas Monitoring

Gas flow, pressure, atmospheric pressure and the concentrations of methane, carbon dioxide, carbon monoxide, hydrogen sulphide and oxygen were measured using a Geotechnical Instruments GA2000 infrared gas analyser and a Gas Data GF60 flow meter.

All gas instruments are maintained and calibrated by the manufacturers in accordance with BAE Systems Environmental's ISO Accredited Quality Management System.

Sampling was carried out by trained BAE Systems Environmental personnel.

Gas monitoring records are given in Appendix 7.

3.13. Topographical Survey

The position of boreholes, trial pits and hand augers was determined relative to National Grid and Ordnance Datum (except for HA3181, HA3182 and HA3183) due to difficult access) by BAE Systems Environmental.

Coordinates and ground levels are shown on the appropriate exploratory point records in Appendix 3 to Appendix 6, with the exploratory point location plan as Figure 7.

3.14. Laboratory Analysis

Sample analysis was carried out by the following laboratories.

- BAE Systems Environmental, Chorley.
- Bodycote Materials Testing Ltd., Clydebank.
- Terra Tek Site investigation and Laboratory Services, Airdrie.

Our in-house laboratory (with MCERTS accreditation) has undertaken the majority of soils analysis, generally using accredited methods. All explosive analysis for explosives in soils and waters were undertaken at the BAE Systems Environmental, Chorley laboratory. Bodycote Materials Testing Ltd., Clydebank conducted the majority of water analyses, in addition to specific soils analysis including asbestos, PCBs, solvents and soil leachate. Bodycote has been audited by BAE Systems Environmental chemists, and they have a fully operational quality system incorporating a wide scope of methods.

The laboratories (BAE Systems and Bodycote), regularly submit their analytical regimes to inter-laboratory comparison through the Water Research Centre AQUACHECK and Laboratory of the Government Chemist CONTEST schemes. Bodycote also participate in the RICE scheme for asbestos analysis.

Duplicate soil and water sampling was undertaken and is discussed in sections 4.5 and 6.6, respectively.

Summary analytical methods with reporting limit and laboratory accreditation are given in Appendix 8.

3.15. Explosives Safety

BAE Systems Environmental is considered a leading expert in the safe investigation and assessment of explosives sites, with over 19 years' experience in this field of work.

All intrusive works were closely supervised by appropriately trained and experienced BAE Systems Environmental engineers. These engineers were given a detailed site-specific induction covering the types of explosives and devices that could be encountered, their appearance and the associated hazards.

Explosives safety was included in the general site induction, which was given to all other personnel involved in the investigation.

Measures taken to mitigate the risks associated with encountering explosives included:

- Hand-dug starter pits through made ground prior to cable percussive boring, rotary drilling and window sampling.
- Enforcing 'man limits' of 2 persons for excavations and 3 persons for drilling.
- Damping down any suspicious material with water, where dry conditions were encountered.
- Clear plans of action in the event of discovering suspicious materials.
- Utilisation of hand-held ordnance detectors in certain areas of the Site.
- Use of engineers experienced in ammunition recognition.

4. SOIL

4.1. Introduction

Chemical analysis conducted comprised 77% of samples from Made Ground, and 23% of samples from natural soils collected during the Stage 2 investigation.

A total of 2529 No. soil samples were chemically analysed for a range of determinands depending on the location of the exploratory point.

Analytical results are presented in Appendix 9 and summarised in Section 4.3.

4.2. Visual and Olfactory Evidence of contamination

Visual and/or olfactory evidence of contamination such as a hydrocarbon odour or oily sheen were noted in 51 No. exploratory points. Representative soil samples were collected and sent for appropriate laboratory testing, which confirmed the presence of contaminants at 37 No. of the 51 No. locations where contamination was suspected. Details of the exploratory points and contaminants detected by the laboratory are included in Appendix 10.

4.3. Summary Soil Analytical Results

Soil samples were analysed for a suite of 13 No. explosives and a range of other determinands specified in the Stage 2 Site Investigation Strategy (Appendix 2). In addition, 32 No. samples of drain sediments were collected and tested for explosives only. Summary results are given Tables 2 to 12.

As a conservative approach the reporting limit has been used as the lowest value when calculating the mean, except where there are no results above the reporting limit.

Determinands	Units	No. Tested	No. Detected	Min.	Mean	Max.
2,4-DNT	mg/kg	2510	11	<1	1.1	74.8
2,6-DNT	mg/kg	2510	6	<1	1	19
EGDN	mg/kg	2510	0	<0.1	-	<5
HMX	mg/kg	2510	6	<2	2	30.5
HNS	mg/kg	2506	5	<0.5	0.5	3.4
NC	mg/kg	2510	65	<1000	3088	36600
NG	mg/kg	2510	567	<0.1	2	442
PETN	mg/kg	2510	0	<5	-	<5
Picric Acid	mg/kg	2510	51	<0.1	0.2	98.9
Picrite	mg/kg	2510	58	<0.25	0.5	241
RDX	mg/kg	2510	39	<2	16	18500
Tetryl	mg/kg	2510	36	<1	2	722
TNT	mg/kg	2510	40	<0.5	20	29700

Table 2 – Soils, Explosives

Determinands	Units	No. Tested	No. Detected	Min.	Mean	Max.
2,4-DNT	mg/kg	32	0	<1	-	<40
2,6-DNT	mg/kg	32	0	<1	-	<40
EGDN	mg/kg	32	0	<1	-	<200
HMX	mg/kg	32	0	<2	-	<80
NC	mg/kg	32	15	<1000	30331	84400
NG	mg/kg	32	19	<1	302	2950
PETN	mg/kg	32	0	<5	-	<25
Picric Acid	mg/kg	32	0	<0.1	-	<1
Picrite	mg/kg	32	10	<0.25	12	174
RDX	mg/kg	32	4	<2	27	264
Tetryl	mg/kg	32	0	<1	-	<40
TNT	mg/kg	32	0	<0.5	-	<20

Table 3 – Drain Sediments, Explosives

Determinands	Units	No. Tested	No. Detected	Min.	Mean	Max.
Arsenic	mg/kg	647	625	<1	9	178
Antimony	mg/kg	460	24	<5	7	276
Barium	mg/kg	461	461	22	259	3230
Beryllium	mg/kg	461	407	<0.3	2	14.5
Bismuth	mg/kg	461	51	<2	2	10
Cadmium	mg/kg	647	229	<0.3	0.6	28.6
Chromium	mg/kg	647	635	<3	33	438
Copper	mg/kg	647	642	<2	138	18600
Lead	mg/kg	647	647	2	756	51200
Magnesium	mg/kg	461	461	165	5134	27200
Manganese	mg/kg	461	460	5	502	3290
Mercury	mg/kg	647	45	<1	1	15
Molybdenum	mg/kg	461	73	<2	2	24
Nickel	mg/kg	647	633	<3	40	248
Phosphorous	mg/kg	461	461	51	725	3580
Selenium	mg/kg	647	231	<1	1.3	16.5
Strontium	mg/kg	461	460	<5	81	1340
Tin	mg/kg	461	46	<20	24	372
Titanium	mg/kg	461	460	4	1023	5950
Vanadium	mg/kg	461	457	<3	67	2340
Zinc	mg/kg	647	647	3	349	40200

Table 4 – Soils, Metals

Determinands	Units	No. Tested	No. Detected	Min.	Mean	Max.
Acenaphthene	mg/kg	633	206	<0.1	0.6	44
Acenaphthylene	mg/kg	633	55	<0.1	0.2	6
Anthracene	mg/kg	633	320	<0.1	1.5	104
Benz(a)anthracene	mg/kg	633	452	<0.1	3.9	309
Benzo(a)pyrene	mg/kg	633	419	<0.1	4.2	305
Benzo(b)fluoranthene	mg/kg	633	447	<0.1	3.5	232
Benzo(ghi)perylene	mg/kg	633	396	<0.1	2.5	168
Benzo(k)fluoranthene	mg/kg	633	420	<0.1	3.2	250
Chrysene	mg/kg	633	492	<0.1	4.0	294
Dibenz(a,h)anthracene	mg/kg	633	203	<0.1	0.6	36.1
Fluoranthene	mg/kg	633	512	<0.1	9.1	726
Fluorene	mg/kg	633	185	<0.1	0.5	25.1
Indeno(1,2,3-cd)pyrene	mg/kg	633	364	<0.1	2.7	182
Naphthalene	mg/kg	633	328	<0.1	0.4	16.8
Phenanthrene	mg/kg	633	518	<0.1	4.4	281
Pyrene	mg/kg	633	508	<0.1	7.4	549

Table 5 – Soils, PAH

Determinands	Units	No. Tested	No. Detected	Min.	Mean	Max.
C5 to C6	mg/kg	430	13	<1.5	2.1	<12
>C6 to C8	mg/kg	430	15	<2.0	2.9	<16
>C8 to C10	mg/kg	430	49	<1.0	2.3	208
>C10 to C12	mg/kg	430	42	<2.0	7.3	1010
>C12 to C16	mg/kg	423	145	<20	54.3	4750
>C16 to C21	mg/kg	423	259	<20	161.4	10200
>C21 to C40	mg/kg	423	399	<20	604.9	22200
Benzene	mg/kg	430	3	<0.5	0.7	<4
Ethyl Benzene	mg/kg	430	0	<0.5	-	<4
m & p - Xylene	mg/kg	430	4	<0.5	0.7	<4
MTBE	mg/kg	430	0	<0.5	-	<4
o - Xylene	mg/kg	430	0	<0.5	-	<4
Toluene	mg/kg	430	3	<0.5	0.7	<4

Table 6 – Soils, TPH & BTEX

Determinands	Units	No. Tested	No. Detected	Min.	Mean	Max.
C6-C7 Aromatic (Benzene)	mg/kg	97	9	<0.02	0.03	0.09
>C7-C8 Aromatic(Toluene)	mg/kg	97	2	<0.1	0.15	3.6
>EC8-EC10 Aromatic	mg/kg	97	11	<1.0	1.40	15.1
>EC10-EC12 Aromatic	mg/kg	97	16	<1.0	6.14	202
>EC12-EC16 Aromatic	mg/kg	97	12	<10	20.57	367
>EC16-EC21 Aromatic	mg/kg	97	34	<10	47.73	915
>EC21-EC35 Aromatic	mg/kg	97	53	<20	103.09	1680
C5-C6 Aliphatic	mg/kg	97	2	<1.5	1.75	6
>C6-C8 Aliphatic	mg/kg	97	1	<2.0	-	11
>C8-C10 Aliphatic	mg/kg	97	14	<1.0	10.00	625
>C10-C12 Aliphatic	mg/kg	97	14	<2.0	23.84	878
>C12-C16 Aliphatic	mg/kg	97	18	<10	49.91	1260
>C16-C21 Aliphatic	mg/kg	97	41	<10	94.68	2710
>C21-C35 Aliphatic	mg/kg	97	64	<20	124.53	1880
MTBE	mg/kg	97	0	<0.1	-	<0.1
Benzene	mg/kg	97	9	<0.02	0.03	0.09
Toluene	mg/kg	97	2	<0.1	0.15	3.6
Ethyl Benzene	mg/kg	97	1	<0.1	-	<0.1
m & p-Xylene	mg/kg	97	7	<0.1	0.13	0.7
o-Xylene	mg/kg	97	3	<0.1	0.12	0.4

Table 7 – Soils, TPH (CWG) & BTEX

Note: TPH (CWG) analysis was generally scheduled where field observations noted visual or olfactory evidence of contamination, or in areas close to hydrocarbon storage tanks.

