

DEFENCE ESTATE ORGANISATION

**RAF UPPER HEYFORD
LAND QUALITY ASSESSMENT
PHASE TWO : INTRUSIVE SURVEY
FACTUAL REPORT**

PROJECT NO: 07686 - FINAL REPORT

**Technical Report
June 1997
by
Aspinwall & Company Ltd**

Defence Estate Organisation
Blakemore Drive
Sutton Coldfield
West Midlands
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Prepared by Aspinwall & Company Limited
for the Ministry of Defence Estate
Organisation
under Commission WS13/1982/2

REPORT RELEASE SHEET
DEFENCE ESTATE ORGANISATION

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Introduction

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- 1.1 In March 1997 Aspinwall & Company (Aspinwall) was commissioned by Defence Estate Organisation (DEO) to undertake an intrusive investigation as part of a Land Quality Assessment at RAF Upper Heyford near Bicester in Oxfordshire.
- 1.2 A Phase I Desk Study (Refs 1 & 2) was undertaken at the site between August 1996 and March 1997 by ERM EnviroClean Ltd (ERM). The Desk Study identified a number of possible sources of contamination at the site and recommended a phased intrusive investigation be designed to establish the likely nature, extent and significance of any contamination.
- 1.3 A proposal for the initial site investigation was submitted by Aspinwall in February 1997 (Ref 3). This document explained how, due to the large size of the site (494 hectares), the objective of this first phase of intrusive investigation should not be to undertake a comprehensive investigation across the whole site, but should be to focus on high risk areas. Following identification of the nature, quantity and extent of contamination in these areas, and establishment of the likely scale of risk, recommendations for undertaking more detailed investigations could be made, if deemed appropriate. Extensive investigation of low risk areas was not thought necessary at this stage. The desk study was used in the design of the Phase Two investigation and its findings have been accepted *de facto* for this current work for their accuracy and completeness. The desk study should be referred to in conjunction with this report.
- 1.4 The Desk Study did not include a detailed assessment of the environmental setting. A more in-depth desk-based review was undertaken as part of the design of the site investigation, including discussions with Cherwell District Council to obtain abstraction data for the area. The Desk Study included information obtained from The Environment Agency regarding licensed abstraction and discharge consents, such that additional liaisons were not required.
- 1.5 This document is Volume 1 of the factual report which is structured as follows:
 - Chapter 2 presents a summary of the findings of the Desk Study;
 - Chapter 3 provides details of the site investigation including a description of the works carried out, sampling methodologies and a summary of the analysis undertaken on soil and groundwater samples; and
 - Chapter 4 provides a description of the ground conditions encountered.
- 1.6 The appendices (presented in a separate volume) incorporate information on water abstractions, from the soil probing exercise (i.e. the soil vapour survey), trial pit logs, borehole logs, the results of chemical testing and details of the radiological survey.

Summary of Desk Study Assessment

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Site Location and Description

- 2.1 RAF Upper Heyford, which is centred on National Grid Reference (NGR) SP 515 265, is located some 8 km to the north west of the centre of Bicester, Oxfordshire (Figure 1). The village of Upper Heyford lies immediately to the west with Somerton to the north west, Fritwell to the north north east, Ardley to the east north east and Middleton Stoney to the south south east. Junction 10 of the M40 is some 3 km to the east north east of the centre of the airfield.
- 2.2 The site is located on a plateau at about 130 m Above Ordnance Datum (AOD), although at its western end its elevation reduces to 115 m AOD associated with the valley of the River Cherwell. The latter, which flows alongside the Oxford Canal, at the nearest point is located about 1 km to the west of the site at an elevation of about 75 m AOD.
- 2.3 The land surrounding the site is predominantly in agricultural usage, either for crops or grazing. At the time of the investigation the crops were largely wheat and rape.
- 2.4 RAF Upper Heyford occupies an area of 494 hectares comprising an airfield and taxiways, hardened aircraft shelters, maintenance areas, offices and a residential and recreational area. Use of the site is controlled by the North Oxfordshire Consortium (NOC). They have leased extensive sections of the main runway and taxiways to two companies, Walon and Keddy, both of whom use the areas to store cars. Other taxiways are used by Thames Valley Police for skid training, whilst much of the grassed area on the northern side of the main runway is used for grazing. A number of buildings have been leased for a range of other purposes including storage, crane maintenance and office space. A number of additional uses are also being considered.
- 2.5 For consistency the site has been divided into the same five areas, A to E, as used in the Phase 1 Desk Study report and indicated on Figure 2. These are discussed in greater detail below.

Area A

- 2.6 Area A includes family housing, offices, maintenance and workshop areas, taxiways and the southern half of the western part of the main runway and associated taxiways. Within this area there are a small number of hardened aircraft shelters and a former petrol filling station. Much of Area A is covered by hardstanding (tarmac and concrete) although there are extensive grassed areas adjacent to the runway and taxiways and smaller grassed areas between buildings. Part of the petrol, oil and lubricants (POL) supply ring main passes beneath area A. There are six POL storage areas and a large number of other above ground and underground storage tanks within Area A (Ref 1 - Figures 3.5a

Summary of Desk Study Assessment

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continued

and 3.6a). POL 19 is currently used by Keddy for car re-fuelling and storage of both petrol and diesel.

Area B

- 2.7 Area B comprises large areas of tarmac/asphalt hardstanding associated with the northern half of the western portion of the main runway, associated taxiways and a large number of hardened aircraft shelters. However, adjacent to these are extensive grassed areas. The POL supply ring main passes beneath area B and connects five POL storage areas; in addition there are a small number of above ground storage tanks in Area B (Ref 1 - Figures 3.5b and 3.6b).

Area C

- 2.8 Area C comprises the northern half of the eastern portion of the main runway and associated taxiways. There are a small number of hardened aircraft shelters and maintenance facilities, in addition to a former weapon storage area, part of which is now used for storage of fireworks. Excepting the footprints of the buildings, which are concrete, the majority of the hardstanding areas are tarmac/asphalt. These are surrounded by grassed areas. The POL supply ring main passes beneath area C. There are four small POL storage areas and a small number of storage tanks (Ref 1 - Figures 3.5c and 3.6c). A watercourse is formed off-site in the vicinity of the weapons storage area by outflow from a pipe draining from beneath the site.

Area D

- 2.9 Area D comprises the southern half of the eastern portion of the main runway and associated taxiways. There are a small number of hardened aircraft shelters and maintenance facilities in addition to a second extensive weapon storage area. The taxiways and hardstanding are tarmac/asphalt and are surrounded by extensive grassed areas. The POL supply ring main passes beneath area D. There are three POL storage areas in addition to two other bulk fuel storage locations (Ref 1 - Figure 3.5d). Only one underground storage tank was identified by the Phase One study as being present in area D (Ref 1 - Figure 3.6d). Two watercourses are discharged to from pipes on site which pass through a surface oil interceptor.

Area E

- 2.10 Area E is dominated by residential and recreational facilities, in addition to a small number of offices. There are tarmac/asphalt roads, concrete foundations and grassed areas. There are a small number of storage tanks (Ref 1 - Figures 3.6e) and also a former petrol filling station. A short section of the POL supply ring main passes beneath the site. There is also a sewage farm within area E but outwith the site. Following a review of the Phase One study this was classed as a

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continued

low potential contamination risk and so did not form part of the intrusive investigations. On the southern side of Area E two watercourse are fed by discharges from site one of which passes through a surface oil interceptor, the second, a storm water drain, discharges directly off site.

Site History

- 2.11 Prior to construction of an airfield in 1916 and its occupation by the Canadian airforce, the area around and including the site was primarily farm land. The base was closed in 1920 but re-opened in 1927 as a bomber station. In 1951 control of the base passed to the United States Air Force (USAF) at which time many new buildings were erected and the runway lengthened. With the arrival of F-111 bombers in 1970, further modifications were carried out including construction of the hardened aircraft shelters. The base closed in 1994. It is now under the control of NOC.

Potential Sources of Contamination

- 2.12 The Desk Study identified a number of possible sources of contamination at the site, which were further assessed as part of the design for this investigation (see Ref 3). Those sources which were considered to present a sufficiently high risk to warrant further investigation included:
- contamination from the storage and use of petroleum hydrocarbons, oil and lubricants (POL - see Tables 3.5a, 3.6a & 3.7a and Figures 3.5 a to e and 3.6 a to e, Ref 1 for locations);
 - contamination resulting from engineering and maintenance practices through the use of solvents, acids, and de-icing agents (see Table 3.10a , Ref 1);
 - explosive ordnance from the storage of bombs;
 - radioactive contamination; and,
 - other possible sources of contamination including the fire practice areas and locations where aircraft are known to have crashed historically.

Areas of Fuel Storage and Spillages

- 2.13 There are 27 POL sites located at Upper Heyford, five were used for either diesel or petrol, one for hazardous waste, two unknown and the remaining nineteen for storage of JP8 (aviation fuel). These tanks are connected by a series of underground pipelines which comprise the POL distribution system. In addition

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continued

there are a large number of above and underground tanks which were predominantly used to store fuel oil. These are generally not connected by the POL supply main but have local supply pipes to buildings etc. The location, volume and nature of these are detailed in Ref 1.

- 2.14 According to Ref 1 and information from DEO(Lands) all fuel tanks have been emptied, cleaned and filled with a water based solution to prevent corrosion. However, selected tanks at POL 19 are being used by Keddy for diesel and petrol storage whilst new tanks have been installed on site by Walon.
- 2.15 Information presented in Ref 1 indicates that there was a significant leak of petrol and diesel from POL 19 in 1993. A site investigation undertaken by Miller Environmental in 1994 (Ref 4) indicates that 4.33 cubic metres (m³) (1145 US gallons) of unleaded petrol was lost and an unknown quantity of diesel. Some 130 m³ of contaminated soil and 2.65 m³ (700 US gallons) of emulsified product were removed from site as part of a clean up operation. The Environment Agency are aware of an additional fuel leak from the POL main, but no details are presented in Refs 1 & 2 or from other sources.

Areas Associated with Engineering and Maintenance

- 2.16 These sources include those areas in and around the aircraft hangars, areas around the dispersals, and also the aircraft washing and maintenance areas. The potential for contamination in these areas relates to possible spillage and disposal of materials into the ground as a result of engineering practices, in particular relating to aircraft maintenance. These areas are detailed in Ref 1.

Explosive Ordnance

- 2.17 An explosive ordnance survey was undertaken by the RAF explosive disposal team in 1995 (Ref 5). The survey comprised an initial desk study to determine areas where there had been any storage or use of explosives. These areas were then searched by 5131 (Bomb Disposal) Squadron using both visual methods and portable detectors. An archive search was also made for Unexploded Ordnance (UXO) incidents. Only a small number of incident details were located and these indicated that only practice bombs were recovered.