Determinands	Units	No. Tested	No. Detected	Min.	Mean	Max.
Naphthalene	mg/kg	100	4	<1.0	1.6	<10
2-Methylnaphthalene	mg/kg	100	7	<1.0	1.7	<10
Acenaphthene	mg/kg	100	4	<1.0	1.6	<10
4-Nitrophenol	mg/kg	100	1	<1.0	-	<10
Dibenzofuran	mg/kg	100	1	<1.0	-	<10
2,4-Dinitrotoluene	mg/kg	100	2	<1.0	1.5	<10
Fluorene	mg/kg	100	7	<1.0	1.6	<10
Phenanthrene	mg/kg	100	37	<1.0	4.6	86
Anthracene	mg/kg	100	14	<1.0	2.1	25
Di-n-butyl phthalate	mg/kg	100	9	<1.0	1.6	<10
Fluoranthene	mg/kg	100	45	<1.0	7.5	231
Pyrene	mg/kg	100	42	<1.0	6.9	211
Benzo(a)anthracene	mg/kg	100	41	<1.0	4.1	104
Chrysene	mg/kg	100	34	<1.0	4.1	107
Bis(2-ethylhexyl)phthalate	mg/kg	100	1	<1.0	-	<10
Di-n-octyl phthalate	mg/kg	100	1	<1.0	-	<10
Benzo(b)fluoranthene	mg/kg	100	30	<1.0	3.6	94
Benzo(k)fluoranthene	mg/kg	100	27	<1.0	3.6	93
Benzo(a)pyrene	mg/kg	100	34	<1.0	4.2	111
Indeno(1,2,3-cd)pyrene	mg/kg	100	17	<2.0	4.3	72
Dibenz(a,h)anthracene	mg/kg	100	3	<2.0	3.1	<20
Benzo(ghi)perylene	mg/kg	100	18	<2.0	4.3	72

Table 8 – Soils, Semi Volatile Organic Compounds (SVOC)

Note: Only those SVOCs detected above the reporting limit have been included in the summary table. 40 No. other compounds were tested for, but were not found in any samples.

Determinands	Units	No. Tested	No. Detected	Min.	Mean	Max.
Dichloromethane	ug/kg	107	18	<25	32	132
1,1,2-Trichloroethane	ug/kg	107	4	<25	41	689
Chlorobenzene	ug/kg	107	3	<25	28	50
Styrene	ug/kg	107	1	<25	-	<25
1,2,3-Trichloropropane	ug/kg	107	4	<25	45	1560
Bromobenzene	ug/kg	107	1	<25	-	<25
2-Chlorotoluene	ug/kg	107	3	<25	29	132
4-Chlorotoluene	ug/kg	106	3	<25	29	148
1,1,2,2-Tetrachloroethane	ug/kg	106	4	<25	53	2380
m,p-Xylene	ug/kg	107	4	<25	32	279
Isopropylbenzene	ug/kg	107	4	<25	46	1770
n-Propylbenzene	ug/kg	107	5	<25	31	197
1,3,5-Trimethylbenzene	ug/kg	106	5	<25	37	712
tert-Butylbenzene	ug/kg	107	3	<25	30	238
1,2,4-Trimethylbenzene	ug/kg	107	6	<25	236	20900
sec-Butylbenzene	ug/kg	107	6	<25	107	3540
p-Isopropyltoluene	ug/kg	107	7	<25	77	572
n-Butylbenzene	ug/kg	106	6	<25	121	5050
1,2,4-Trichlorobenzene	ug/kg	107	3	<25	104	200
Naphthalene	ug/kg	107	7	<25	105	241
1,2,3-Trichlorobenzene	ug/kg	107	5	<25	106	583

Table 9 – Soils, Volatile Organic Compounds VOC

Note 1: The laboratory indicated that 43 No. results for various determinands did not have an exact mass spectral match, which could possibly indicate an inflated result.

Note 2: Five samples had reporting limits raised to between 200µg/kg and 1200µg/kg for all determinands due to high moisture content and have not been included in the calculation of summary results.

Note 3: Reporting limits for 91 No. out of 107 No. results for 1,2,4-Trichlorobenzene, Naphthalene and 1,2,3-Trichlorobenzene and 46 No. out of 107 No. results for sec-Butylbenzene, p-Isopropyltoluene and n-Butylbenzene were raised to 100µg/kg or 200µg/kg, due to high retention of internal standards. Since the reporting limit is taken as the lowest value when calculating the mean, this has resulted in increased mean values for these determinands.

Note 4: Only those VOCs detected above the reporting limit have been included in the summary table.
38 No. other compounds were tested for, but were not found in any samples.

Determinands	Units	No. Tested	No. Detected	Min.	Mean	Max.
PCB 28	ug/kg	164	5	<1	6.0	275
PCB 52	ug/kg	164	13	<1	4.6	151
PCB 101	ug/kg	164	19	<1	6.3	310
PCB 118	ug/kg	164	21	<1	6.1	269
PCB 138	ug/kg	164	19	<1	5.0	151
PCB 153	ug/kg	164	20	<1	7.7	298
PCB 180	ug/kg	164	12	<1	2.9	28

Table 10 – Soils, PCB

Determinand	No. Tested	No. Detected	Max (%)
Amosite	2365	1	30.9
Chrysotile	2365	16	18
Crocidolite	2365	1	0.18

Table 11 – Soils, Asbestos

Solvents

Sixty samples from exploratory points located around acids tanks/buildings, above ground storage tanks (AST) and underground storage tanks (UST) were tested for a suite of 37 No. solvents. None were detected.

Asbestos Personal Monitoring

Personal asbestos monitoring was carried out between 8 December - 11 December 2008 whilst hand sampling around steam mains at AS21 – AS41. All results recorded <0.01Fibres/ml, which is within current guidelines for clearance certification.

Determinands	Units	No. Tested	No. Detected	Min.	Mean	Max.
pH	-	577	-	3.6	6.9	11.4
Total Monohydric Phenol	mg/kg	24	0	<0.15	-	<0.15
Sulphur	mg/kg	10	2	<20	3959	39400
Total Sulphate	mg/kg	454	445	50	1217	75000
Carbamite	mg/kg	20	7	<5	9.3	31.5
Water Soluble Sulphate	g/l	39	22	<0.003	0.02	0.5
Perchlorate	mg/kg	16	0	<1	-	<1

Table 12 – Soils, Other Determinands

4.3.1. Discussion

A full discussion of the soil results from the Stage 2 Site Investigation will be given in combination with results from previous investigations, in relation to the proposed development areas, as part of the interpretative report (B0060-00-R2-1).

4.4. Leachability Analysis

To take account of the link between soil and water environments and to provide an assessment of the potential for soil contamination to become mobilised and impact on the water environment, analysis of contaminant leachability from selected soil samples was also undertaken for each metal parameter, in accordance with Environment Agency Remedial Targets Methodology - Hydrogeological risk assessment for land contamination, Appendix B (2006).

In the Stage 2 assessment, leachability tests were scheduled on 201 No. samples according to BS EN 12457-1 Part 1 one stage batch test at a liquid to solid ratio of 2:1.

Leachate analytical results obtained in the Stage 2 investigation are given in Appendix 11 and summarised in Table 13.

A further 13 No. samples from the burning grounds investigation were previously analysed at a liquid to solid ratio of 10: 1, and have been summarised separately in Table 14.

As a conservative approach the reporting limit has been used as the lowest value when calculating the mean.

Determinands	Units	No. Tested	No. Detected	Min.	Mean	Max.
pH	n/a	209	-	2.9	6.8	10
As	mg/l	209	119	<0.25	4.3	102
Cd	mg/l	209	27	<0.05	0.1	6
Pb	mg/l	209	186	<0.05	6.4	252
Hg	mg/l	209	2	<0.1	0.1	0.4
Cu	mg/l	209	200	<0.05	8.0	220
Ni	mg/l	209	189	<0.1	4.1	143
Zn	mg/l	209	153	<0.5	43.5	1671
Cr	mg/l	209	184	<0.05	7.0	1137
Se	mg/l	209	13	<1	1.5	41
B	mg/l	209	209	1.9	101	1146
Ba	mg/l	209	177	<0.1	91.9	923
Be	mg/l	209	41	<0.1	0.4	29
Mn	mg/l	209	206	<0.05	61.2	1365
Mo	mg/l	209	54	<1.5	8.5	1205
Sb	mg/l	209	139	<0.1	1.4	63
Sn	mg/l	209	109	<0.1	0.7	12
Mg	mg/l	208	206	<0.1	7.2	171
V	mg/l	209	180	<0.05	5.5	166

Table 13 – 2:1 Leachability Summary Results

Determinands	Units	No. Tested	No. Detected	Min.	Mean	Max.
Arsenic	mg/l	13	2	<0.00075	0.0008	0.0011
Boron	mg/l	13	8	<0.02	0.06	0.15
Cadmium	mg/l	13	2	<0.00022	0.0002	0.0004
Chromium	mg/l	13	6	<0.001	0.005	0.044
Copper	mg/l	13	10	<0.0016	0.0263	0.27
Lead	mg/l	13	12	<0.00001	0.0535	0.29
Mercury	mg/l	13	2	<0.00001	0.00001	0.00004
Nickel	mg/l	13	10	<0.0015	0.0058	0.023
Selenium	mg/l	13	1	<0.001	-	<0.01
Zinc	mg/l	13	11	<0.005	1.125	9.4

Table 14 – 10:1 Leachability Summary Results

4.5. Duplicate Soil Sampling

Duplicate soil samples were taken at 127 No. locations and sent for identical analysis to ascertain the variability and the reproduction of chemical results. Representative composite samples were taken at each location in an attempt to ensure that the samples were as similar as possible.

A plan showing the locations where duplicate soil samples were collected is presented as Figure 8. Analytical results for duplicate soil samples are given in Appendix 12.

Findings

In general, the 38 No. results for **metals** showed good correlation, with the exception of one result for titanium, one result for copper and one result for magnesium showing significant variations.

Results for **explosives** (127 No.) generally showed good correlation, with the exception of one result for picrite, two results for Nitrocellulose (NC) and three results for Nitroglycerine (NG) showing significant variations.

In general, results for **leachability** (8 No.) showed good correlation, with the exception of one result for cadmium, one result for vanadium and four results for boron showing significant variations.

Results for **PAH** (35 No.) showed good correlation, with the exception of two or three determinands in 4 No. samples showing significant variations.

Results for **TPH** (33 No.) showed good correlation, with the exception of two samples showing significant variations.

In both original and duplicate samples (202 No. in total), **Asbestos** was not detected, showing good correlation of results.

In general, the 39 No. results for **VOCs and SVOCs** showed good correlation, with the exception of one result for pyrene, one result for fluoranthene and one result for 1,2,3-Trichlorobenzene showing significant variations.

Results for **sulphate** (22 No.), **percentage solids** (11 No.) and **pH** (7 No.) showed good correlation.

One duplicate sample was analysed for **PCB's**, none were detected in the original or duplicate sample.

Two duplicates were tested for **perchlorate**, and none were detected in the original or duplicate samples.

5. GEOTECHNICAL PROPERTIES

5.1. General

This appraisal summarises the condition and engineering properties of ground materials beneath the area proposed for the use of Sustainable Urban Drainage Systems (SUDS) and Flood Compensation. In addition, a preliminary assessment of the mound material has been undertaken to determine its potential re-use as part of the earthworks at the Site.

A geotechnical sampling location plan, which includes the locations of the SUDS ponds and Flood Compensation area is presented as Figure 9.

Assessment is based on observations during fieldworks and a limited program of geotechnical laboratory testing.

5.2. Ground Conditions Summary

Materials encountered during this investigation were generally consistent with those found during previous investigations and have been assigned material type codes depending on their composition. Fifteen different types of material have been identified and are shown in Table 15. Material codes will be used when referring to ground conditions on Site.

As part of the interpretative report, results from this investigation will be combined with data from previous investigations allowing the extent of the different types of materials across the Site to be determined.

Geology			Code	Description
Topsoil		Relict / Natural Topsoil	**TPSL**	Topsoil
Made Ground	**Type 1**	Made Ground: Reworked natural	**MGT1A**	Reworked natural or made ground with a little anthropogenic material.
		Made Ground	**MGT1B**	Made ground matrix with some, occasional or more anthropogenic material.
	Type 2	Soil with Ash and clinker	**MGT2A**	Made ground matrix with ash, clinker or blaes.
		Ash and Clinker as a unit	**MGT2B**	Ash, clinker or blaes. May contain occasional sands and gravels.
		Pulverised Fuel Ash	**MGT2C**	Pulverised Fuel Ash or made ground matrix with Pulverised Fuel Ash.
	Type 3	Fill Material	**MGT3**	Majority of material comprises variable fill of girders, cans, bricks, plastic, concrete etc
Hard standing (bitumen and concrete)			**HSTD**	Concrete flooring, bitumen surfaces, pavements, remains of old roads.
Superficial		Clippens Peat Formation	**CPF**	Soft Peat.
		Killearn Formation	**KF**	Glaciofluvial sands and gravels mainly comprising quartzite, sandstone and igneous with occasional silts and clays
		Linwood Paisley Formation	**LPF**	Glaciomarine silts and clays, occasionally slightly sandy/gravelly, varying in colour depending on state of weathering. Can be encountered as firm and occasionally stiff at the surface due to desiccation.
		Wilderness Till Formation	**WTF**	Firm to stiff silts and clays with varying amounts of sands and gravels. Can be encountered as soft at surface level due to weathering.
Solid		Clyde Plateau Volcanic Formation	**CPVF**	Intrusive igneous formation of Basalt.
		Lawmuir Formation	**LWMF**	Interbedded sandstones and mudstones.
		Lower Limestone Formation	**LLGS**	Interbedded sandstones, mudstones and limestone with occasional thin coal beds.

Table 15 – Material Type Codes

5.3. Material Properties

Representative samples were taken from selected trial pits and subjected to a geotechnical testing regime comprising:

- Moisture Content
- Atterberg Limits
- Particle Size Distribution including sedimentation analysis on selected samples
- Compaction Testing – 4.5 kg rammer and vibrating hammer methods
- Organic Matter analyses

Geotechnical testing was carried out by TerraTek at their laboratory in Airdrie, using UKAS accredited tests, where possible. The test certificates are presented in Appendix 13.

5.4. Proposed Sustainable Urban Drainage Systems (SUDS) Ponds

A total of 10 No. areas for the use of SUDS have been indicated at the Site. The majority of these are located within the Core Development Area (CDA) and to the immediate west of the core development area.

A total of 25 No. trial pits were excavated within the proposed SUDS pond areas: TP2135, TP2136, TP2211, TP2212, TP2289 - TP2299, TP2384 - TP2389 and TP2429 - TP2432.

Representative tub and bulk samples were recovered for geotechnical testing from these trial pits.

Atterberg Limits

A total of 12 No. Atterberg limit tests were undertaken on selected samples recovered from the proposed SUDS pond areas.

A sample from TP2361 at 1.0mbgl was recovered from MGT2A Made Ground and a Plasticity Index of 19% was recorded indicating a soil of low plasticity (CL).

Ten Atterberg Limit tests were undertaken on samples recovered from the Linwood/Paisley Formation. The Atterberg Limit test results for the Linwood/Paisley Formation encountered within the proposed SUDS Pond area are summarised in Table 16.

	Moisture Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
Maximum	52	56	40	25
Minimum	14	25	13	7
Average	29	39	25	14
Number	14	10	10	10

Table 16 - Atterberg Limit test summary for Linwood/Paisley Fm.

Interpretation using the Casagrande chart, of plasticity determinations on samples recovered from the Linwood and Paisley Formation indicates that the material may behave as a silt/clay of low to high plasticity (CL to CI/MH).

A sample from TP2136 at 2.7mbgl was recovered from the Wilderness Till Formation (WTF) and a Plasticity Index of 22% was recorded indicating a soil of intermediate plasticity (CI).

Particle Size Distribution

A total of 18 No. PSDs were undertaken followed by 14 No. sedimentation analyses from samples recovered from the proposed SUDS pond areas. The clay fraction of the soils was calculated with the percentage passing the 2 micron sieve.

A sample from TP2136 at 1.0mbgl was recovered from the MGT1A Made Ground and a silt fraction of 29.6% and a clay fraction of 15.7% was recorded. This material can be described as a clayey silty sand.

A sample from TP2429 at 0.4mbgl was recovered from the MGT1B Made Ground and a silt/clay fraction was noted to be absent. This material can be described as a slightly cobbly sandy gravel.

A sample from TP2432 at 1.0mbgl was recovered from the MGT2A Made Ground and a silt/clay fraction of 0.2% was recorded. This material can be described as a sand and gravel.

A total of 15 No. PSDs and 13 No. sedimentation analyses were undertaken on samples recovered from the Linwood/Paisley Formation (LPF) from the proposed SUDS pond areas.

Two PSD were undertaken on samples recovered from TP2212 at 1.7mbgl and TP2291 at 1.5mbgl. Combined silt/clay fractions of 9.2% and 3.8% were recorded for samples from TP2212 and TP2291. These materials have been described as silty sand and gravel.

Sedimentation analysis was undertaken on the remaining 13 No. samples and silt fractions ranging from 22.5% to 77.8% and clay fractions from 8.3% to 33.3% were recorded. A maximum silt fraction of 77.8% was recorded from a sample recovered from TP2298 at 2.3mbgl. A maximum clay fraction of 33.3% was recorded from a sample recovered from TP2290 at 1.0mbgl.

Compaction Testing

A total of 6 No. compaction tests using a 4.5kg rammer were undertaken on selected samples recovered from the proposed SUDS pond areas.

A compaction test was undertaken on MGT2A Made Ground from TP2297 at 0.8mbgl using the 4.5kg rammer. A maximum dry density of 1.59Mg/m³, at optimum moisture content of 16.6% and natural moisture content of 31% was recorded. Indicating that the Type 2a Made Ground within this area is wet of optimum.

A total of 5 No. compaction tests were undertaken on samples recovered from the LPF at depths ranging from 0.5mbgl to 2.4mbgl using the 4.5kg rammer. Maximum dry densities ranging from 1.72Mg/m³ (TP2294) to 1.9Mg/m³ (TP2387), at optimum moisture contents of 12% and 10.9% and natural moisture contents of 30% and 20% respectively. Thus indicating that the LPF encountered within the proposed SUDS pond areas is wet of optimum.

Organic Matter

A total of 7 No. organic matter tests were undertaken on samples recovered from the proposed SUDS areas.

Organic matter concentration of 1.1% was recorded for a sample of MGT1A Made Ground recovered from TP2136.

Organic matter concentration of 1.6% was recorded for a sample of MGT2A Made Ground recovered from TP2297.

Organic matter concentrations ranging from 0.9% (TP2291) to 2.0% (TP2430) were recorded for samples of the LPF from the proposed SUDS area.

5.5. Flood Compensation Area

The Flood Compensation area is located to the south of the CDA. A total of 5 No. trial pits were excavated, TP2360 - TP2363 and TP2548 being excavated within this area. Representative tub and bulk samples were recovered for geotechnical testing from these trial pits.

Atterberg Limits

A total of 3 No. Atterberg Limit tests were undertaken on selected samples recovered from depths ranging from 1.2mbgl to 1.8mbgl. Samples from TP2360 and TP2548 at depths of 1.8mbgl and 1.2mbgl respectively were recovered from the LPF. Plasticity Index of 9% (TP2360) and 10% (TP2548) was recorded indicating soils of low plasticity (CL).

Sample from TP2361 at 1.5mbgl was recovered from the WTF and a Plasticity Index of 8% was recorded indicating a soil of low plasticity (CL).

Particle Size Distribution

A total of 5 No. PSDs were undertaken followed by 2 No. sedimentation analyses. The clay fraction of the soils was calculated with the percentage passing the 2 micron sieve.

A sample from TP2260 at 0.5mbgl was recovered from the MGT1A Made Ground and a silt/clay fraction of 3.5% was recorded. This material can be described as a slightly silty gravelly sand.

A sample from TP2363 at 0.5mbgl was recovered from the MGT2A Made Ground and silt/clay fraction was noted to be absent. This material can be described as a sandy gravel.

A sample from TP2362 at 1.5mbgl was recovered from the Killearn Formation (KF) and a silt/clay fraction of 0.1% was recorded. This material can be described as a gravelly sand.

Samples from TP2360 and TP2548 at depths of 1.8mbgl and 1.2mbgl respectively were recovered from the LPF. A sedimentation analysis was undertaken on these samples and silt fractions of 75.9% and 35.7%, with clay fractions of 14.4% and 22.7% were recorded for TP2360 and TP2548 respectively.

5.6. Mound Material

A total of 30 No. trial pits have been excavated within the blast mounds at the Site. Fifteen trial pits were excavated within the blast mounds at the Site during March 2006 and comprised trial pits 26/117B, 28/501E, 28/100D, 24/312B, 16/007P, 29115, 28/112C, 34/212H, 24/212B, 43/302B, 43/311, 24/207B, 28/208S, 28/215C and 35/001J.

A further 15 No. trial pits were excavated within the blast mounds during the Stage 2 investigation and comprised trial pits TP2024, TP2052, TP2137, TP2227, TP2300 - TP2304, TP2364, TP2383, TP2435, TP2436, TP2484 and TP2684 for geotechnical testing.

Undrained Shear Strength

Undrained shear strength were estimated on site using a hand vane. Hand vane tests undertaken within 0.3mbgl were performed in-situ, deeper tests were undertaken on representative excavated blocks of cohesive soil. A total of 21 No. tests were undertaken.

A total of 9 No. hand vane tests were undertaken on the MGT1A Made Ground at depths of approximately 0.3mbgl. Shear strength values ranging from 12kN/m² to 85kN/m² were recorded.

A total of 4 No. hand vane tests were undertaken on the MGT1A Made Ground at depths of approximately 0.3mbgl. Shear strength values ranging from 30kN/m² to 95kN/m² were recorded.

A total of 3 No. hand vane tests were undertaken on the MGT2A Made Ground at depths ranging from 0.3mbgl to 1.0mbgl. Shear strength values ranging from 34kN/m² to 90kN/m² were recorded.

A total of 5 No. hand vane tests were undertaken on the LPF at depths ranging from 3.3mbgl to 5.0mbgl. Shear strength values ranging from 20kN/m² to 98kN/m² were recorded.

Atterberg Limits

A total of 33 No. Atterberg Limit tests were undertaken on selected samples recovered from the blast mounds.

Nineteen tests were undertaken on samples recovered from MGT1A Made Ground. The Atterberg Limit test results for the MGT1A Made Ground are summarised in Table 17.

	Moisture Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
Maximum	40	46	30	28
Minimum	11	22	10	7
Average	23	36	19	17
No. of Tests	23	19	19	19

Table 17 - Atterberg Limit test summary for Type 1a Made Ground.

Interpretation using the Casagrande chart, of plasticity determinations on MGT1A Made Ground indicates that the material may behave as a silt/clay of low to intermediate plasticity (CL to MI/CI).

A total of 4 No. Atterberg Limit tests were undertaken on the MGT1B Made Ground. The Atterberg Limit test results for the MGT1B Made Ground are summarised in Table 18.

	Moisture Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
Maximum	35	50	26	24
Minimum	15	34	14	20
Average	24	42	19	22
No. of Tests	5	4	4	4

Table 18 - Atterberg Limit test summary for Type 1b Made Ground

Interpretation using the Casagrande chart, of plasticity determinations on MGT1B Made Ground indicates that the material may behave as a clay of low to intermediate plasticity (CL to CI).

A total of 4 No. Atterberg Limit tests were undertaken on the MGT2A Made Ground. The Atterberg Limit test results for the MGT2A Made Ground (excluding TP2302) are summarised in Table 19.