Radioactive Contamination

- 2.18 A surface radioactivity survey was undertaken by Dera (formerly Defence) Radiological Protection Service (DRPS) in January 1995 (Ref 6) in targeted areas of the site where it was suspected that radioactive materials might once have been. Radioactive contamination is also possible in areas where wastes or ashes from incinerators have been buried, the source of this contamination being radium luminising paint once used in aircraft instruments. Radioactive contamination

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continued

above typical background levels was not identified during the surface survey, the exception being in building 315 where slightly elevated radioactivity was ascribed to construction materials containing trace quantities of naturally occurring radioactive substances. There remains a minor potential for radioactive material to be present in parts of the site which were not investigated in 1995.

PCBs from Transformers

- 2.19 There is no knowledge of any major spillages of polychlorinated biphenyls (PCBs) in relation to transformers at the site. Localised contamination may be present in the immediate vicinity of transformers at the site but is likely to be limited because of the relatively low mobility of PCBs. It is understood that PCBs have been removed from all electrical equipment on site when found (Ref 1). Results of the testing undertaken in 1994 on 73 transformer oil samples (Ref 7) indicate that only two samples registered PCB concentrations greater than 10 parts per million (ppm), one of 26 and one of 79 ppm.

Other Areas

- 2.20 The Desk Study (Refs 1 & 2) identifies an area which was used for fire training. Typical potential contaminants include fuels. An aircraft crash site is also mentioned (but with no date specified) at the western end of the runway and which may also have associated contaminants in the form of fuel or oils, although a significant volume of soil from this location was excavated and disposed of.

Asbestos Register

- 2.21 The asbestos register (compiled on the basis of visual inspection only) for the site is contained in Annex E of the Desk Study and in Ref 7. It indicates chrysotile, crocidolite and amosite are present in many facilities, its condition ranging from good to poor.

Surface Water Drainage

- 2.22 The surface water drainage system at RAF Upper Heyford collects storm water via a series of drains across the site. These discharge to surface water courses which drain the plateau area. It is understood from Refs 1 and 2 that all surface water discharges leave the site via oil interceptors which were cleaned upon closure of the site.
- 2.23 Sewage treatment was undertaken outwith the site boundary at the sewage treatment works located to the south east of area E. In addition there are a number of small facilities installed to treat sewage to the north of the site.

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continued

Environmental Setting

Geology

- 2.24 The Desk Study indicates that, due to the presence of a poorly protected major aquifer in which groundwater movement is likely to be rapid, RAF Upper Heyford is considered highly sensitive to contaminant releases. This opinion is concurred with here. The discussion regarding the geology, and hence hydrogeology contained within Ref 1 has been expanded upon as part of this study and further details are presented below.
- 2.25 The British Geological Survey (BGS) 1:63 360 solid and drift sheet 218, Chipping Norton indicates that the site is not drift covered (Figure 3) although the Desk Study (Ref 1) cites published sources which indicate up to 3m of silty clays with sandy or gravelly horizons (although the Desk Study does not quote these publications). The majority of the site is underlain by Great Oolite Limestone which is described in the geological memoir (Ref 8) as comprising limestones, marl, sandstones, siltstones and mudstones, the maximum thickness of which is some 25m. This is in contrast to the 34m quoted in the Desk Study and which has been taken from the BGS map. The latter was published in 1968, the memoir in 1987. It is assumed here that being more recent, the memoir is the more accurate of the two sources of information.
- 2.26 The Great Oolite Limestone is underlain, in the region, by the Sharp's Hill Beds and the Chipping Norton Limestone, all part of the Great Oolite Group. These in turn are underlain by the Inferior Oolite Group which comprises the Clypeus Grit, Lower Estuarine Series and the Northampton Sands. However, the BGS map indicates that the Sharp's Hill Beds, Chipping Norton Limestone and Clypeus Grit are absent in the vicinity of Upper Heyford. Thus the Great Oolite Limestone directly overlies the sand, sandstones and thin mudstones of the Lower Estuarine Series which overlie the sandy limestones, shelly limestones and sandstones of the Northampton Sand. The Inferior Oolite Group is underlain by the Lias Group which are of considerable thickness and comprise mudstones, siltstones and mainly thin limestones. The geological succession is summarised in Table 2.1.
- 2.27 The strata beneath the site dip gently in a south easterly direction. They thin in a westerly direction such that the western site boundary in the vicinity of the runway overlies the outcrop of the Lower Estuarine Series. Although faults cut the strata regionally there are none recorded beneath the site, the nearest being over 4 km to the north west.
- 2.28 The Miller Environmental Report (Ref 4) indicates that, in the vicinity of POL 19 at least, the depth to limestone is between 1.4 and 3.5m. The material encountered was dominated by clay material, both silty and "chalky" with limestone pebbles. At one location made ground was penetrated to 2.6m. It is

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likely that the superficial material overlying the weathered bedrock varies in nature and thickness across the site depending upon the extent of excavation for foundations etc.

Table 2.1. Summary of the Solid Geological Succession in the Chipping Norton District (From Ref 8)

Period	Group	Formation	Composition	Thickness (m)
Jurassic	Great Oolite Group	Great Oolite Limestone	<i>White Limestone</i> - limestones, marls & mudstones	8 - 10.3
			<i>Hampen Marly Beds</i> - limestones, siltstones, sandstones & mudstone	c.6 - 9
			<i>Tayton Stone</i> - limestones	4.1 - 6.1
		Sharp's Hill Beds*	Mudstones, seatearths, siltstones, sandstones and limestones	0 - 4.7
		Chipping Norton Limestone*	Limestone	0 - 10.7
	Inferior Oolite Group	Clypeus Grit*	Limestone	0 - 7.5
		Lower Estuarine Series	Sands, sandstones and thin mudstones	0 - 9.7
		Northampton Sand	Limestones and sandstones	0 - 11.2
	Lias Group	Upper Lias	Mudstones and thin limestones at base	7.5 - 55+
		Marlstone Rock Bed	Limestone	0 - 7.5
		Middle Lias	Silts, siltstones and mudstones	10 - 25
		Lower Lias	Mudstones and thin limestones	85 - 240

* formation absent from beneath Upper Heyford airbase

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continued

Hydrogeology

- 2.29 As stated in the Desk Study the site overlies a major aquifer which is used extensively for water supply. However, the hydraulic characteristics of the aquifer are not discussed in the Desk Study. Details regarding licensed abstractions which were obtained by ERM from The Environment Agency are presented in Appendix 1 in addition to details of private/domestic supplies obtained from Cherwell District Council by Aspinwall.
- 2.30 Limestone has a low primary permeability such that little water movement takes place through the rock matrix. However, movement does occur through secondary features such as joints and bedding planes, especially where these have been enlarged by solution processes. In such instances groundwater movement can be very rapid with little filtration. However, the Great Oolite Limestone also comprises mudstone strata which have a much lower permeability, especially perpendicular to the bedding. Although leakage can occur through mudstones, the rate of leakage is subservient to the rates of lateral water movement which may occur through the limestones. Such a system of limestone and mudstone horizons, especially where the mudstones are thick and laterally extensive, will yield a multiple layered aquifer. Each water bearing horizon acts, or will act, as an aquifer unit, with the degree of interaction between units determined by the thickness, lateral continuity and permeability (both primary and that associated with fractures) of intervening mudstone strata.
- 2.31 If this conceptual model of a layered aquifer system is correct then if any contaminants are present and reach the water table they could move rapidly in a lateral direction, especially where flushing occurs due to heavy rainfall. However, their vertical progress through the aquifer may be limited by lower permeability mudstone horizons. This will especially be the case if the contaminant is a light non-aqueous phase liquid.
- 2.32 The Great Oolite Group and Inferior Oolite Group are defined as major aquifers in the National Rivers Authority (NRA, now superseded by The Environment Agency) Groundwater Protection Policy (Ref 9). These aquifers may be used for local and public water supply, they support the discharge of surface water courses and are dominated by fracture flow processes. The definition as a major aquifer is confirmed on The Environment Agency groundwater vulnerability map of the area (Ref 10).

Hydrology

- 2.33 The layered aquifer system detailed above has resulted in a series of springs which rise around the plateau surface on which the Upper Heyford base is located. The 1:25000 scale Ordnance Survey sheet 1069, Bicester, indicates of the order of 20 such sites within 1 km of the site boundary (Figure 4). These rise at elevations of between 90 and 125 m AOD, the lower elevation springs generally being to the

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continued

west of the site. The range in water levels for these springs suggests that they represent discharge points for a number of aquifer layers and that there is no single water table beneath the site. Several of these springs (locations B, G1, I, J, K and L) are associated with site storm water outfall points, which are understood to all discharge off site via oil interceptors.

- 2.34 The springs shown on the 1:25000 scale Ordnance Survey (OS) map drain to three river systems. Those to the west flow a short distance before entering the River Cherwell, a north-south flowing water course located at the nearest point 1 km to the west of the site. The springs to the north of the site combine and flow in a dominantly eastwards direction through the village of Ardley to form the Padbury Brook which is tributary to the Great Ouse. The springs on the southern side of the site form the Gallos and Gagle Brooks (Figure 4) which are tributary to the River Ray which in turn flows into the Cherwell.
- 2.35 According to the NRA General Quality Assessment Scheme (Ref 11) the water courses detailed above are of variable quality. Adjacent to the site the Cherwell is a Class C (fair) quality water course improving to Class B (good) downstream. The Padbury Brook is initially (from its source to just east of Ardley) Class F (bad) becoming Class C (fair) to the east. The initial grading as Class F appears to be somewhat anomalous as the stream passes through agricultural land, and at the time of the site investigation was dry along part of its length. Furthermore, it does not gradually improve in quality, but changes suddenly. The Gallos Brook is defined as Class B (good) to Class C (fair) whilst the River Ray is generally Class E (poor). The quality of the Gagle Brook is not defined in Ref 11, neither is the quality of the streams which flow directly to the Cherwell from the western side of the site.
- 2.36 In addition to the springs and watercourses there are a small number of ponds located off site including Crowfoot Pond, Trow Pond, several in and around Ardley and those to the west of Middleton Stoney (Figures 1 and 4). These ponds have not been assessed as part of this investigation as it is considered that it is the watercourses themselves that are at higher risk.