	Moisture Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
Maximum	30	39	21	21
Minimum	15	33	16	16
Average	21	36	18	18
No. of Tests	8	3	3	3

Table 19 - Atterberg Limit test summary for MGT2A Made Ground

An Atterberg Limit test was undertaken on a sample recovered from MGT2A Made Ground at TP2302. The Atterberg Limit test confirmed this sample as non-plastic. Interpretation using the Casagrande chart, of plasticity determinations on MGT2A Made Ground indicates that the material may generally behave as a clay of low to intermediate plasticity (CL to CI).

A total of 8 No. moisture content tests were undertaken on the MGT2A Made Ground and values ranging from 15% to 30% with an average of 21% were recorded.

A total of 6 No. Atterberg Limit tests were undertaken on samples recovered from the LPF. The Atterberg Limit test results for the LPF are summarised in Table 20.

	Moisture Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
Maximum	44	53	32	21
Minimum	9	21	11	10
Average	27	38	21	17
No. of Tests	7	6	6	6

Table 20 - Atterberg Limit test summary for the Linwood/Paisley Fm

Interpretation using the Casagrande chart, of plasticity determinations on the LPF indicates that the material may behave as a clay of low to high plasticity (CL to CH).

Particle Size Distribution

A total of 14 No. PSDs were undertaken followed by 12 No. sedimentation analyses from samples recovered from the blast mounds. The clay fraction of the soils was calculated with the percentage passing the 2 micron sieve.

A total of 6 No. PSD tests and sedimentation analysis were undertaken on samples recovered from the MGT1A Made Ground. Silt fractions of between 22.9% and 68%, with clay fractions of between 0.8% and 24.1% were recorded. This material can be described as a silty clay and silty sand/gravel.

A total of 6 No. PSD tests and 4 No. sedimentation analyses were undertaken on samples recovered from the MGT2A Made Ground.

Silt/clay fractions of 0.1% and 0.2% were recorded for samples recovered from TP2024 and TP2031 respectively. These soils can be described as sand and gravel.

Silt fractions of between 21.6% and 40%, with clay fractions of between 7.1% and 16.8% were recorded for the MGT2A Made Ground. This material can be described as a silty sand and silty clay.

A total of 2 No. PSD tests and sedimentation analysis were undertaken on samples recovered from the LPF at TP2137 and TP2227. Silt fractions of 37.4% and 36.1%, with clay fractions of 21.9% and 12% were recorded for TP2137 and TP2227 respectively. This material can be described as a sandy clayey silt.

Particle Density

A total of 3 No. Particle Density tests were undertaken on samples recovered from the MGT1A Made Ground. Particle densities of 2.66Mg/m³, 2.69Mg/m³ and 2.70Mg/m³ were recorded for samples recovered from trial pits TP16/007P, TP28/208S and TP35/100J.

A Particle Density of 2.68Mg/m³ was recorded for a sample from the MGT2A Made Ground from trial pit TP29/115.

Compaction Testing

A total of 16 No. compaction tests using a 4.5kg rammer were undertaken on selected samples recovered from the blast mounds.

A total of 9 No. compaction tests were undertaken on MGT1A Made Ground using the 4.5kg rammer. Maximum dry densities ranging from 1.62Mg/m³ (TP2364) to 2.23Mg/m³ (TP28/112C), at optimum moisture contents of 16.5% and 6.8% and natural moisture contents of 33% and 11% respectively. Indicating that the MGT1A Made Ground encountered within the blast mound is wet of optimum.

A total of 2 No. compaction tests were undertaken on MGT1B Made Ground using the 4.5kg rammer. A maximum dry density of 1.88Mg/m³ at an optimum moisture content of 15% and natural moisture content of 24% was recorded for a sample recovered from TP28/100D. A maximum dry density of 2.02Mg/m³ at an optimum moisture content of 11% and natural moisture content of 19% was recorded for a sample recovered from TP34/212B. Indicating that the MGT1B Made Ground encountered within the blast mound is wet of optimum.

A total of 5 No. compaction tests were undertaken on MGT2A Made Ground using the 4.5kg rammer. Maximum dry densities ranging from 1.91Mg/m³ (TP2484) to 2.02Mg/m³ (TP34/212H), at optimum moisture contents of 10.1% and 12% and natural moisture contents of 26% and 20% respectively. Indicating that the MGT2A Made Ground encountered within the blast mound is wet of optimum.

California Bearing Ratio (CBR) Tests

A total of 12 No. CBR tests were undertaken on representative samples from 4 No. blast mounds. The CBR tests were undertaken at optimum moisture content, below optimum moisture content and above optimum moisture content. The optimum moisture contents were derived from the compaction tests.

A total of 3 No. CBR tests were undertaken on the MGT1A Made Ground. CBR values at below the optimum moisture content ranged from 51% to >100%. CBR values at optimum moisture content ranged from 19% to 36%. CBR values above the optimum moisture content ranged from 2.2% to 5.6%.

A CBR test was undertaken on the MGT2A Made Ground. A CBR value at below the optimum moisture content of 60% was recorded. A CBR value at the optimum moisture content of 9.5% was recorded. A CBR value at above the optimum moisture content of 4.7% was recorded.

Organic Matter

A total of 3 No. organic matter tests were undertaken on made ground samples recovered from the blast mounds at the Site.

Organic matter concentration of 1.4% was recorded for a sample of MGT1A Made Ground recovered from TP2303.

Organic matter concentrations of 1.3% and 1.7% were recorded for samples of MGT2A Made Ground recovered from TP2304 and TP2435 respectively.

6. GROUNDWATER

6.1. Introduction

Ninety three boreholes and twenty two window sample boreholes were drilled for groundwater monitoring purposes during the Stage 2 Site Investigation.

Groundwater monitoring was carried out between 2 December 2008 and 23 March 2009, with the exception of one round of sampling of boreholes in the burning grounds, which took place on 21 July 2008. Details of the monitoring rounds carried out are given in section 3.2 and monitoring records for groundwater are given in Appendix 7. A groundwater monitoring point location plan is given in Figure 10.

6.2. Groundwater Observations

In order to obtain a comparable set of groundwater level data, water table levels in the superficial boreholes and piezometric levels within the bedrock boreholes were recorded in all boreholes between 3 March and 5 March 2009 using a Solinst dip meter.

Details of groundwater strikes during drilling, response zones and rest groundwater levels recorded in early March are given in Table 21.

Borehole	Strike During Drilling (mbgl)	Strata Groundwater Strike Encountered	Response Zone of Installation	Rest Level * on 3 – 5 March	Rest Level (mAOD) on 3 – 5 March
Superficial Boreholes					
BH2001	1.00	Made Ground	Linwood/Paisley Fm	1.00	9.93
BH2002	6.10	Sandstone	Linwood/Paisley Fm	0.00	12.29
BH2003	2.40	Made Ground	Killearn Fm	0.95	16.20
BH2041	1.20	Sand	Linwood/Paisley Fm	0.66	8.42
BH2061	Dry	-	Killearn Fm	Dry	Dry
BH2063	Dry	-	Wilderness Till Fm	1.38	10.87
BH2091	0.80	Made Ground	Linwood/Paisley Fm	0.70	15.50
BH2092	Dry	-	Linwood/Paisley Fm	2.60	10.77
BH2093	5.30	Sandstone	Linwood/Paisley Fm	1.28	10.52
BH2198	4.00	Linwood/Paisley Fm	Linwood/Paisley Fm	1.67	8.73
BH2199	Dry	-	Wilderness Till Fm	1.66	9.54
BH2221	3.00	Linwood Paisley Fm	Linwood/Paisley Fm	0.00	10.06
BH2222	1.20	Made Ground	Made Ground (MGT2B)	0.93	9.17
BH2224	1.24	Wilderness Till Fm	Made Ground (MGT1B)/ Wilderness Till Fm	0.89	9.90
BH2225	2.00	Linwood Paisley Fm	Linwood/Paisley Fm	0.45	9.23
BH2226	2.35	Linwood/Paisley Fm	Linwood/Paisley Fm	1.42	8.67
BH2259	Dry	-	Made Ground (MGT1A)	1.93	10.49
BH2260	Dry	-	Linwood/Paisley Fm	1.07	10.32
BH2261	0.80	Made Ground	Killearn Fm	0.22	10.41
BH2262	4.20	Linwood Paisley Fm	Linwood/Paisley Fm	1.41	10.38
BH2263	2.50	Linwood Paisley Fm	Linwood/Paisley Fm	0.71	9.60
BH2264	6.80	Gravel	Killearn Fm	0.77	11.14
BH2265	Dry	-	Wilderness Till Fm	1.31	9.59
BH2266	2.35	Linwood Paisley Fm	Linwood/Paisley Fm	1.43	9.27
BH2267	4.60	Linwood Paisley Fm	Linwood/Paisley Fm	1.12	8.62

Borehole	Strike During Drilling (mbgl)	Strata Groundwater Strike Encountered	Response Zone of Installation	Rest Level * on 3 – 5 March	Rest Level (mAOD) on 3 – 5 March
BH2268	7.00	Linwood Paisley Fm	Linwood/Paisley Fm	1.88	8.37
BH2269	4.50	Wilderness Till Fm	Made Ground (MGT1A)/ Wilderness Till Fm	1.85	8.94
BH2348	4.00	Gravel	Killearn Fm	1.67	8.57
BH2349	3.90	Linwood Paisley Fm	Linwood/Paisley Fm	1.26	6.97
BH2350	5.00	Wilderness Till Fm	Wilderness Till Fm	0.86	9.57
BH2351	1.20	Linwood/Paisley Fm	Linwood/Paisley Fm	0.49	7.23
BH2352	5.65	Linwood Paisley Fm	Linwood/Paisley Fm	0.61	7.43
BH2353	Dry	-	Linwood/Paisley Fm	0.49	10.26
BH2354	1.45	Made Ground	Linwood/Paisley Fm	1.36	6.94
BH2355	0.50	Peat	Linwood/Paisley Fm	0.54	8.12
BH2379	10.00	Linwood/Paisley Fm	Linwood/Paisley Fm	0.36	8.91
BH2412	Dry	-	Wilderness Till Fm	0.24	11.21
BH2413	Dry	-	Wilderness Till Fm	0.70	10.39
BH2414	0.50	Made Ground	Wilderness Till Fm	0.38	11.06
BH2415	Dry	-	Linwood/Paisley Fm	1.13	9.79
BH2477	5.00	Wilderness Till Fm	Wilderness Till Fm	1.00	10.40
BH2529	7.00	Linwood Paisley Fm	Linwood/Paisley Fm	1.35	8.23
BH2530	0.80	Linwood Paisley Fm	Linwood/Paisley Fm	0.62	8.74
BH2531	Dry	-	Linwood/Paisley Fm	1.92	8.02
BH2532	1.35	Made Ground	Made Ground (MGT1A)/ Linwood/Paisley Fm	1.40	9.69
BH2533	0.90	Made Ground	Linwood/Paisley Fm	0.77	9.00
BH2534	0.40	Made Ground	Linwood/Paisley Fm	0.56	7.87
BH2535	2.00	Linwood Paisley Fm	Linwood/Paisley Fm	1.97	6.43
BH2537	Dry	-	Wilderness Till Fm	0.46	9.24
BH2583	1.20	Linwood/Paisley Fm	Linwood/Paisley Fm	1.51	11.47
BH2584	4.60	Linwood/Paisley Fm	Linwood/Paisley Fm	1.10	10.11
BH2585	1.90	Made Ground	Linwood/Paisley Fm	0.16	10.56
BH2586	3.40	Linwood/Paisley Fm	Wilderness Till Fm	0.80	9.83
BH2587	2.00	Made Ground	Made Ground (MGT2A)	1.60	7.54
BH2588	7.00	Linwood/Paisley Fm	Linwood/Paisley Fm	1.33	9.74
BH2635	4.30	Linwood/Paisley Fm	Linwood/Paisley Fm	1.10	8.50
BH2636	5.00	Linwood/Paisley Fm	Linwood/Paisley Fm	0.99	8.08
BH2643	0.40	Peat	Wilderness Till Fm	0.53	11.97
BH2644	5.25	Linwood Paisley Fm	Linwood/Paisley Fm	1.44	9.48
BH2648	1.00	Made Ground	Wilderness Till Fm	0.89	13.81
BH2651	6.00	Linwood Paisley Fm	Wilderness Till Fm	0.94	11.08
BH2662	3.85	Linwood/Paisley Fm	Linwood/Paisley Fm	2.38	20.49
BH2663	0.40	Sand & Gravel	Wilderness Till Fm	1.28	21.83
BH2666	Dry	-	Linwood/Paisley Fm	1.02	8.32
BH2667	5.75	Linwood Paisley Fm	Linwood/Paisley Fm	1.25	7.50
BH2668	0.30	Made Ground	Linwood/Paisley Fm	0.45	7.14
BH2669	5.00	Linwood Paisley Fm	Linwood/Paisley Fm	0.58	7.26
BH2670	4.45	Linwood Paisley Fm	Linwood/Paisley Fm	1.70	6.08
BH2671	2.25	Made Ground	Linwood/Paisley Fm	1.42	5.82
BH2672	0.90	Linwood/Paisley Fm	Linwood/Paisley Fm	1.14	4.96
BH2673	3.00	Linwood Paisley Fm	Linwood/Paisley Fm	0.85	6.41
BH2674	2.00	Linwood Paisley Fm	Linwood/Paisley Fm	1.24	5.55
BH2675	6.45	Linwood Paisley Fm	Linwood/Paisley Fm	1.38	6.48
BH2676	Dry	-	Linwood/Paisley Fm	1.56	7.76
BH2677	1.10	Sand	Linwood/Paisley Fm	1.09	9.51
BH2678	1.30	Made Ground	Linwood/Paisley Fm	0.87	9.78
BH2679	3.30	Peat	Linwood/Paisley Fm	2.75	9.92
BH2680	Dry	-	Linwood/Paisley Fm	1.36	8.44