Site Investigation

3

Scope of Works

3.1 The site investigation consisted of four phases as follows:

- a soil vapour screening survey to enable the targeting of trial pits in areas where POL contamination was most likely;
- a trial pit investigation to establish the type and extent of any soil contamination beneath high risk areas of the site;
- a deep drilling investigation to establish the depth to water, nature of the aquifer and to allow installation of groundwater level and quality monitoring points; and
- a spring survey to assess spring discharge and quality.

In addition, radiological monitoring of arisings from selected trial pits was carried out to determine if these were contaminated.

3.2 The objective of this phase of investigation was not to undertake a comprehensive investigation across the whole site, but to focus on those areas which were considered to be higher risk. Following identification of the nature, quantity and extent of contamination in these areas, and establishment of the likely scale of risk, recommendations for undertaking more detailed investigations could be made, if deemed appropriate. Extensive investigation of low risk areas was not thought necessary at this stage.

3.3 A summary of the site investigation techniques used for each area of potential contamination is provided in Table 3.1.

3.4 All site work was carried out with due regard to existing standards and guidance including the British Standard Code of Practice for Ground Investigation (Ref 12), the draft British Standard Code of Practice for the Identification of Potentially Contaminated Land and its Investigation (Ref 13), and the British Standard for Water Quality (Ref 14) as well as the standard protocols developed on site investigation works for our own in-house purposes.

3.5 The site investigation scope of works was confirmed in correspondence with DEO and was subsequently undertaken between 16 April and 9 May 1997, in accordance with the method statement and health and safety plan drawn up prior to the investigation.

Site Investigation *continued***3****Table 3.1. Site Investigation Summary**

Area of Investigation	Method	Purpose
Fuel storage and spillage areas	Soil vapour survey	To prioritise further investigations
	Trial pits	To allow examination of ground strata and to collect soil and water samples
Areas associated with Engineering Activities	Trial pits	To allow examination of ground strata and to collect soil and water samples
Areas potentially affected by Radioactivity	Screening and sampling of trial pits	To provide confirmation of the absence of radiological contamination
Fire practice areas, burning grounds, sites of aircraft crashes etc.	Trial pits	To collect soil and water samples
Site wide	Boreholes	To collect samples of groundwater from underlying aquifers
	Spring assessment	To collect groundwater samples and assess spring discharge

Soil Vapour Survey

3.6

A number of locations on the site were identified in the Desk Study as being areas where POL were formerly used or stored. The route of the POL supply ring main was identified and areas with a significant number of junctions suggested as being at greatest risk due to contamination from leaks. In addition, the fire practice area was investigated, partly because this and areas of POL storage, were of concern to The Environment Agency, Thames Region. An initial soil vapour probe survey was therefore undertaken in these areas using Aspinwall's HySIARR (Hydraulic Standpipe Installation and Retrieval Rig). This is a landrover-mounted facility which can insert plastic perforated standpipes into the ground allowing subsequent monitoring of the soil vapour. On this site probe holes were formed to depths of between 0.2 and 1.2m. The soil vapour within the standpipe was tested using a portable Flame Ionisation Detector, which can measure hydrocarbon vapours to parts per million level.

Site Investigation *continued*

3

- 3.7 This technique was used to identify locations potentially affected by fuel or oil spillages and to locate any significant contamination plumes. The method provides a rapid screening technique and where significantly elevated hydrocarbon vapours were detected, trial pits were excavated to further investigate potential contamination by fuels.
- 3.8 HySIARR probing was carried out in a number of areas (Figures 5 to 9) in order to assess for any potential contamination by hydrocarbons. The areas investigated included:
- the POL ring main, with particular emphasis on areas with a significant number of pipe junctions;
 - POL storage locations 17, 19, 20 and 23, with POLs 3, 10, 21, and 22 also investigated as part of the POL pipe junction assessment outlined above;
 - the fire practice area; and
 - selected underground and above ground storage tanks which could either not be accessed for, or fully investigated by, excavation of trial pits.

The HySIARR was not used to investigate the air crash site as this was adequately assessed by trial pitting, whilst only selected POLs were investigated to provide confirmation of the results of the trial pitting. The former petrol station was not investigated due to the presence of extensive areas of hardstanding which would have required breaking out. Instead a concrete breaker was utilised to allow a trial pit to be excavated. Detailed results of the soil vapour survey are presented in Appendix 2 and summarised in Table 3.2.

Trial Pit Excavation, Sampling and Chemical Analysis

- 3.9 A total of 149 locations (Figures 10 - 14) were selected for excavation for the purposes of visual and olfactory examination of sub-surface strata, and for the collection of disturbed samples for chemical analysis. Trial pits were positioned to target those areas identified as high risk in the Phase One Desk Study report which were considered more susceptible to potential contamination as a result of historical activities. They were largely associated with POL storage/use and engineering/maintenance facilities, however, it should be noted that only the major engineering/workshop areas were investigated. Where trial pits could not be excavated due to limited access a soil vapour survey point was installed. The feature under investigation at each trial pit location is indicated on Table 3.3. Trial pits were chosen as the principle method of investigation as they are considered to be the most effective technique to permit close examination of sub-surface strata and to collect soil samples as they expose more ground to visual examination than boreholes.

Site Investigation *continued***3****Table 3.2. Summary of Soil Vapour Survey (see Figures 5 to 9 for locations)**

Location	No. of Holes	Summary of Results
POL 17	8	All concentrations < 10 ppm
POL 19	5	All concentrations < 1 ppm
POL 20	8	All concentrations < 1 ppm
POL 23	13	All concentrations < 1 ppm
Fire practice area	8	All concentrations < 1 ppm, except three > 10 000 ppm
Miscellaneous areas	17	All concentrations <= 1 ppm
POL Supply Ring Main - Area A	30	All concentrations <= 1 ppm, except one > 10 000 ppm
Area B	23	All concentrations < 10 ppm
Area C	12	Except one concentration = 20 ppm, all < 1 ppm,
Area D	9	All concentrations < 1 ppm, except two, 1000 & 6000 ppm
Area E	3	All concentrations < 1 ppm
POL Supply Ring Main Junctions		
Area A1	50	All concentrations < 10 ppm
Area A2	39	All concentrations <= 10 ppm
Area C1	58	All concentrations < 1 ppm, except one = 7 ppm
Area D1	20	All concentrations < 1 ppm
Area D2	32	All concentrations < 1 ppm
Area D3	20	All concentrations < 1 ppm

NB: ppm = part per million

- 3.10 Trial pits were excavated using a JCB 3CX wheeled excavator to depths up to 3 m below ground level (bgl) although the majority of pits were less than 2m deep. A hydraulic breaker was used in areas of hardstanding although this was only required for a small number of pits.
- 3.11 Of the total number of pit locations, 8 were not excavated due to the presence of a large number of services as indicated by cable avoidance tool (CAT) scans. Attempts made to re-locate these pits as close as possible to the area being investigated were not successful. Thirty trial pits in all were terminated prematurely (Table 3.3) either due to ground conditions or the presence of services. In four of these instances a second pit was dug nearby and given the suffix A. Trial pits were generally terminated when weathered bedrock was encountered which could not be further penetrated by the JCB. Such terminations were often at relatively shallow depths.

Site Investigation *continued*

Table 3.3. Upper Heyford - Summary of Locations of Trial Pits and Ground Conditions Encountered

Trial Pit Number	Area	Area Investigated	Depth m	Depth to Bedrock m	Made Ground Encountered m	Hydrocarbon Odour ?	Water Strike	Main Natural Lithology
1	B	Air crash site	1.8	1.8				silty clay & limestone
2	B	Air crash site	2.1	2.1		strong odour		silty clay & limestone
3	B	Air crash site	1.7	1.7				silty clay & limestone
4	A	Air crash site	1.1	1.1				silty clay & limestone
5	A	Air crash site	0.85	0.85				silty clay & limestone
6	A	Air crash site	1.9	1.9				silty clay & limestone
7	A	POL 24	1.7	1.7				silty clay & limestone
8	A	POL 1	1.2	1.2	occ ash 0.2 to 0.8			silty clay & limestone
9	A	UST	2.1	2.1				silty sand & limestone
10	A	POL 2	1.3	1.3	occ ash 0.2 to 0.7			sandy silt & limestone
11	A	POL 2	1.6	1.6	occ ash 0.5 to 1.0			sandy silt & limestone
12	A	POL 2	1.4	1.4	occ ash sand 0.2 to 1.2			sand, gravel, ash, silt
13	A	POL 21	1.6	1.6	occ ash brick 0 to 0.7			silty clay & limestone
14	A	POL 21	1	1	coal ? 0.4 -0.45			sandy silt & limestone
15	A	POL 21	2.6	2.6	occ ash 2.2 to 2.6	odour from 2.2		silty clay & limestone
16	A	POL 21	1.2	1.2				sandy & clayey silt & limestone
17	A	POL 21	1.6	1.6	occ ash 0.2 to 0.5			sandy & clayey silt & limestone
18	A	POL 3	1.7	1.7				gravel, clay & silt
19	A	Building 327 - maintenance dock	1.3	1.3				silty clay & limestone
20	A	Building 328 - maintenance dock	1.5	1.5	occ ash brick 0.2 to 0.8			silty clay & limestone
21	A	Former AST	0.5	aban.	brick/stone to 0.5			fill
22	A	Former AST	1.6	1.6				silty clay & limestone
23	A	Building 234 - workshop	1.6	1.6	occ ash 0 to 0.6			sandy silt & limestone
24	A	Former AST	0.5	aban.				silt & limestone
25	A	Former AST	1.4	1.4				sandy silt & limestone
26	A	Former AST	0.4	aban.				fill
27	A	Former AST	0.6	aban.	tarmac 0.3 to 0.4			silty clay & limestone
28	A	Former AST	0.5	aban.				silty clay & limestone
29	A	Former AST	not excavated					
30	A	Former AST	not excavated					
31	A	UST	0.8	aban.	rubble brick conc etc 0.3 to 0.8			
31A	A	UST	0.8	aban.	rubble brick conc etc 0.3 to 0.8			
32	A	AST	1.1	1.1				silty clay & limestone
33	A	UST	not excavated					
34	A	UST	1.2	1.2				silty clay & limestone
35	A	Former AST	1.5	1.5	occ ash brick 0.4 to 0.6	odour 0.2 to 0.6		silty clay & limestone
36	A	Car maintenance area	1.1	1.1				silty sand & limestone
37	A	AST/Auto hobby shop	not excavated					
38	A	Former AST/vehicle maintenance	2.1	2.1	occ wire glass brick to 0.7		yes	sandy silt & limestone
39	A	POL 19	1.7	1.7				sandy silt & limestone
40	A	POL 19	0.5	aban.				sandy silt & limestone
41	A	POL 19	1.4	1.4				silty clay & limestone
42	A	POL 19	1.7	1.7		odour at 1.5	yes	silty sandy clay & limestone
43	A	POL 19	1.6	1.6			yes	silt sand clay & limestone
44	A	POL 19	2	2			yes	sandy silt & limestone
45	A	Building 335 - maintenance dock	1.6	1.6	occ concrete ash 0.1 to 0.7			silty clay & limestone
46	A	Building 337 - fire station	1.4	1.4	occ brick wood ash 0.2 to 0.9			silty clay & limestone
47	A	Former AST	1.4	1.4	occ glass plastic to 0.6			sandy silt & limestone
48	A	Building 424 - Hazardous waste facility	not excavated					
49	A	Building 1368 - Hush house/AST	1.3	1.3				sandy silt & limestone
50	A	Building 1443 - Hush house/AST	2	2				sandy silt & limestone
51	A	Former PFS	1.1	1.1		odour 0.35		silty clayey sand + limestone
52	E	AST/photographic laboratory	1	1				silty clay & limestone
53	E	Former PFS	2.7	2.7	occ ash metal wood to 2.7	odour at 1.7		silty clay & limestone & fill
54	E	Laundrette	1.1	1.1				silty clayey sand + limestone
55	E	UST	1.2	aban.				silty clay & limestone
56	E	Former AST	0.8	aban.	steel concrete 0.1 to 0.5			silty sand & limestone
57	E	UST/AST	1.1	aban.				silty clayey sand + limestone
58	E	Former AST	1.2	1.2				silty clayey sand + limestone
59	B	POL 17	1.9	1.9				silty sandy clay & limestone
60	B	POL 17	1.3	1.3				silty sandy clay & limestone
61	B	POL 17	1.3	1.3	occ ash 0.4 to 0.7	odour at 1.2		silty clay & limestone
62	B	POL 17	1.5	1.5				silty sandy clay & limestone
63	B	POL 16	1.1	1.1				sandy silt & limestone
64	B	POL 15	1.4	1.4				silty clay & limestone
65	B	AST	1.3	1.3				sandy silt & limestone
66	B	AST	1.5	1.5	steel brick conc wood 0.2 to 1.3			fill
67	B	AST	1.4	1.4				silty clay & limestone
68	B	Former AST	1.1	1.1				silty sandy clay & limestone

Site Investigation *continued*

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Table 3.3 (continued). Upper Heyford - Summary of Locations of Trial Pits and Ground Conditions Encountered

Trial Pit Area Number	Area Investigated	Depth m	Depth to Bedrock m	Made Ground Encountered m	Hydrocarbon Odour ?	Water Strike	Main Natural Lithology
69	B AST	1.1	1.1				clayey sandy silt & limestone
70	B Former AST	1.2	1.2	occ metal flint to 0.5			clayey sandy silt & limestone
71	B POL 23	1.3	1.3	occ ash to 0.5			clayey sandy silt & limestone
72	B POL 23	1.7	1.7				silty clay & limestone
73	B POL 13	2	2				silt sand clay & limestone
74	B POL 23	1.4	1.4				silty clay & limestone
75	B POL 23	2	2		odour from 1.3		silty clay & limestone
76	B POL 23	1.3	1.3				silty clay & limestone
77	B Building 1372 - Hush house/AST	1.6	1.6				silt sand clay & limestone
78	B Building 248 - POL	0.4	aban.				silty sand & limestone
78A	B Building 248 - POL	1.7	aban.				silt sand clay & limestone
79	B Air crash site	0.9	0.9				silty clay & limestone
80	B Air crash site	1.2	1.2				silty sandy clay & limestone
81	C POL 11	0.4	aban.				fill
81A	C POL 11	1.8	1.8				silty sandy clay & limestone
82	C AST	1.1	1.1	occ plastic ash brick to 0.4			clayey sandy silt & limestone
83	C AST	1	1				silty clayey sand & limestone
84	C POL 22	1.2	1.2	occ ash to 0.3			silty clayey sand & limestone
85	C POL 22	0.9	0.9	occ ash to 0.3			silty clayey sand & limestone
86	C POL 9	1.7	1.7				silty sandy clay & limestone
87	C Former AST	1.9	1.9	concrete wood to 0.4			silty clay & limestone
88	C Building 3202 - hardened refueling area	2	2				silty clay & limestone
89	C POL 10	2	2	occ ash to 0.5			clayey sandy silt & limestone
90	D POL 5	1.1	1.1				clayey sandy silt & limestone
91	D POL 5	2.4	2.4	occ ash 0.3 to 0.9	odour from 0.8		sandy silt & limestone
92	D POL 20	1.4	1.4				clayey silt & limestone
93	D POL 20	1.6	1.6		strong odour		sand gravel clay silt & limestone
94	D POL 20	1.4	1.4				clayey sandy silt & limestone
95	D POL 20	1.2	1.2	occ brick to 0.2			sandy silt clay & limestone
96	D POL 20	0.4	aban.				sand gravel & limestone
97	D POL 25	1.5	1.5	occ brick ash concrete 0.2 to 0.9			clayey sandy silt & limestone
98	D POL 25	1.8	1.6	occ brick ash concrete 0.2 to 0.6			sandy silt & limestone
99	D POL 25	1.9	1.9				sandy silt & limestone
100	D POL 25	1.8	1.6		odour from 1.3		sandy silt & limestone
101	D POL 25	1.8	1.8	occ ash wood brick 0.2 to 0.7			sandy silt & limestone
102	D POL 25	1.5	1.5	occ wood metal brick 0.2 to 0.5			sandy silt & limestone
103	D Building 382 - POL	1.2	1.2				sandy silt & limestone
104	D Building 385/386 - POL	1.3	1.3				clayey sandy silt & limestone
105	D Building 385/386 - POL	3	3	occ ash brick 0.2 to 0.6	odour from 1.2		sandy silt & limestone
106	D Building 1108 - Maintenance workshop	1.3	1.3			yes	silty clay & limestone
107	D Building 1108 - Maintenance workshop	0.9	aban.				
107A	D Building 1108 - Maintenance workshop	2.1	2.1	occ ash 0.4 to 0.5 & 0.9 to 1.4		yes	sand silt clay and limestone
108	A POL 24	1.2	1.2				silty clay & limestone
109	A Building 2003 - aircraft shelter	2.3	2.3	occ ash 0.9 to 1.4	odour 0.9 to 1.4		clayey sandy silt & limestone
110	A Building 2005 - aircraft shelter	1.4	1.4	occ brick 0.2 to 0.5			clayey sand silt & limestone
111	A Building 2007 - aircraft shelter	1.8	1.8	occ ash 0.2 to 0.6			clayey sandy silt & limestone
112	A Former AST/vehicle maintenance	1.6	1.6	occ metal to 0.5			clayey sandy silt & limestone
113	C Building 212 - maintenance/UST	0.4	aban.	fibrous metallic to 0.4			
114	A Building 156 - Hazard store/Former AST	not excavated					
115	A Former AST	not excavated					
116	A Former AST	not excavated					
117	A AST	0.5	aban.	occ metal ash to 0.5			silty clayey sand & limestone
118	A Former AST	2.3	2.3	occ wood brick 0.3 to 1.0			clayey sand fill & limestone
119	A AST	0.2	aban.				
120	A UST	1.4	aban.	brick wood cloth to 0.7			sand gravel clay & limestone
121	A AST	1.3	1.3	occ ash to 0.3			sandy clayey silt & limestone
122	E Former AST	1.3	1.3	occ ash brick metal 0.3 to 0.7			sand silt clay and limestone
123	E AST	0.9	0.9	occ brick glass plastic 0.1 to 0.4			silty clayey sand & limestone
124	C Weapons storage area	2	2		odour 1.7 to 2.0		sandy clayey silt & limestone
125	A Former AST	1	1	occ ash 0.2 to 0.7			sandy silt & limestone
126	A Formerly Building 299A	1.4	1.2				sand silt clay and limestone
127	B Building 234 (UST within building)	1.6	1.6				sandy silt & limestone
128	D UST	1.5	1.5				sandy clayey silt & limestone
129	E UST	1.4	1.4				silty clay & limestone
130	B Former AST	1.2	1.2				silty clay & limestone
131	A Building 56 - maintenance workshop	1.2	1.2				sand silt clay & limestone
132	A Building 336 - Hanger wash down	0.95	aban.				sand silt clay & limestone
133	E Former AST	0.8	0.8				silty sandy clay & limestone
134	D SVS - elevated flammable gas	1.7	1.7		odour from 0.9		silty sandy clay & limestone

Site Investigation *continued*

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Table 3.3 (continued). Upper Heyford - Summary of Locations of Trial Pits and Ground Conditions Encountered

Trial Pit Number	Area	Area Investigated	Depth m	Depth to Bedrock m	Made Ground Encountered m	Hydrocarbon Odour ?	Water Strike	Main Natural Lithology
135	C	Dead grass	1.7	1.7				silty sandy clay & limestone
138	B	Dead grass	0.5	aban.	tarmac from 0.5			silty clay & limestone
137	A	SVS - elevated flammable gas	0.9	0.9	occ ash to 0.25			sandy silt & limestone
138	A	Walton PFS	2.2	2.2	ash brick tarmac 0.2 to 0.9	odour from 0.9	yes	sandy clayey silt & limestone
139	B	Air crash site	1.8	1.8				silty clay & limestone
140	A	UST	1.6	1.6				silty sandy clay & limestone
141	A	Building 156 - hazard store/UST	1.5	1.5				silty sandy clay & limestone
142	A	Fire practice area	1.4	1.4	occ ash to 0.2	slight odour		sand silt clay and limestone
143	A	Fire practice area	1.2	1.2	ash 0.3 to 0.4			sandy clay silt & limestone
144	A	Fire practice area	1.2	1.2	ash 0.3 to 0.6	odour from 0.55		sandy clayey silt & limestone
145	A	Fire practice area	1.1	1.1	occ ash to 0.6			sandy clayey silt & limestone
146	A	Fire practice area	1.2	1.2	occ ash at 0.2	strong odour		sand silt clay and limestone
147	A	Fire practice area	1.2	1.2				sandy silt clay and limestone
148	A	Fire practice area	1.1	1.1	occ ash to 1.1	odour from 0.7		sandy silt clay and limestone
149	A	Fire practice area	1.2	1.2	occ ash 0.2 to 0.5	strong odour		sandy clay and limestone

Notes: aban. - trial pit abandoned before reaching bedrock, occ - occasional, water strikes are in base of pits, lithology is indicative - see log for full description.
UST - underground storage tank, AST - above ground storage tank, PFS - petrol filling station

- 3.12 During excavation, the exposed ground strata were carefully examined and recorded by experienced scientists from Aspinwall. The trial pit logs are provided in Appendix 3. The depth of these pits, depth to bedrock, presence of water and hydrocarbons, in addition to the material encountered are summarised in Table 3.3. On completion, all trial pits were immediately backfilled with arisings, ensuring reasonable consolidation. The trial pits which were excavated through hardstanding were reinstated following backfilling.