Borehole	Strike During Drilling (mbgl)	Strata Groundwater Strike Encountered	Response Zone of Installation	Rest Level * on 3 – 5 March	Rest Level (mAOD) on 3 – 5 March
BH2681	4.00	Linwood/Paisley Fm	Wilderness Till Fm	1.61	5.63
BH2725	0.90	Sand	Wilderness Till Fm	2.38	29.60
BH3084	1.30	Made Ground	Linwood/Paisley Fm	1.04	10.09
BH3085	1.10	Peat	Linwood/Paisley Fm	0.83	9.75
WS2645	1.20	Peat	Linwood/Paisley Fm	1.86	9.91
WS2646	1.20	Peat	Peat	0.47	12.52
WS2647	Dry	-	Peat	0.55	14.12
WS2649	1.60	Made Ground	Peat	0.76	15.23
WS2650	1.20	Peat	Linwood/Paisley Fm	1.40	9.87
WS3086	2.00	Peat	Linwood/Paisley Fm	0.31	11.52
WS3087	0.40	Peat	Linwood/Paisley Fm	1.52	12.07
WS3088	1.20	Peat	Peat & Linwood/Paisley Fm	0.77	13.15
WS3089	1.20	Peat	Linwood/Paisley Fm	2.69	9.25
WS3090	Dry	-	Linwood/Paisley Fm	0.70	10.79
WS3091	0.50	Peat	Peat & Linwood/Paisley Fm	0.43	12.07
WS3092	Dry	-	Peat	0.60	13.47
WS3093	1.60	Peat	Peat	0.43	13.58
WS3094	Dry	-	Peat	0.63	14.46
WS3095	2.80	Sandstone	Linwood/Paisley Fm / Wilderness Till Fm	2.03	11.72
WS3096	1.20	Sand	Linwood/Paisley Fm	1.23	11.10
WS3097	2.20	Sand	Killearn Fm	1.55	13.92
WS3098	3.00	Sand	Killearn Fm	1.29	9.51
WS3099	1.60	Wilderness Till Fm	Wilderness Till Fm	1.09	11.33
WS3100	Dry	-	Linwood/Paisley Fm	1.84	8.41
WS3101	1.10	Wilderness Till Fm	Wilderness Till Fm	0.64	10.64
WS3102	1.10	Wilderness Till Fm	Wilderness Till Fm	1.11	10.02
Bedrock Boreholes					
BH2223	20.00	Basalt	Clyde Plateau Volcanic Fm	2.18	23.05
BH2356	39.00	Sandstone	Sandstone	0.00	8.29
BH2380	36.00	Basalt	Clyde Plateau Volcanic Fm	1.61	9.56
BH2416	24.50	Sandstone	Sandstone	1.73	10.50
BH2528	14.00	Basalt	Clyde Plateau Volcanic Fm	3.63	17.65
BH2536	32.00	Mudstone	Mudstone	1.24	9.33
BH2652	32.00	Mudstone	Mudstone	2.18	12.28
BH2653	36.50	Mudstone/Siltstone	Mudstone	1.02	11.68
BH2664	19.80	Basalt	Clyde Plateau Volcanic Fm	1.08	32.80
BH2682	32.00	Mudstone	Mudstone	0.28	7.79
BH2683	23.00	Basalt	Clyde Plateau Volcanic Fm	2.24	10.82

Table 21 - Groundwater Strikes & Observations in superficial and bedrock monitoring boreholes

* metres below top of cover (cover height is generally 0.2 to 0.4m above ground level)

Summary

Rest water levels in the superficial deposits are generally between 0.5 and 1.5mbgl.

In the bedrock, piezometric levels were found to be between 0.28 and 3.63mbgl, with boreholes BH2002, BH2221, BH2261, BH2356, BH2379, BH2412 and BH2585 recording artesian groundwater conditions (rest water level above ground level).

6.3. Groundwater Flow

Shallow groundwater Flow

To determine shallow groundwater flow direction, groundwater levels were compared both between boreholes and relative to nearby surface watercourses and drainage channels. It is considered that shallow groundwater flow direction is predominantly towards the nearest surface watercourse and is locally determined by the presence of the existing natural drainage network.

Shallow groundwater is shown to be flowing into the Site from the northern, western and north-eastern boundaries, with localised flow towards the Dargavel Burn and its tributaries, which in turn flow in a southerly direction from the Site towards the River Gryfe.

In the vicinity of the ponds within the CDA, the shallow groundwater flow is towards these surface water features and the Craigton Burn.

In the vicinity of the picrite lagoons, located on the eastern boundary of the Site, within retained land (RL), there appears to be a “recharge mound” associated with these lagoon features. As a result, there is a radial groundwater flow pattern centred on the lagoons, with shallow groundwater flowing in towards the centre of the Site in a westerly direction, and out of the Site in an easterly direction.

Bedrock Groundwater Flow

Groundwater levels were measured in 13 No. bedrock boreholes (6 No. in Clyde Plateau Volcanic Formation, 3 No. in Lawmuir Formation and 4 No. in Lower Limestone Formation). No regional flow direction was apparent from the available information in the Clyde Plateau Volcanic Formation or the Lawmuir Formation. However, from the general decline in topography from the north–west to the south-east across the site and the piezometric levels recorded in the Lower Limestone Formation, it is considered that regional groundwater flow will be towards the south and south-east.

A full assessment of groundwater occurrence in both the superficial deposits and bedrock and an interpretation of groundwater flow directions will be made within the interpretative report.

6.4. In-Situ Permeability Testing

Rising head permeability tests were carried out on 12 No. boreholes between 11 February and 19 March. Three tests were undertaken in the bedrock aquifers, with the remainder carried out in a range of soils types identified on site.

Groundwater was removed from the borehole using a PP1 Powerpack pump until the measured level had fallen by at least 2m. Groundwater levels were then recorded during a period of recovery sufficient to allow calculations of permeability using the method detailed in BS5930:1999 Code of Practice for Site Investigations (Incorporating Amendment No.1, December 2007).

Field measurements and calculations used to determine permeability are presented in Appendix 14. A summary of the results are shown below in Table 22.

Borehole	Response Zone	Permeability (m/s)
Superficial Boreholes		
ASPA	Linwood/Paisley Fm	5.4×10^{-7}
WS3098	Killearn Fm	1.4×10^{-7}
WS3087	Linwood/Paisley Fm	1.6×10^{-7}
BH1412	Linwood/Paisley Fm	2.5×10^{-5}
BH2225	Linwood/Paisley Fm	7.4×10^{-7}
BH2264	Killearn Fm	1.0×10^{-6}
BH2648	Wilderness Till Fm	2.0×10^{-7}
BH2669	Linwood/Paisley Fm	2.4×10^{-7}
BH2671	Linwood/Paisley Fm	1.0×10^{-6}
Bedrock Boreholes		
LPI09BH	Clyde Plateau Volcanic Fm	9.3×10^{-6}
BH1074D	Lawmuir Fm	2.0×10^{-5}
BH2682	Lower Limestone Fm	2.2×10^{-6}

Table 22 - Permeability Test Results

6.5. Summary Groundwater Analytical Results

Groundwater samples were analysed for a range of determinands (including explosives, metals, PAHs, TPHs and others) detailed in the Stage 2 Site Investigation Strategy (Appendix 2). A summary of results for both shallow and deeper groundwater are given in the following tables and discussed below. Analytical results are given in Appendix 15.

Summary explosive results have not been tabulated, but are discussed below.

Determinands	Units	No. Tested	No. Detected	Min.	Max.
Al	µg/l	7	6	1.0	6.6
As	µg/l	281	231	<0.25	476
B	µg/l	281	270	<1	1,996
Cd	µg/l	281	33	<0.05	3.8
Cr	µg/l	281	142	<0.05	18
Hexavalent Cr	µg/l	274	3	<5	22
Cu	µg/l	281	271	<0.05	79
Fe	mg/l	280	243	<0.0005	1,060
Hg	µg/l	281	1	<0.1	0.4
Ni	µg/l	281	273	<0.10	129
Pb	µg/l	281	51	<0.05	70
Se	µg/l	281	8	<1	1.8
Zn	µg/l	281	226	<0.5	1,316

Table 23 - Groundwaters, Metals

Determinands	Units	No. Tested	No. Detected	Min.	Max.
1,2:5,6 Dibenzanthracene	µg/l	280	6	<0.02	0.34
Acenaphthene	µg/l	280	13	<0.02	0.47
Acenaphthylene	µg/l	280	6	<0.02	0.30
Anthracene	µg/l	280	12	<0.02	0.47
Benzanthracene	µg/l	280	10	<0.02	0.39
Benzo(b)fluoranthene	µg/l	280	15	<0.02	0.44
Benzo(g,h,i)perylene	µg/l	280	8	<0.02	0.53
Benzo(k)fluoranthene	µg/l	280	15	<0.02	0.39
Benzo-a-pyrene	µg/l	280	10	<0.02	0.40
Chrysene	µg/l	280	11	<0.02	0.37
Fluoranthene	µg/l	280	42	<0.02	4.24
Fluorene	µg/l	280	11	<0.02	0.96
Indeno (1,2,3-CD) pyrene	µg/l	280	9	<0.02	0.50
Naphthalene	µg/l	280	83	<0.02	7.73
Phenanthrene	µg/l	280	42	<0.02	1.62
Pyrene	µg/l	280	38	<0.02	2.77
Total PAH	µg/l	280	25	<0.2	11

Table 24 - Groundwaters, PAH

Determinands	Units	No. Tested	No. Detected	Min.	Max.
GRO Range Hydrocarbons	mg/l	139	0	<0.01	<0.01
DRO Range Hydrocarbons	mg/l	139	5	<0.01	0.06
MRO Range Hydrocarbons	mg/l	139	5	<0.01	0.14
Total Petroleum Hydrocarbons	mg/l	139	6	<0.01	0.17