Trial Pit Sampling and Quality Control

- 3.13 Soil samples were collected from exposed ground strata in all trial pits. Samples were taken from within the excavator bucket using stainless steel sampling equipment. Care was taken to ensure that samples were removed from the centre of the excavator bucket. All sampling equipment was cleaned to minimise the potential for cross-contamination. Visible dirt was removed from the stainless steel trowel after the collection of each sample, and washed with detergent and clean water if further cleaning was necessary. Soil samples were placed in 1 kg plastic air tight containers before being boxed and sent to Geochem laboratory in Chester accompanied by Chain of Custody documentation.
- 3.14 Samples for analysis were selected from the trial pits on the basis of depth, nature of strata or where visual or olfactory evidence of contamination was apparent. Not all strata were sampled, but only those determined as being the most appropriate by the environmental scientist on site. Sampling depths are shown on the trial pit logs contained in Appendix 3 and in the certificates of chemical analysis in Appendix 4.
- 3.15 Groundwater samples were only collected from four of the seven trial pits where it was encountered due to low seepage rates at the remaining three locations. Samples were taken from the bucket of the JCB and transferred to bottles

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supplied by the laboratory. Details are presented on the trial pit logs in Appendix 3.

- 3.16 All samples were submitted to Geochem, a UKAS accredited laboratory, regularly audited by Aspinwall and who have shown acceptable results in inter-laboratory schemes such as CONTEST.

Chemical Analysis of Samples from Trial Pits

- 3.17 All soils samples were tested for a standard analytical suite as follows:

<i>Soils (Suite A)</i>	pH, total (acid soluble) sulphate, soluble sulphate, total
<i>301 samples:</i>	metals (arsenic, cadmium, chromium, mercury, selenium, lead, nickel, zinc and copper) water soluble boron and total solvent extract.

- 3.18 In addition to this basic suite, supplementary testing was undertaken on a number of samples based upon visual and olfactory information gathered during the site investigation. Eleven soil samples were analysed for Volatile Organic Compounds (VOCs) by Gas Chromatography Mass Spectroscopy (GCMS) with forty two samples analysed for mineral oil by TLC. Following these initial analyses more detailed analyses were requested in order to identify particular species present. The additional testing includes:

Polyaromatic Hydrocarbons (PAH's) by Thin Layer Chromatography - Flame Ionisation (TLC-FID)	8
Diesel range organics	6
Petrol range organics	4
Semi-volatile organic compounds	6
NRA leaching tests (As, Hg, Se, Cr, Cd, Cu, Ni, Zn, pH)	4
Hexavalent chromium	2
Solvent extractable matter	2

All results of the soils analysis are presented in Appendix 4.

- 3.19 Three samples which contained fibrous material were submitted for asbestos analysis.
- 3.20 Water samples were taken from trial pits 38, 91, 106 and 138 and analysed for the following range of "indicator" determinands: mineral oil, total non-volatile aromatics, NSO/resins, total petroleum hydrocarbons (TPH), and solvent

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extractable matter. In addition metals and major ions were analysed for in the sample from TP138.

Borehole Drilling, Sampling and Testing

- 3.21 Information presented on the BGS 1:63 360 scale geological map and the map memoir (Ref 8) was used with reports made available by DEO (Refs 1, 2 & 4) to design the site investigation. Prior to assessment of this information it was proposed (Ref 3) that a number of shell and auger boreholes be drilled across the site to provide shallow long term groundwater monitoring locations. However, at the review stage it was determined that bedrock would be very shallow and shell and auger techniques would therefore be inappropriate. The most suitable drilling method determined was rotary air flush using a rock roller through weathered material and a down hole hammer through competent bedrock. Furthermore, it was envisaged that the Great Oolite Limestone would be sufficiently competent to remain open without a well screen and a formation stabiliser. However, because of the nature of the aquifer several boreholes did not even remain open during drilling. The method was therefore revised to drill with casing where necessary (boreholes 1 and 2) with well screen and formation stabiliser installed at all locations.
- 3.22 Originally five locations were proposed for installation of "deep" groundwater monitoring wells (Ref 3). However, following the review of available information and curtailment of the shell and auger drilling this number was increased to seven. Six of these were around the site perimeter, and the seventh in the centre of the site (Figure 4). Each hole encountered very different ground conditions (as detailed in the logs in Appendix 5) and which required a number of techniques in order to complete the hole as summarised below:

Borehole 1 - drilled dry to a depth of 37 m below ground level (bgl), following which no returns were obtained. Drilling continued, but due to the potential for the bit to become blocked in the hole it was removed and the hole dipped. Standing water was measured at 43.6 m bgl, borehole depth 46.5 m bgl. Although some slightly damp returns had been obtained at a shallower depth there had been no water strike. The ground conditions included initially limestone, then a mudstone and a sand band before more limestone and then from 15.5 m to 34.0 m bgl mudstone. A thin limestone band, sandstone and void were encountered from 34 to 35 mbgl before returns ceased.

Well screen was installed from 36 m bgl to the base of the borehole. 1 millimetre (mm) slotted screen was surrounded by a fabric wrap to limit ingress of fines and surrounded by a sand pack. Bentonite pellets were installed above the sand to seal off the test section. During emplacement, water which was not previously observed, was noted at about 15m. A second well screen was therefore installed, surrounded by a sand pack and sealed with bentonite to the surface. The deeper screened section is termed borehole 1A, the shallower borehole 1B. The screened

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sections have very different water levels indicating that the grout seal between them is effective.

Borehole 2 - encountered limestone to 21.3 m bgl and then mudstone to 40 m bgl with no water strike. It was hypothesised that the aquifer had drained at this location and that groundwater was moving down dip along the upper mudstone surface. The base of the hole through the mudstone was therefore sealed with grout and fabric wrapped well screen installed at the base of the limestone. The screened section was surrounded by a sand pack with a bentonite seal to the surface. Subsequent monitoring demonstrated slow water ingress.

Borehole 3 - limestone was encountered to 4.3 m bgl, with a thin mudstone band from 3.4 to 4.0 m bgl. Water was struck at 1m. Two well screens were installed, one above and one below the mudstone band, separated by a bentonite seal. This installation was chosen to assess the hydraulics of thin mudstone bands.

Borehole 4 - encountered limestone to 4.1 m bgl, then mudstone to 19.8 m bgl, with 3 thin sandstone bands between 11.3 and 14.1 m bgl. Water was struck within the mudstone at 16.8 mbgl, indicating that the mudstones in the area do allow water transmission, in a lateral direction at least. Well screen was installed in the mudstone with a 1m bentonite seal above the sand pack and grout to the surface.

Borehole 5 - encountered limestone to 3.4 m bgl with a clay band from 1.0 to 1.2 m bgl. Mudstone was encountered at 3.4 m bgl. With a water strike at 1.0 m bgl the hole was terminated at the top of the mudstone and well screen was installed.

Borehole 6 - was drilled to 16 m bgl, initially through limestone, with two clay layers, then through mudstone with two sandstone layers. Water was struck at 12.55m in mudstone, although the returns were slightly damp at 3.4 m bgl (no inflow was detected following 0.5 hours standing). Well screen was installed to the base of the borehole with a bentonite seal to surface. Attempts to install a second screen in the "damp" zone at 3.4 m bgl failed. Two rock samples obtained during drilling from 0 to 1 and 1 to 2 m bgl had a hydrocarbon odour and were subsequently submitted to the laboratory for analysis.

Borehole 7 - encountered limestone to 6.0 m bgl with mudstone to 7.5 m bgl and a water strike at 4.6 m bgl. The mudstone was backfilled with grout and well screen installed to 5.2 m bgl surrounded by a sand pack, with a bentonite seal above this.

In all instances where possible the well screen was installed so as to pass through the water table (either at rest or when pumped) so as to allow any floating free product to enter the screen. Either grout, bentonite or a combination of both were used to seal off sections of borehole to minimise the potential for vertical water migration either up or down the borehole annulus.

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- 3.23 Upon completion all boreholes were dipped and plumbed for depth, details of which are presented in Table 3.4 together with screened section information. Each borehole was then dipped on a daily basis for the duration of the site investigation to determine any short term fluctuations (Table 3.5). All boreholes were then developed by pumping and backsurging. The exceptions were boreholes 2 and 6 which could not deliver sufficient water for pumping. At borehole 4 the water strike was in the mudstone, however, the borehole still yielded significant water confirming that the mudstone bands can have a moderate lateral permeability.

Table 3.4. Borehole Completion Details

Borehole Number	Datum Elevation (mAOD)	Ground Elevation (mAOD)	Depth (m bTOP)	Screened Interval (m bgl)	Lithology of Screened Interval
1A	116.38	116.42	42.64	36.6 to 42.6	mudstone
1B	116.26		16.39	13.4 to 16.4	limestone
2	137.91	137.98	25.06	22.1 to 25.1	limestone
3A	121.67	121.71	4.29	4.1 to 4.3	limestone
3B	121.67		2.99	0.5 to 3.0	limestone
4	121.87	121.88	19.70	10.8 to 19.8	mudstone with sandstone bands
5	120.08	120.20	2.74	0.2 to 2.7	limestone
6	121.49	121.56	15.89	12.9 to 15.9	mudstone with sandstone bands
7	131.00	131.01	5.34	2.3 to 5.3	limestone

Note: datum at each borehole is the top of the plastic well pipe

m AOD - metres above Ordnance Datum, m TOP - metres below top of plastic pipe

- 3.24 Following borehole development a permeability test was undertaken at each hole. The type of test undertaken is known as a "slug test". This involves monitoring water levels in the borehole, using a pressure transducer linked to a portable computer at the surface, whilst a weighted float is alternately inserted and then removed from beneath the water table. The rate with which the water returns to its equilibrium level, in between each insertion and removal, is combined with selected borehole dimensions to determine the aquifer permeability in the vicinity of the borehole. The results are analysed using the methods detailed in Refs 15 and 16, and are summarised in Table 3.6. Detailed analyses and water level plots are presented in Appendix 6. This system was varied in borehole 2 due to its low permeability, where following bailing, water level recovery was monitored and analysed as a rising head test using the method in Ref 17.