Table 25 - Groundwaters, TPH

Determinands	Units	No. Tested	No. Detected	Min.	Max.
1,12-Benzoperylene	µg/l	137	2	<0.1	0.35
1,2-Benzanthracene	µg/l	137	1	<0.1	0.11
1,2-Dichlorobenzene	µg/l	137	2	<0.1	0.25
1,3-Dichlorobenzene	µg/l	137	1	<0.1	0.17
2,6-Dinitrotoluene	µg/l	137	1	<0.1	0.17
2-Methylphenol	µg/l	137	1	<0.1	1.18
4-Methylphenol	µg/l	137	2	<0.1	1.66
Acenaphthene	µg/l	137	1	<0.1	0.35
Anthracene	µg/l	137	1	<0.1	0.16
Benzo(a)pyrene	µg/l	137	5	<0.1	0.18
Benzo(b)/(k) fluoranthene	µg/l	137	4	<0.1	0.35
Butyl benzyl phthalate	µg/l	137	6	<0.1	4.53
Chrysene	µg/l	137	2	<0.1	0.21
Diethyl phthalate	µg/l	137	6	<0.1	0.66
Di-n-octyl phthalate	µg/l	137	2	<0.1	2.5
Fluoranthene	µg/l	137	12	<0.1	1.68
Fluorene	µg/l	137	3	<0.1	0.13
Indeno(1.2.3-C.D)pyrene	µg/l	137	3	<0.1	0.12
Napthalene	µg/l	137	11	<0.1	0.4
Phenanthrene	µg/l	137	7	<0.1	0.4
Phenol	µg/l	137	16	<0.1	0.59
Pyrene	µg/l	137	5	<0.1	1.16

Note: A further 32No. SVOCs were tested for, but were not detected in any samples. See appended results

Table 26 - Groundwaters, Detected SVOCs

Determinands	Units	No. Tested	No. Detected	Min.	Max.
pH	-	280	280	4.3	12.2
Ammoniacal Nitrogen	mg/l	280	276	<0.01	2,850
Chloride	mg/l	78	75	<5	2,383
Cyanide (Free)	mg/l	280	8	<0.03	0.05
Cyanide (Total)	mg/l	280	11	<0.03	0.08
Hardness	mg/l	76	76	28	894
Phenol	µg/l	281	16	<0.1	0.6
Phosphate	mg/l	75	38	<0.2	12
Sulphate	mg/l	280	231	<0.03	1,815
Sulphide	mg/l	277	11	<0.03	9.2
Thiocyanate	mg/l	270	157	<0.1	1.5

Table 27 - Groundwater, Others

Explosives

All shallow and bedrock groundwater monitoring boreholes were sampled for explosives. All samples were analysed for the presence of picrite, picric acid, EGDN, HMX, RDX, TNT, Tetryl, NG, PETN, 2,4 DNT and 2,6 DNT. Samples were initially tested at a laboratory reporting limit of 50µg/l.

Picrite was the only explosive detected during all initial rounds in 4 No. shallow monitoring boreholes located around the picrite lagoons (ASPA, BH2679, WS3087 and WS3094). Reported concentrations ranged between 199µg/l to 30,400µg/l.

Shallow groundwater sampled from PER22 contained more silt than water, which resulted in a raised reporting limit of 500µg/l. No explosives were detected in this borehole.

Explosives-Lower reporting Limit

Following on going discussions with the regulator regarding assessment criteria for explosives in waters, it was decided by BAE Systems Environmental to carry out further analysis on 44 No. baseline shallow and bedrock boreholes at a lower (non-UKAS) reporting limit of 10µg/l. These samples were collected between 8 and 15 April 2009.

Picrite was detected in the shallow groundwater with concentrations ranging from 18µg/l to 4480µg/l in four boreholes adjacent to the picrite lagoons (ESGF, ESGC, ESGD and ASPA).

Picrite was also detected at 63µg/l in PER22 located adjacent to a burning ground, and at 144µg/l in PER04 located in an ash tip.

EGDN was detected between 11µg/l and 16µg/l in shallow borehole BH1412 next to the main burning ground, ESGF located next to the picrite lagoons and BH1622 located adjacent to a Nitrocellulose (NC) handling house in Ball Powder.

Explosives in Bedrock groundwater

Picrite was reported on one occasion in bedrock boreholes BH2536 (68µg/l) and BH2683 (83µg/l). Both boreholes were re-sampled during two subsequent rounds at a lower reporting limit of <10ug/l. No explosives were detected during these subsequent rounds. BAE Systems Environmental are confident that there are unlikely to be explosives present within the bedrock aquifers.

Metals

Arsenic was detected in 231 No. samples ranging from 0.17µg/l to 476.0µg/l. The highest concentrations were found in shallow boreholes associated with ash tips (PER02 and PER04) and burning grounds (PER22 and BH2673). Arsenic was detected during both rounds of monitoring in bedrock borehole BH2683 at 50µg/l and 70µg/l.

Notable concentrations of **boron** between 1215µg/l and 1996µg/l were detected in shallow boreholes associated with ash tips (BH2680, PER02, PER04) and PER22 adjacent to a burning ground. Samples from bedrock borehole BH2683 contained boron at 1035µg/l and 1215µg/l.

Cadmium was detected in 33 No. samples. Concentrations were generally marginally above the reporting limit. The highest concentration was found in shallow borehole BH2679, which is located on an ash tip.

PER22, located next to a burning ground, contained the maximum concentration of **chromium** detected (18µg/l). Other notable concentrations between 7µg/l and 10µg/l were found in shallow borehole BH2265 next to an acetone tank and window

sample boreholes WS2646, WS3089 and WS3091 to the west of the picrite lagoons.

Hexavalent chromium was detected in shallow borehole BH2265 during both rounds of sampling at 7.1µg/l and 10µg/l. Shallow borehole BH2636 next to Dargavel House contained 22µg/l during one round of sampling.

Iron was detected ranging from 12 to 1,060 mg/l in shallow boreholes BH2643, WS3087 and WS3088 in the east of the Site near the picrite lagoons, BH2669 in the sulphur dump and BH2680 beside a road near the magazines in Georgetown.

Lead was detected in 51 No. samples with notable concentration in 6 No. shallow boreholes to the west and south of the picrite lagoons ranging from 14µg/l to 70 µg/l. Five of these boreholes did not contain lead above the reporting limit in the second round of sampling.

Mercury was detected in one sample (shallow borehole BH2268) at 0.4µg/l.

Concentrations of **copper** up to 79µg/l were found in shallow boreholes BH1504 and BH2679, which are both associated with ash tips, and WS3095 located next to an electrical substation.

Nickel ranging from 37µg/l to 129µg/l was detected in 3 No. shallow boreholes in the sulphur dump (BH1504, BH2668 and BH2669), one associated with an ash tip/Refuse Coup (BH2679) and one next to the large boiling out unit in ammunition breakdown (BH2477).

Zinc ranging from 387µg/l to 1316µg/l was detected in 4 No. shallow boreholes associated with ash tips (GT10, ESGD, BH2679 and BH1504). Other notable concentrations (77µg/l to 90µg/l) were detected in 3 No. shallow boreholes to the west of the picrite lagoons (ESGJ, WS2649 and WS3092) and BH2583 next to a clothing store and lead compound. Bedrock borehole BH2356 contained zinc at 221µg/l in one round of sampling.

PAHs

PAHs greater than the reporting limit were detected in 81 No. samples from across the Site. Generally total PAHs were less than the reporting limit. Notable concentrations of total PAH ranged from 1.1µg/l to 11.0µg/l in shallow boreholes BH1623, ESGD, ESGC, WS3091, BH2643, WS3099, WS2650, WS3098 and BH2648.

Total PAHs at 2.5µg/l were detected during one round in bedrock borehole BH2683.

TPHs

TPHs were detected in 3No. shallow boreholes up to a maximum concentration of 0.09mg/l (BH2678). Possible fuel types were noted as ‘mineral oil’ in BH2678 and BH2586, and as ‘weathered diesel’ in BH2537.

Possible ‘mineral oil’ was found in 2 No. bedrock boreholes (BH2682 & BH2683) up to a maximum concentration of 0.17mg/l.

SVOCs

SVOCs were detected in 46 No. samples. The maximum concentration of 4.5µg/l butyl benzyl phthalate was found in shallow borehole BH2644 next to a tyre store/coal store. The most commonly detected SVOC was phenol, which was found in 16 No. samples.

SVOCs were detected up to 0.7µg/l in 4 No. bedrock boreholes (BH2356, BH2664, BH2682 and BH2683).

VOCs

One hundred and thirty six groundwater samples from across the site were analysed for a suite of 55 No. VOCs. Toluene was the only VOC detected and was found at 8 No. locations ranging from 0.006mg/l to 0.015mg/l. Five occurrences were in boreholes installed in peat around the picrite lagoons (WS2647, WS3091, WS3092, WS3093, WS3094). Other occurrences were found near blending houses in Gun Propellant section (BH2379), beside an acetone storage tank (BH2265) and at Dargavel House (BH2636).

PCBs

Nineteen samples taken from superficial boreholes close to electrical sub-stations were analysed for PCBs. None were detected.

Others

Low pH values, down to 4.4, were generally associated with shallow boreholes near the picrite lagoons (WS2646, WS2647, WS3087, WS3091, WS3092 and WS3094).

High pH values ranging between 10.5 to 12.2 were detected in shallow boreholes BH2671 (Netherfield Tip), BH2636 next to Dargavel House and BH2265 beside an acetone storage tank.

The highest concentration of **ammoniacal nitrogen** (2490mg/l) was detected in shallow borehole ASPA located to the east of the picrite lagoons. One sample from shallow borehole BH2636 contained 2850mg/l. All other concentrations were less than 49mg/l.

Notable concentrations of **chloride** ranging from 2,111mg/l to 2,383mg/l were detected in bedrock borehole BH2682 in the main ash tip. Elevated concentrations were also found in bedrock boreholes BH2536 (283mg/l) and BH2653 (268mg/l), and shallow boreholes BH2681, BH2680, BH2636, BH2673 and BH2412 between 261mg/l and 706mg/l.

Elevated concentrations of **sulphate** were found associated with the picrite lagoons, sulphur dump and shallow borehole BH2092 next to a store.

Notable concentrations of **sulphide** between 4.1mg/l and 9.2mg/l were found in shallow borehole BH2680 and bedrock borehole BH2683, both associated with ash tips and shallow borehole BH2725 at the northern perimeter road.

A fuller assessment of the distribution of contaminants encountered in groundwater from both the superficial deposits and bedrock will be undertaken in the interpretative report.

6.6. Duplicate Groundwater Sampling

Duplicate groundwater samples were taken on 8 No. occasions as detailed in Table 28.

Borehole Reference	Date Taken	Bodycote Lab. Ref.	BAE Lab. Ref.	Duplicate Reference	Bodycote Lab. Ref.	BAE Lab. Ref.
BH2001	27/01/09	106055	20091180	BH4001	106060	20091232
BH2477	29/01/09	106412	20091206	BH4477	106417	20091233
BH2532	05/02/09	106722	20091719	BH4532	106723	20091765
BH2648	03/02/09	106529	20091724	BH4648	106548	20091754
BH2648	12/02/09	107278	20092049	BH4648	107281	20092052
BH2673	28/01/09	106177	20091222	BH4673	106184	20091234
BH2682	12/02/09	107277	20092048	BH4682	107280	20092051
WS3096	03/02/09	106538	20091745	WS5096	106547	20091767

Table 28 - Duplicate Groundwater Samples

Summary analytical results for duplicate groundwater samples are given in Appendix 16.

Some variation was apparent in results for **chloride** in 3 No. duplicates, **iron** in 3 No. duplicates, **PAH** in 2 No. duplicates and **TPH** in 1 No. duplicate. In general, analytical results from duplicate groundwater samples show a good correlation for all other determinands.