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Table 3.5. Water Level Monitoring Results

Borehole Number	Date of Water Level Measurement below datum					
	29/04/97	30/04/97	01/05/97	02/05/97	08/05/97	09/05/97
1A				34.98	34.93	34.98
1B				12.75	12.78	12.79
2			24.81	24.77	23.84	24.24
3A	1.70	1.69	1.68	1.68	1.64	1.63
3B	1.65	1.65	1.65	1.65	1.64	1.64
4		12.25	12.26	12.26	12.08	12.15
5					1.19	1.16
6					8.52	8.61
7		3.22	3.20	3.20	2.99	2.93
	Water Level Measurement (m AOD)					
1A				81.40	81.45	81.40
1B				103.61	103.58	103.57
2			113.10	113.14	114.07	113.67
3A	119.97	119.98	119.99	119.99	120.03	120.04
3B	120.02	120.02	120.02	120.02	120.03	120.03
4		109.62	109.61	109.61	109.79	109.72
5					118.89	118.92
6					112.97	112.88
7		128.78	128.80	128.80	129.01	129.07

Note: datum at each borehole is the top of the plastic well pipe.

- 3.25 Table 3.6 is divided into 6 columns, the first of which details the location tested. Columns 2 and 3 present the hydraulic conductivity determined each time the slug is either inserted (a falling head test - FHT), or removed (a rising head test - RHT). Where the water table passes through the well screen during the test (as opposed to being within the plain casing) then an adjustment can be made to account for the porosity of the sand pack. The resulting hydraulic conductivity when this is accounted for is presented in columns 4 and 5. In some instances a "double straight line" response is obtained which comprises a steep initial change in water level, followed by a later more gradual change. Where such a response has occurred details are presented in column 6 in addition to the depth of screened interval tested.
- 3.26 Water samples were taken from each borehole after development and testing. A variable frequency electric submersible pump was installed in each hole and used to purge stagnant borehole water. The discharge water was monitored continuously using a flow through cell & multi-parameter probe measuring pH, electrical conductivity (EC), temperature, turbidity, redox and dissolved oxygen, the results of which are presented in Appendix 7. When the measured parameters had stabilised the pump frequency was reduced to minimise sample alteration, then once the pump pipeline volume had been discharged, five sample bottles were filled, each for a different series of determinands. In addition, following pump removal, the water table surface was bailed a small number of times before a bailed sample was obtained to determine if any floating product was present.

Site Investigation *continued*

3

Following sampling the pump was flushed through with dilute Decon 90 (a laboratory grade detergent) followed by tap water.

Table 3.6. Permeability (Slug) Test Results (m/d)

Borehole	FHT	RHT	FHT*	RHT*	Test Section
BH1A	0.80	0.64			36 to 42m
BH1 Falling	0.011				horiz. k of mudstone @ 17m, (m = 10)
BH1 B	26	18			13 to 16
BH2		0.25			24.8 to 25
BH3A	38	20			4.1 to 4.3
BH3B	14	71	59	307	1.6 to 3.0
BH4	4	20	17	87	10.8 to 1.8, k = 4/17 for double st. line of RHT*
BH5	1.1	46	4.8	198	1.0 to 3.5m
BH6	0.05	0.068			12.9 to 15.9, k = 0.69 for double st line of FHT
BH7	1.0	1.2	4.2	5.3	3 to 5m

Note: * test adjusted for test within screened section (see Ref 14), k - hydraulic conductivity, FHT - falling head test, RHT - rising head test.

3.27 The sampling system was changed in borehole 1A as the pump became blocked with fines and in boreholes 2 and 6 where permeability was insufficient to support pumping. In these instances bailed samples were obtained following purging by bailing.

3.28 All samples were stored in cool boxes upon collection. They were generally transported to the laboratory on the day of collection or within 24 hours. All samples were analysed for the following determinands:

- major ions* - sodium, potassium, magnesium, calcium, chloride, sulphate, bicarbonate, nitrate, ammoniacal nitrogen
- metals* - arsenic, cadmium, chromium, mercury, lead, nickel, zinc, copper, boron, selenium
- "indicators"* - chemical oxygen demand (COD), biochemical oxygen demand (BOD), total organic carbon (TOC), total petroleum hydrocarbons (TPH), total alkalinity
- others* - pH, EC, solvent extract, phosphate

Site Investigation *continued*

3

The samples were filtered by the laboratory prior to analysis, except those to be analysed for COD and BOD, analysis for which was carried out on unfiltered samples. Where both bailed and pumped samples were obtained from one borehole the bailed sample was only analysed for TPH. The results are presented in Appendix 8.

Spring Inspection and Sampling

- 3.29 The 1:25000 scale OS map was used to identify "springs" (including water courses fed by stormwater drains from the base) surrounding the site as detailed on Figure 4. Each of these was visited in order to determine its nature and discharge. At this time any additional springs identified, which are not denoted on the OS map, were also assessed. In situ measurements of pH, EC and temperature were made as an aid to determining any springs with distinctly different water sources (and therefore chemistry). At springs with a significant discharge, water samples were taken. These were stored in cool boxes and submitted to Geochem for analysis of the same determinands as the groundwater samples. Details of the springs visited are presented in Table 3.7, with analytical results in Appendix 9. It must be noted that all discharges are visual estimates and are used for comparison between springs rather than absolute gaugings.

Table 3.7. Surface Water Sampling at Upper Heyford

Spring	NGR (SP)	Date Visited	Q l/s	Sample taken	pH	Temp deg C	EC uS/cm	Date Visited	Q l/s	Sample taken	pH	Temp deg C	EC uS/cm
A	5345 2660	22/04/97	dry										
B	5245 2742	23/04/97	1 to 2	yes	6.8	9.6	642	09/05/97	1 to 2	yes	7.0	9.4	709
C1	4955 2822	23/04/97	<		6.8	11.	870						
C2	4953 2792	23/04/97	0.05	yes	7.	10.	855						
D	4975 2733	23/04/97	1	yes	7.	9.0	945	09/05/97	1 to 2	yes	7.4	9.	103
E	4940 2698	23/04/97	dry										
F	4978 2660	23/04/97	<		7.	7.9	684	09/05/97	<0.				
G	4977 2622	24/04/97	0.5 to	yes	7.4	9.6	775						
G2	4972 2625	24/07/97	0.3 to 0.5		7.2	10.	698						
G3	4968 2623	24/07/97	marsh										
H	4960 2557	24/04/97	0.		6.9	8.7	91						
I	5054 2553	24/04/97	<		7.4	10.	547	09/05/97	1	yes	7.5	10.	382
J	512 2527	24/04/97	stagnant		7.7	10.	485	09/05/97	trickle				
K	519 261	22/04/97	very low ?		7.2	9.5	658						
L	520 2685	22/04/97	1	yes	7.4	10.	729						
M	2600 5297	22/04/97	1	yes	6.8	9.7	664						
N	5088 2865	23/04/97	dry										
O	4998 2874	24/04/97	1		6.8	10.	778						
P1	4965 2582	24/04/97	1	yes	7.4	10.	770						
P2	4963 258	24/04/97	dry										
Q	496 2572	24/04/97	0.		7.2	9.2	855						
R1	4966 2525	24/04/97	<		7.3	8.8	728						
R2	4963 2529	24/04/97	1 to 2	yes	7.3	9.4	770						
S	4958 254	24/04/97	0.5		7.4	9.5	790						

Spring locations shown on Figure 4. Q - estimated discharge, Temp - temperature, EC - electrical

- 3.30 One spring, spring D, in close proximity to the base, and with easy access was used as a "control". Daily measurements of pH/EC and discharge estimates were made throughout the period of site investigation (Table 3.8). This was carried out to

Site Investigation *continued***3**

allow any rainfall induced changes to be detected. These were noted on the last day of the investigation and extra samples were taken. Furthermore, a previously dry spring (spring I, which also includes storm drain runoff) had started to flow and was therefore sampled.

Table 3.8. Daily Variations in Quality at Spring D

Date/Time	pH	Temperature (degrees C)	Electrical Conductivity uS/cm	Water Level (m)	Weather
22/04/97 11:50	6.9	9.5	940	0.02	dry
23/04/97 09:30	7.1	9.0	945	0.02	dry
24/04/97 09:25	7.2	8.8	920	0.02	dry
25/04/97 14:05	7.1	8.6	874	0.02	raining 25/4/97 and 26/4/97
28/04/97 14:15	7.8	8.8	973	0.02	dry
29/04/97 09:50	7.5	8.8	934	0.02	dry
30/04/97 17:30	7.3	9.1	887	0.02	dry
01/05/97 14:30	7.5	9.3	926	0.02	dry
02/05/97 09:45	7.5	8.8	969	0.02	dry
08/05/97 13:35	7.6	9.1	982	0.02	showers
09/05/97 11:00	7.4	9.1	1033	0.03	very heavy overnight rain

Note: water level is measured at the centre of a circular discharge pipe

Radiological Investigation

- 3.31 A surface radioactivity survey had previously been undertaken at the site (Ref 6) in 1995. As part of that exercise radioactivity was not identified at levels in excess of typical background. To provide extra confidence in the results, the trial pitting exercise was undertaken in conjunction with DRPS who screened the arisings from selected trial pits with a 44B portable probe, capable of detecting gamma radiation. In addition a limited number of representative samples were taken from the site and submitted for laboratory analysis by DRPS. The DRPS report detailing the radiological investigation is included in Appendix 10.

Summary of Ground Conditions

4

Shallow Ground Conditions

- 4.1 The trial pit logs are presented in Appendix 3. In general across the site a layer or layers of silt or clay, often sandy, and comprising a significant proportion of gravel to cobble sized pieces of limestone were encountered (see below for discussion regarding the nature of this material). This unconsolidated material was underlain by weathered limestone bedrock, which, excepting where concrete or services were encountered, limited the depth of trial pits. The average depth to bedrock was 1.5m (standard deviation 0.4m) with a range from a minimum of 0.8 to a maximum of 3.0m. There is little difference in the depth to bedrock in each area as indicated in Table 4.1.
- 4.2 In 60 trial pits material was encountered which could clearly be described as fill (made ground). In many instances overlying material appeared to be natural, suggesting that at a number of locations the natural material may have been excavated and then replaced following completion of whatever work was required. Because of this difficulty in differentiation, the trial pit log legends (Appendix 3) only indicate fill where it is obviously fill. Re-worked natural ground is not differentiated, and, unless underlain by fill would not be possible to easily identify.

Table 4.1. Summary of Ground Conditions in each Area at Upper Heyford

Area	No. of Pits Excavated ⁺	Depth to Bedrock (m)			No. of Pits with Fill*	No. of Pits with water	No. of Pits with Odour
		Average	Maximum	Minimum			
A	70	1.5	2.6	0.9	37	5	11
B	30	1.5	2.1	0.9	5	0	3
C	13	1.6	2.0	0.9	6	0	1
D	21	1.6	3.0	1.1	8	2	5
E	11	1.3	2.7	0.8	4	0	1

* *i.e. any record of fill, no matter how limited*

⁺ *includes locations where two pits were excavated following abandonment of the first pit*

- 4.3 The fill material encountered generally comprised small amounts of ash or clinker (see Table 3.3). Brick, concrete, tarmac, wood and metal were also found, although excepting, a small number of trial pits, this material was generally limited in thickness. Trial pits where greater amounts of fill were encountered are:

- Area A - TP14 (near POL 21) a 0.05m thick layer of "coal type" material
 - TP21 (near building 320) - brick and stone fill from 0.1 to 0.5m

Summary of Ground Conditions *continued***4**

- TP27 (near building 345) - band of asphalt/tarmac from 0.3 to 0.4m
- TP31 (near building 103) - rubber, brick, timber, metal, asphalt etc. from 0.3 to 0.8m
- TP120 (near building 295) - brick, wood, cloth and coal present at 0.5m
- TP138 (near building 259) - band of asphalt/tarmac from 0.4 to 0.5m
- TP143 (fire practice area) - ash from 0.3 to 0.4m
- TP144 (fire practice area) ash from 0.3 to 0.6m
- Area B - TP66 (near building 253) - steel, brick, breeze block, wood, concrete, tarmac from 0.2 to 1.3m
- TP136 (north of HAS 3014) - tarmac and concrete road at 0.5m, not penetrated
- Area C - TP87 (near building 207) - concrete from 0.1 to 0.2m, with wood and textile to 0.4m
- TP113 (near building 209) - blue/white powdery, fibrous material from 0.1 to 0.4m
- Area E - TP56 (near building 570) - concrete, breeze block, kerb-stone, tarmac and wire from 0.1 to 0.5m

Of the above, the unidentified material in TP113 is of concern, the remainder generally being "builders rubble". The ash/clinker may also be of some concern, depending upon its source and the leachability of any contaminants.

- 4.4 Seven of the trial pits encountered water which was generally trickling in to the base of the pit. Some of this may be perched groundwater although information in Ref 1 indicates that historically there has been a problem on site with leaking water mains.
- 4.5 In twenty one of the trial pits an odour was detected which in all instances was tentatively identified as being from hydrocarbons. The odour varied from slight to strong. The locations identified are as follows:
- Area A - TP15 (POL 21) hydrocarbon odour & ground staining
 - TP35 (adjacent to building 72) - slight hydrocarbon odour & ground staining
 - TP42 (POL 19) - hydrocarbon odour and oily sheen on water in pit
 - TP51 (former petrol filling station near building 62) - black staining & possible hydrocarbon odour
 - TP109 (between buildings 2002 & 2003) - petroleum odour
 - TP138 (near building 259) - hydrocarbon odour
 - TP142 (fire practice area) - slight hydrocarbon odour
 - TP144 (figure practice area) - slight hydrocarbon odour
 - TP146 (fire practice area) - strong hydrocarbon odour
 - TP148 (fire practice area) - slight hydrocarbon odour & some staining of the ground

Summary of Ground Conditions *continued***4**

- TP149 (fire practice area) - strong hydrocarbon odour
 - Area B - TP2 (western end of main runway - crash site) - strong hydrocarbon odour
 - TP61 (POL 17) - strong hydrocarbon odour
 - TP75 (POL 23) - very strong hydrocarbon odour and black staining of ground
 - Area C - TP124 (Weapons Storage Area) - strong hydrocarbon odour & ground stained
 - Area D - TP91 (POL 5 - hydrocarbon odour
 - TP93 (POL 20) - very strong hydrocarbon odour
 - TP100 (POL 25) - hydrocarbon odour
 - TP105 (POL - building 386) - hydrocarbon odour
 - TP134 (Junction of POL supply main) - hydrocarbon odour
 - Area E - TP53 (former petrol filling station - building 493) - hydrocarbon odour
- 4.6 The trial pits identified with a hydrocarbon odour can be divided into several groups:
- those adjacent to POL storage area/POL pipeline;
 - those adjacent to former petrol filling stations;
 - those adjacent to the fire practice area; and
 - miscellaneous buildings and air crash site.

Deep Ground Conditions

- 4.7 The ground conditions encountered beneath the unconsolidated material and weathered bedrock are detailed in Chapter 3 with the borehole construction information. In summary, at the locations drilled, the site is underlain by limestone strata, of between 4.1 and 21.3m thick with occasional clay, mudstone and sand/sandstone bands, overlying a thick mudstone sequence with occasional limestone and sandstone bands. Groundwater is present within a number of horizons depending upon the lithology present.
- 4.8 The direction of groundwater movement is radially outwards from the site in all directions. This is evidenced from the groundwater elevations and the presence of springs. Because of the complexity arising from the number of aquifer layers present at the site it is not possible to construct a meaningful water table map.

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5

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Figures

Figure

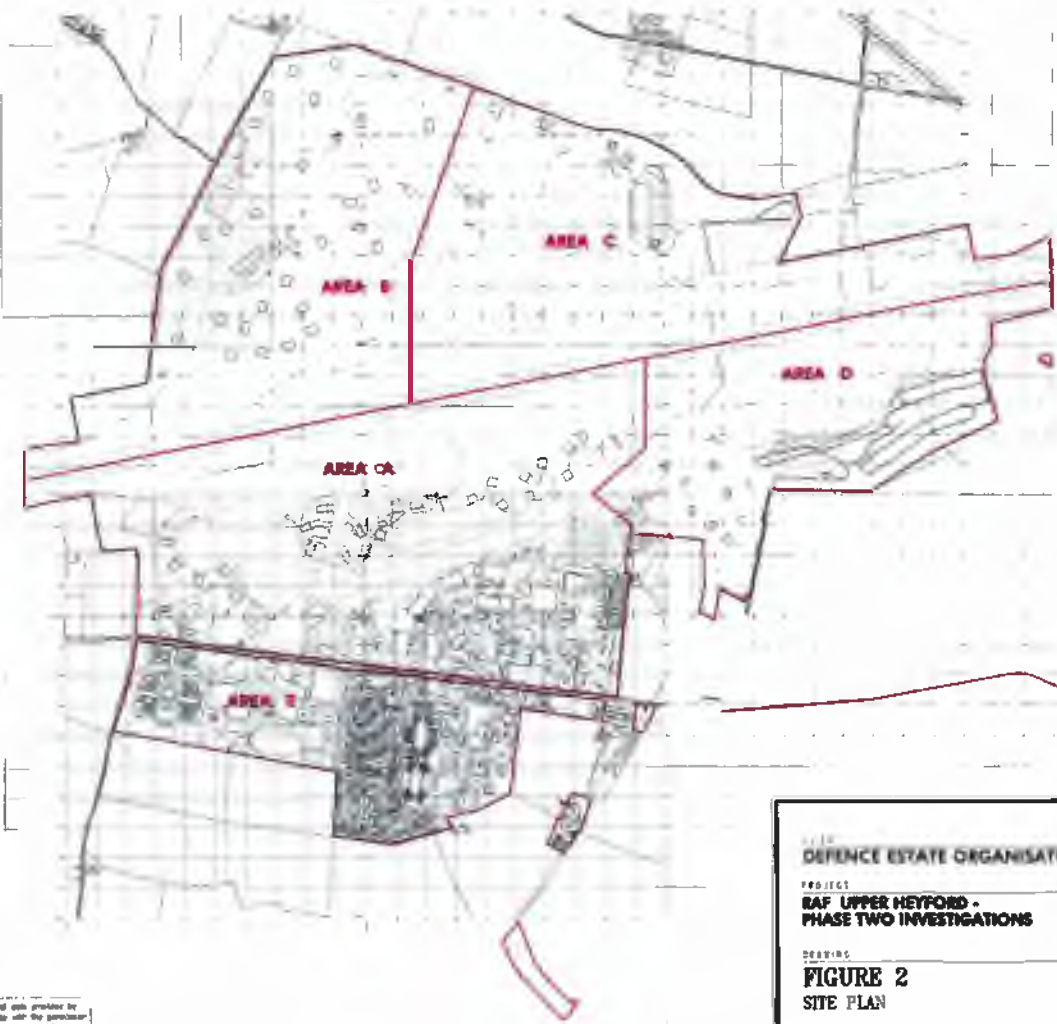
1

Site Location

Figure

2

Site Plan



KEY
 Site Boundary

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DATE 08.06.07
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**FIGURE 2
 SITE PLAN**