7. SURFACE WATER

7.1. Introduction

Surface water samples were taken between 18 February and 24 March 2009 at 42No. locations listed in Table 29 below. The rationale for each sampling location is also given in this table. Twenty three samples were analysed for a comprehensive suite of contaminants given in the Stage 2 Site Investigation Strategy (Appendix 2). Nineteen samples from Fire Ponds, NG Ponds and NC Lagoons were analysed for a suite of explosives only.

A surface water monitoring location plan is presented as Figure 11, with analytical results given in Appendix 17.

Point	Water-course	Location	Rationale
SW01	Dargavel Burn	Northern perimeter	Water quality entering Site
SW02	Dargavel Burn	Southern perimeter	Water quality leaving Site
SW03	Dargavel Burn	East of NC III	Water quality in Dargavel Burn downstream of Lance Section
SW04	Dargavel Burn	South of Dargavel House	Water quality in Dargavel Burn in centre of Site
SW05	Dargavel Burn	Centre of Rocket Propellant Section	Water quality in Dargavel Burn downstream of picrite drains
SW06	Craigton Burn	South Gun Propellant Section	Water quality in Craigton Burn prior to confluence with Dargavel Burn
SW07	Picrite Drain	Rocket Propellant Section	Water quality leaving picrite lagoons
SW08	Unnamed Burn	Centre of Rocket Propellant Section	Water quality leaving rocket propellant section prior to confluence with Dargavel Burn
SW09	Unnamed Burn	Picrite drain in Georgetown	Water quality leaving picrite lagoons prior to confluence with Dargavel Burn
SW10	Unnamed Burn	South-east of NC Section in Factory III	Water quality leaving NC III prior to confluence with Dargavel Burn
SW12	Craigton Burn	Eastern perimeter	Water quality in Craigton Burn entering the site
SW13	North pond	Dargavel Pond B	Water quality in pond
SW14	East pond	Dargavel Pond C	Water quality in pond
SW15	South pond	Dargavel Pond A	Water quality in pond
SW16	Unnamed Burn	North-east Gun Propellant Section	Water quality entering Cordite Burn from NGI
SW17	Cordite Burn	Northern perimeter	Water quality in Cordite Burn entering the Site
SW18	Unnamed burn	East Gun Propellant Section	Water quality entering Craigton Burn from NCI
SW19	Cordite Burn	Gun Propellant Section	Water quality in Cordite Burn prior to confluence with Craigton Burn
SW20	Unnamed burn	South-east of Ammo Breakdown Section	Water quality leaving area of proposed landfill site
SW21	Unnamed burn	East of north pond	Water quality entering pond from NCI
SW22	Unnamed burn	Western perimeter	Water quality entering Site
SW23	Unnamed drainage ditch	North-west of Ammo Breakdown Section	Water quality entering site north-west of Ammo Breakdown Section from Reilly Quarry and adjacent farmland

Point	Water-course	Location	Rationale
SW24	Unnamed culverted drain	Sampled from manhole cover on Reilly Road outside western perimeter of Site	Water quality entering Site south of Lance section from Reilly Quarry
BGSW01	Unnamed culverted drain	East of main burning ground	Water quality leaving main burning ground
FP01	Dargavel Pond	South-western edge of Dargavel Pond B	Water quality in Dargavel Pond B
FP02	Dargavel Pond	Western edge of Dargavel Pond A	Water quality in Dargavel Pond A
FP03	Dargavel Pond	Southern edge of Dargavel Pond A	Water quality in Dargavel Pond A
FP04	Dargavel Pond	Southern edge of Dargavel Pond C	Water quality in Dargavel Pond C
FP05	Dargavel Pond	Northern edge of Dargavel Pond C	Water quality in Dargavel Pond C
FP06	Dargavel Pond	South-eastern edge of Dargavel Pond B	Water quality in Dargavel Pond B
NC01	NC Lagoon	NC Lagoon in NC II	Water quality in NC Lagoon
NC02	NC Lagoon	NC Lagoon in NC II	Water quality in NC Lagoon
NC03	NC Lagoon	NC Lagoon in NC III	Water quality in NC Lagoon
NC04	NC Lagoon	NC Lagoon in NC III	Water quality in NC Lagoon
NC05	NC Lagoon	NC Lagoon in NC I	Water quality in NC Lagoon
NC06	NC Lagoon	NC Lagoon in NC I	Water quality in NC Lagoon
NG02	NG Pond	NG Pond in NGII	Water quality in NG pond*
NG04	NG Pond	NG Pond in NGIII	Water quality in NG pond
NG05	NG Pond	NG Pond in NGIII	Water quality in NG pond
NG06	NG Pond	NG Pond in NGIII	Water quality in NG pond
NG07	NG Pond	NG Pond in NGI	Water quality in NG pond
NG08	NG Pond	NG Pond in NGI	Water quality in NG pond

*Note: sampling points NG01 and NG03 were dry

Table 29 - Surface Water Sampling Locations

7.2. Summary Surface Water Analytical Results

Laboratory analytical results for metals, PAHs, TPHs and others are summarised in the following tables and discussed below.

Summary explosive results have not been tabulated, but are discussed below.

As a conservative approach the reporting limit has been used as the lowest value when calculating the mean.

Determinands	Units	No. Tested	No. Detected	Min.	Mean	Max
As	µg/l	23	23	0.30	0.72	2.90
Al	µg/l	23	10	<10	34.48	161
B	µg/l	23	23	13	64.96	510
Ba	µg/l	23	23	23	65.22	112
Cd	µg/l	23	3	<0.05	0.05	0.08
Cr	µg/l	23	23	0.24	1.27	7.70
Cu	µg/l	23	20	<0.05	1.77	5.00
Fe	µg/l	23	23	0.60	275.27	1350
Hg	µg/l	23	0	<0.1	-	<0.1
Mg	µg/l	23	23	4.1	7.29	24
Mn	µg/l	23	23	0.62	46.60	296.00
Ni	µg/l	23	23	0.46	1.63	3.90
Pb	µg/l	23	22	<0.05	0.50	2.10
Sb	µg/l	23	3	<0.1	0.10	0.14
Se	µg/l	23	0	<1	-	<1
V	µg/l	23	23	0.88	3.17	19

Table 30 - Surface Waters, Metals

Determinands	Units	No. Tested	No. Detected	Min.	Mean	Max
Naphthalene	mg/l	23	13	<0.02	0.02	0.06
Acenaphthylene	mg/l	23	2	<0.02	0.02	0.07
Acenaphthene	mg/l	23	6	<0.02	0.03	0.08
Fluorene	mg/l	23	2	<0.02	0.12	1.35
Phenanthrene	mg/l	23	7	<0.02	0.02	0.03
Anthracene	mg/l	23	1	<0.02	0.02	0.03
Fluoranthene	mg/l	23	5	<0.02	0.04	0.48
Pyrene	mg/l	23	4	<0.02	0.02	0.04
Benzanthracene	mg/l	23	0	<0.02	-	<0.02
Chrysene	mg/l	23	0	<0.02	-	<0.02
Benzo(b)fluoranthene	mg/l	23	2	<0.02	0.02	0.03
Benzo(k)fluoranthene	mg/l	23	2	<0.02	0.02	0.02
Benzo-a-pyrene	mg/l	23	0	<0.02	-	<0.02
Indeno (1,2,3-CD) pyrene	mg/l	23	1	<0.02	-	0.02
1,2:5,6 Dibenzanthracene	mg/l	23	0	<0.02	-	<0.02
Benzo(g,h,i)perylene	mg/l	23	1	<0.02	-	0.02

Table 31 - Surface Waters, PAH

Determinands	Units	No. Tested	No. Detected	Min.	Mean	Max
GRO Range Hydrocarbons	23	mg/l	0	<0.01	-	<0.01
DRO Range Hydrocarbons	23	mg/l	1	<0.01	-	0.01
MRO Range Hydrocarbons	23	mg/l	9	<0.01	0.16	1.51

Table 32 - Surface Waters, TPH

Determinands	Units	No. Tested	No. Detected	Min.	Mean	Max
pH	-	23	23	6.3	7.6	7.9
Ammoniacal Nitrogen	mg/l	23	13	<0.01	0.19	0.75
BOD	mg/l	23	12	<3	6	48
Chloride	mg/l	23	23	14	37	146
COD	mg/l	23	15	<5	20	109
Conductivity	µS/cm	23	23	155	304	1017
Hardness	mg/l	23	23	72	145	399
Phosphorus	mg/l	23	4	<0.01	0.05	0.81
Phenol	µg/l	23	0	<0.1	-	0.1
Thiocyanate	mg/l	23	10	<0.1	0.1	0.28
Sulphate	mg/l	23	23	7	40	231
Sulphide	mg/l	23	1	<0.03	-	0.72
Suspended Solids	mg/l	23	10	<5	33	364
Temperature	°C	23	23	15.7	17.6	18.9
Alkalinity (total)	mg/l	23	23	10	84	343
Cyanide (total)	mg/l	23	0	<0.03	-	0.03

Table 33 - Surface Waters, Other Determinands

Explosives

Forty one surface waters were initially analysed for explosives at a reporting limit of 50µg/l. **Picrite** was detected in SW07, located in the picrite drain, at 813µg/l. All other results were less than the reporting limit.

Following discussions with the regulator regarding assessment criteria for explosives in surface waters, a lower (non-UKAS) reporting limit of 10µg/l was achieved by BAE Systems for a subsequent round of surface water monitoring undertaken between 6 and 7 April 2009.

TNT and **RDX** were detected at 20µg/l and 19µg/l respectively in BGSW01, adjacent to the main burning ground. **EGDN** was detected in SW04 and SW21 at 12µg/l and 13µg/l respectively. **Picrite** was detected in SW02, SW05, SW08, SW09 and SW20 between 18µg/l and 28µg/l, and in SW07 at 1210µg/l.

PAHs

PAHs were detected at or marginally above the reporting limit in SW02, SW06, SW12, SW15, SW20, SW21, SW22, SW23 and SW24. Concentrations of fluorene were detected in SW08 (0.48mg/l), SW22 (0.95mg/l) and SW20 (1.35mg/l).

TPHs

Mineral Range Organics (MRO) hydrocarbons were detected above the reporting limit in 9No. surface waters, up to 1.5mg/l in SW20.

Metals

Aluminium was detected in 105 No. samples. Notable concentrations ranged from 20µg/l to 161µg/l in SW02, SW05, SW07, SW08, SW09, SW20 and SW22.

Manganese was detected in all 84 No. samples tested with notable concentrations ranging from 117µg/l to 296µg/l in SW07, SW08, SW09 and SW24.

The highest concentrations of **copper** were detected in SW09 (3.3µg/l) and SW20 (5.0µg/l).

The maximum concentrations detected for **boron** (510µg/l)**, manganese** (296µg/l)**, barium** (112µg/l)**, magnesium** (24mg/l)**, chloride** (146mg/l)**, sulphate** (231mg/l)**, conductivity** (1,017µS/cm)**, hardness** (399mg/l) and **alkalinity** (343mg/l)were found in surface water entering the Site from Reilly Quarry (SW24).

Sulphide was only detected in one sample (SW19) at 0.72mg/l.

Ammoniacal Nitrogen

Thirteen samples contained detectable concentrations of ammoniacal nitrogen ranging from 0.1mg/l to 0.75mg/l and are found in surface water samples from across the Site. The highest concentrations of ammoniacal nitrogen were found in water entering the Site from Reilly Quarry and adjacent farmland. High levels of ammoniacal nitrogen were also recorded in drainage features, draining the picrite lagoons.

8. SOIL GAS MONITORING

8.1. Introduction

One hundred and twenty eight boreholes and window sample boreholes constructed during the Stage 2 Investigation and Burning Grounds Investigation were installed for gas and groundwater monitoring purposes.

Boreholes and window samples were installed across the Site in each of the three proposed development areas: CDA, ROS and RL.

Response zones were generally located in natural superficial deposits and bedrock strata. Given the relatively thin nature (<1m) of the made ground deposits, few monitoring wells were screened across these horizons.

Gas monitoring was conducted on 21st July 2008 for the 6 No. boreholes installed in the burning ground areas, and between 2nd December 2008 to 11th February 2009 for boreholes installed during the Stage 2 Site Investigation.

A total of 163 No. boreholes were monitored for gas during the Stage 2 Site Investigation, including:

- 42 No. 'baseline' boreholes from previous investigations
- 6 No. boreholes from the Burning Grounds investigation
- 115 No. boreholes from the Stage 2 Site Investigation

Thirty nine boreholes in or around the CDA were monitored over 5 No. rounds, baseline boreholes were monitored once and Stage 2 investigation boreholes outside the CDA were monitored twice.

Soil gas concentrations including methane, carbon dioxide, oxygen, carbon monoxide and hydrogen sulphide were measured along with gas flow rate, borehole pressure and atmospheric pressure. Both peak and steady readings for gas concentrations were recorded.

Gas monitoring was carried out during falling atmospheric pressure on the following dates:

- 2 – 9 December 2008 (42 No. baseline boreholes)
- 15 – 16 December 2008 (14 No. Stage 2 boreholes)
- 19 January (10 No. Stage 2 boreholes)
- 21 January (7 No. Stage 2 boreholes)
- 29 January (23 No. Stage 2 boreholes)
- 2 February (22 No. Stage 2 boreholes)
- 4 - 5 February (47 No. Stage 2 boreholes)

Low atmospheric pressure conditions (<1000mb) were experienced during monitoring which took place on the following dates:

- 3 - 4 December 2008 (18 No. baseline boreholes)
- 12 January 2009 (18 No. Stage 2 boreholes)
- 19 - 21 January 2009 (37 No. Stage 2 boreholes)
- 26 January 2009 (25 No. Stage 2 boreholes)
- 3 - 5 February 2009 (69 No. Stage 2 boreholes)

Measurements were made with a Geotechnical Instruments GA2000 infra-red gas analyser and a Gas Data GF60 flow meter.

Gas monitoring field records are included in Appendix 7 and summary gas monitoring results are given in Appendix 18. A gas monitoring location plan is presented as Figure 12.

8.2. Core Development Area: 58 No. monitoring locations.

In general, methane levels were less than 0.5% by volume. Methane was recorded in 23 No. of 58 No. monitoring locations at concentrations ranging between 0.1% and 1.7% by volume. The highest recorded peak concentration (1.7%) was recorded in BH2269. The highest recorded steady concentration (2%) was recorded in BH2635.

Carbon dioxide was recorded in 49 No. of 58 No. monitoring locations at concentrations between 0.1% and 5.5% by volume. The highest recorded peak concentration (4.5%) was recorded in BH1089. The highest recorded steady concentration (5.5%) was recorded in BH2644.

Oxygen concentrations ranged between 12.6% - 22.1% (steady) and 13.3% - 21.8% (peak). Depleted oxygen (i.e. concentrations below 15% volume) were recorded in two boreholes; BH1455 on one occasion (14.3%) and BH2092 on three occasions (12.6% to 13.2%).

Hydrogen sulphide was detected at 12 No. locations. The maximum concentration (2ppm) was detected in 3 No. boreholes (BH1074D, BH1108 and BH1621S).

Carbon monoxide was detected at 33 No. locations at concentrations up to 10ppm (BH2416).

A summary of gas readings in the CDA is given in Table 34.

Parameter	Units	No. Monitored	No. Detected	Min.	Mean	Max.
CH_4 peak	% v/v	194	18	0.1	0.4	1.7
CH_4 steady	% v/v	194	35	0.1	0.4	2
CO_2 peak	% v/v	194	78	0.1	1.4	4.5
CO_2 steady	% v/v	194	145	0.1	1.3	5.5
O_2 peak	% v/v	194	47	13.3	20.2	21.8
O_2 steady	% v/v	194	194	12.6	20.2	22.1
CO peak	ppm	194	14	1	1.6	4
CO steady	ppm	194	45	1	3.9	10
H_2S peak	ppm	194	1	1	3.9	1
H_2S steady	ppm	194	11	1	1	2
BH pressure	mbar	194	194	-7.7	0.7	14.9
peak BH flow	l/hr	194	20	-5.2	2.3	15
steady BH flow	l/hr	194	49	-3.1	0.1	2.8

Table 34 – CDA, Summary Gas Data

Gas flow rates were both positive and negative. Positive gas flows ranged from 0.1 to 2.8 l/hr (steady) and 0.1 to 15.0 l/hr (peak). Negative flows (suction) were recorded and ranged from minus 0.1 to minus 3.1 (steady) and minus 0.1 to minus 5.2 l/hr (peak).

A total of 25 No. monitoring locations demonstrated positive flow rates. Thirteen monitoring locations demonstrated negative flow rates, however seven of these also demonstrated positive flow rates on separate monitoring occasions.

8.3. Recreational Open Space: 67 No. monitoring locations

The majority of methane levels were less than 0.5% by volume. Methane was recorded in 28 No. of 67 No. monitoring locations at concentrations ranging between 0.1% and 98.1% by volume. The highest recorded peak concentration (98.1%) and steady concentration (68.3%) were found in BH2681.

Carbon dioxide was recorded in 50 No. of 67 No. monitoring locations at concentrations between 0.1% and 6.1% by volume. The highest recorded peak concentration (6.1%) was recorded in BH2668. The highest recorded steady concentration (5.3%) was recorded in BH2663.

Oxygen concentrations ranged between 6.2% - 22.1 (steady) and 3.8% - 21.8% (peak). Depleted oxygen (i.e. concentrations below 15% volume) was recorded in BH2681 (3.8%) and PER01(14.9%).

Hydrogen sulphide was detected at 5 No. locations at 1ppm, which was the maximum concentration found.

Carbon monoxide was detected at 31 No. locations at concentrations up to 8ppm (BH2668).

A summary of gas readings in the ROS is given in Table 35.

Parameter	Units	No. Monitored	No. Detected	Min.	Mean	Max.
CH_4 peak	% v/v	112	22	0.1	9.9	98.1
CH_4 steady	% v/v	112	26	0.1	4.8	68.3
CO_2 peak	% v/v	112	49	0.1	1.6	6.1
CO_2 steady	% v/v	112	64	0.1	1.5	5.3
O_2 peak	% v/v	112	31	3.8	20	21.8
O_2 steady	% v/v	112	112	6.2	20.4	22.1
CO peak	ppm	112	12	1	2.8	6
CO steady	ppm	112	26	1	2.9	8
H_2S peak	ppm	112	1	1	1	1
H_2S steady	ppm	112	4	1	1	1
BH pressure	mbar	112	112	-2.7	1.1	6.3
peak BH flow	l/hr	112	12	-6.8	3.3	28
steady BH flow	l/hr	112	30	-0.5	0.3	3.7

Table 35 – ROS, Summary Gas Data

Gas flow rates were both positive and negative. Positive gas flows ranged from 0.1 to 3.7 l/hr (steady) and 0.1 to 28.0 l/hr (peak). Negative flows (suction) were recorded and ranged from minus 0.1 to minus 0.5 l/hr (steady) and minus 0.1 to minus 6.8 l/hr (peak).

A total of 25 No. monitoring locations demonstrated positive flow rates. Nine monitoring locations demonstrated negative flows, however three of these also demonstrated positive flow rates on a separate monitoring occasion. For some of the boreholes an initial negative peak reading became a steady positive flow reading.

8.4. Retained Land: 42 No. monitoring locations.

A third of recorded methane concentrations were less than 0.5% by volume. Methane was recorded in 24 No. of 42 No. monitoring locations at concentrations between 0.1% and 66.4% by volume. The highest recorded peak concentration (66.41%) and steady concentration (62.1%) were found in BH2682.

Carbon dioxide was recorded in 37 No. of 42 No. monitoring locations at concentrations ranging between 0.1% and 8.3% by volume. The highest recorded peak concentration (8.3%) and steady concentration (7.9%) were detected in BH2679.

Oxygen concentrations ranged between 1% to 21.7% (steady) and 0.7% to 21.1% (peak). Depleted oxygen (i.e. concentrations below 15% volume) was recorded in ESGA (1.0%), BH2682 (1.6%), GT13 (5.4), ESGC (12.6%) and ESGD (13.5%).

Hydrogen sulphide was detected at 3 No. locations at 1ppm, which was the maximum concentration found.

Carbon monoxide was detected at 13 No. locations at concentrations up to 12ppm (WS3088).

Parameter	Units	No. Monitored	No. Detected	Min.	Mean	Max.
CH_4 peak	% v/v	73	24	0.3	8.9	66.4
CH_4 steady	% v/v	73	37	0.1	5	62.1
CO_2 peak	% v/v	73	39	0.1	2	8.3
CO_2 steady	% v/v	73	62	0.1	1.9	7.9
O_2 peak	% v/v	73	9	0.7	17.2	21.1
O_2 steady	% v/v	73	73	1	19.2	21.7
CO peak	ppm	73	1	3	3	3
CO steady	ppm	73	13	2	4.8	12
H_2S peak	ppm	73	0	0	0	0
H_2S steady	ppm	73	3	1	1	1
BH pressure	mbar	73	73	-9.1	0.9	9
peak BH flow	l/hr	73	6	-5.6	-1	1.5
steady BH flow	l/hr	73	19	-2.4	0.4	3

Table 36 - RL, Summary Gas Data

Gas flow rates were both positive and negative. Generally, negative peak flow rates became positive steady flow rates. A total of 19 No. monitoring locations demonstrated positive flow rates ranging from 0.1 to 1.5 l/hr (peak) and 0.1 to 3 l/hr (steady). Peak negative flows (suction) were recorded at 6 No. locations and ranged from minus 0.3 to minus 5.6 l/hr. A steady negative flow (-2.4 l/hr) was recorded in WS2649.

9. ORDNANCE WALKOVERS

9.1. Walkovers

A visual walkover survey was undertaken on the 18th and 19th February 2009, addressing areas identified in Figure 13. These included the wooded area to the west of Ammunition Breakdown section and an area in the south-east of Retained Land. The primary aim of this work was to conduct a visual inspection of the ground surface, noting areas where potential ordnance maybe located within the upper part of the soil profile. Work comprised of:

- Two suitably qualified engineers, walking at a distance of approximately 10m from each other to form a 20m wide 'path'
- During each pass, engineers were instructed to visually inspect the ground at a distance of approximately 7m to both their left and right, ensuring sufficient overlap;
- Paths were completed in a north – south direction. Larger areas were split into manageable 'sections' to ensure adequate coverage was achieved;
- Where any items of uncertain composition were identified, a note of their location was made, with a more detailed inspection subsequently carried out by an explosives safety engineer;
- Where visual inspection could not be completed (due to density of tree cover) this was noted on the map.

Findings from the above demonstrated no items of unexploded ordnance present. Details of field observations are included on Figure 13.

9.2. Trial Pitting

In addition to the above, 59 No. trial pits were excavated within areas subjected to the visual walkover survey. The rationale for this element of work, was to ensure verification of findings achieved from the visual walkover survey. Work briefly comprised of:

- Pits excavated by a mechanical excavator (JCB 3CX or similar), using a flat edged bucket. Excavations were undertaken in shallow increments as instructed by qualified personnel.
- Suitably qualified personnel made regular visual inspections of the exposed surface, in addition to scanning the newly exposed surface using a hand held ordnance locater. Both forms of inspection were made at regular intervals.
- In addition to inspection of the exposed surface, a hand held ordnance locater was used at regular intervals to survey the spoil heap for metallic objects.

Should any suspected unexploded ordnance (UXO) be encountered, an explosives safety engineer determined whether it was both suitable and safe to remove the object.

9.3. Summary

An empty initiator and three empty ammunition boxes were found around the Ammunition Breakdown section. No items considered to be unexploded ordnance were found during the walkover survey or during trial pitting.