DATE 08.06.07
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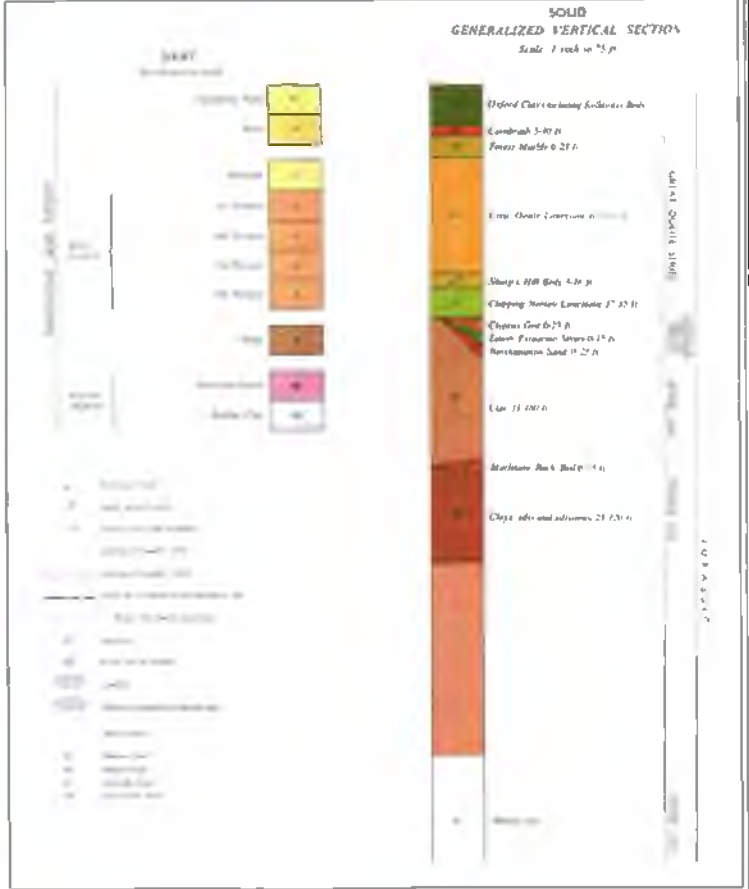
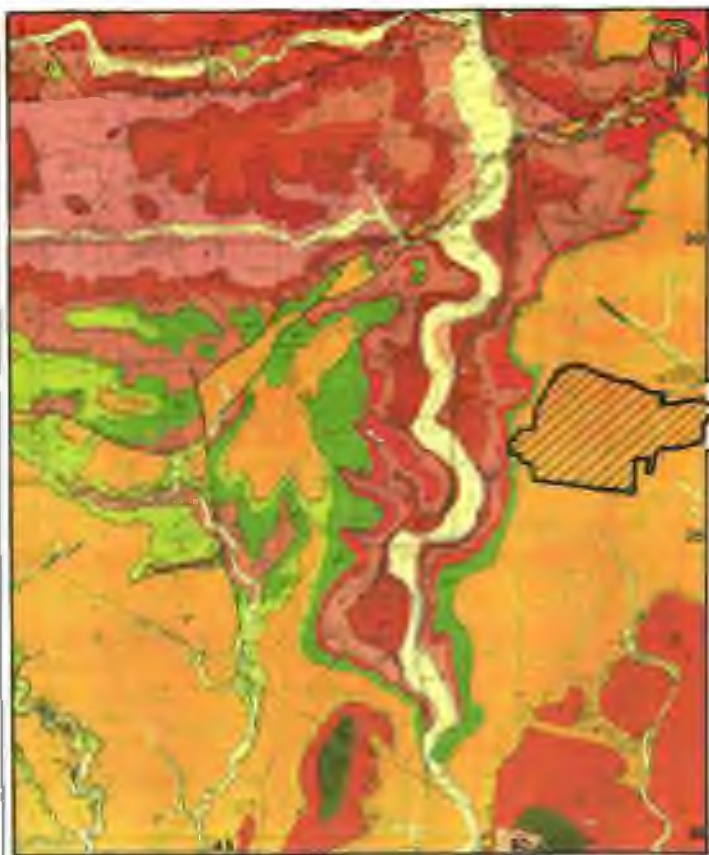
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Figure

3

Geology

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Approximate site area

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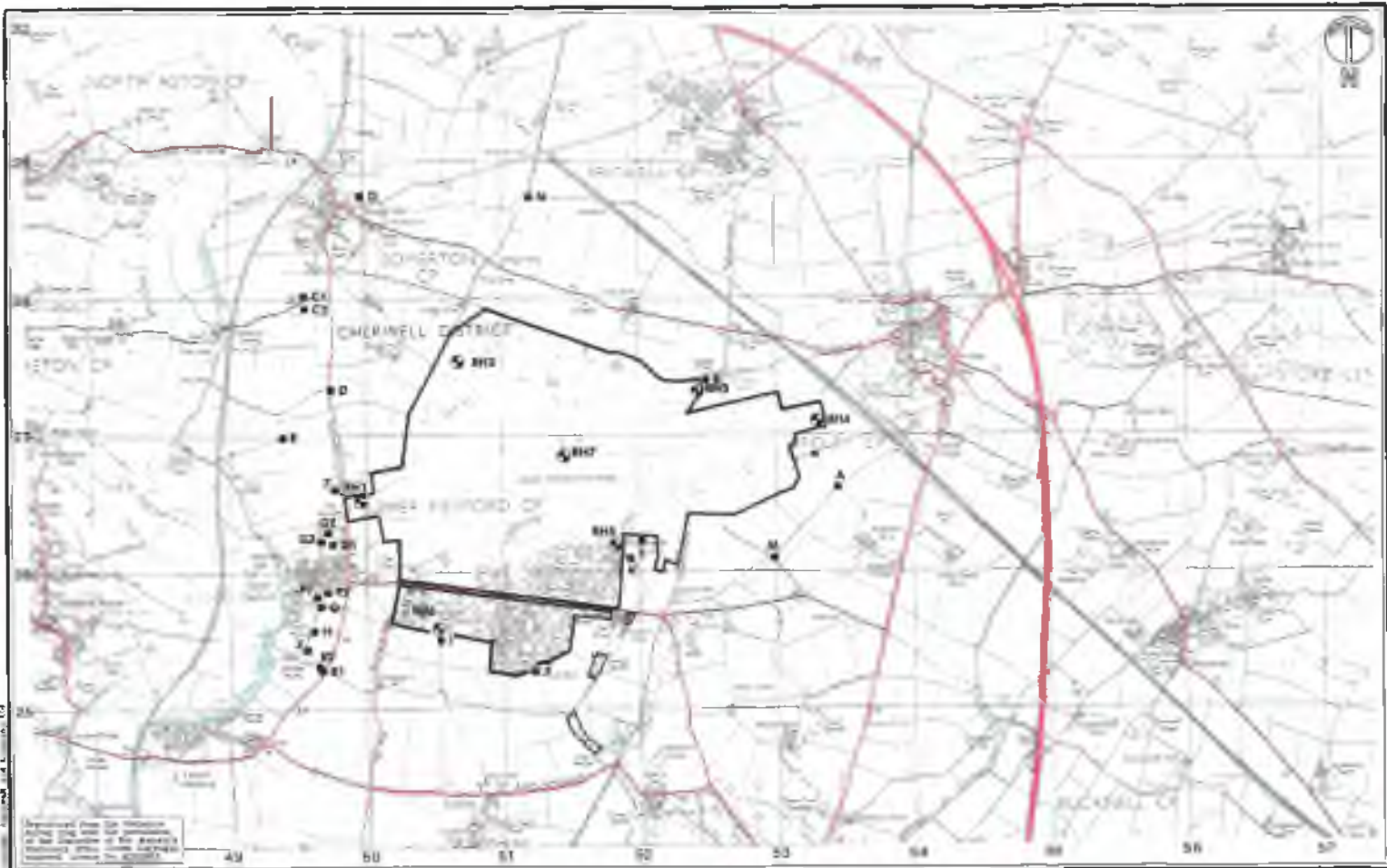
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 DRAWING: **FIGURE 3 GEOLOGY**

Figure

4

**Location of Boreholes & Surface Water Course Sampling
Points**



- KEY
- Borehole locations
 - Surface water sampling locations

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**FIGURE 4
LOCATION OF BOREHOLES AND
SURFACE WATER SAMPLING POINTS**

Figure

5, 5A

Soil Vapour Survey Sampling Points - Area A



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- Boundary of Area A
- Soil vapour survey point
- POL supply ring main (taken from ERM desk study)

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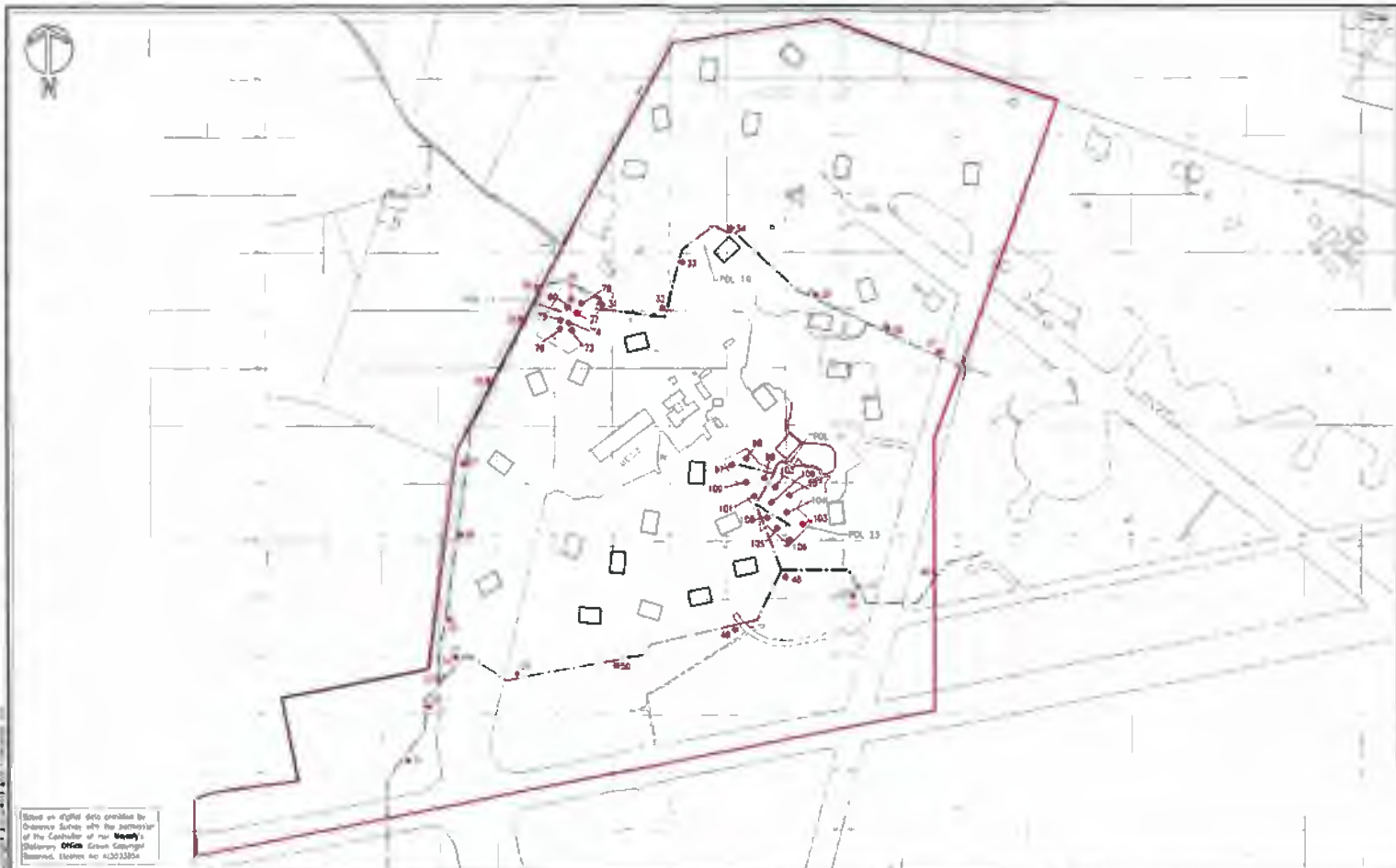
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FIGURE 5A
DETAIL OF AREAS A1 - A2
SOIL VAPOUR SURVEY SAMPLING LOCATIONS

Figure

6

Soil Vapour Survey Sampling Points - Area B



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- Boundary of Area B
- Soil vapour survey point
- POL supply ring main (taken from ERM desk study)

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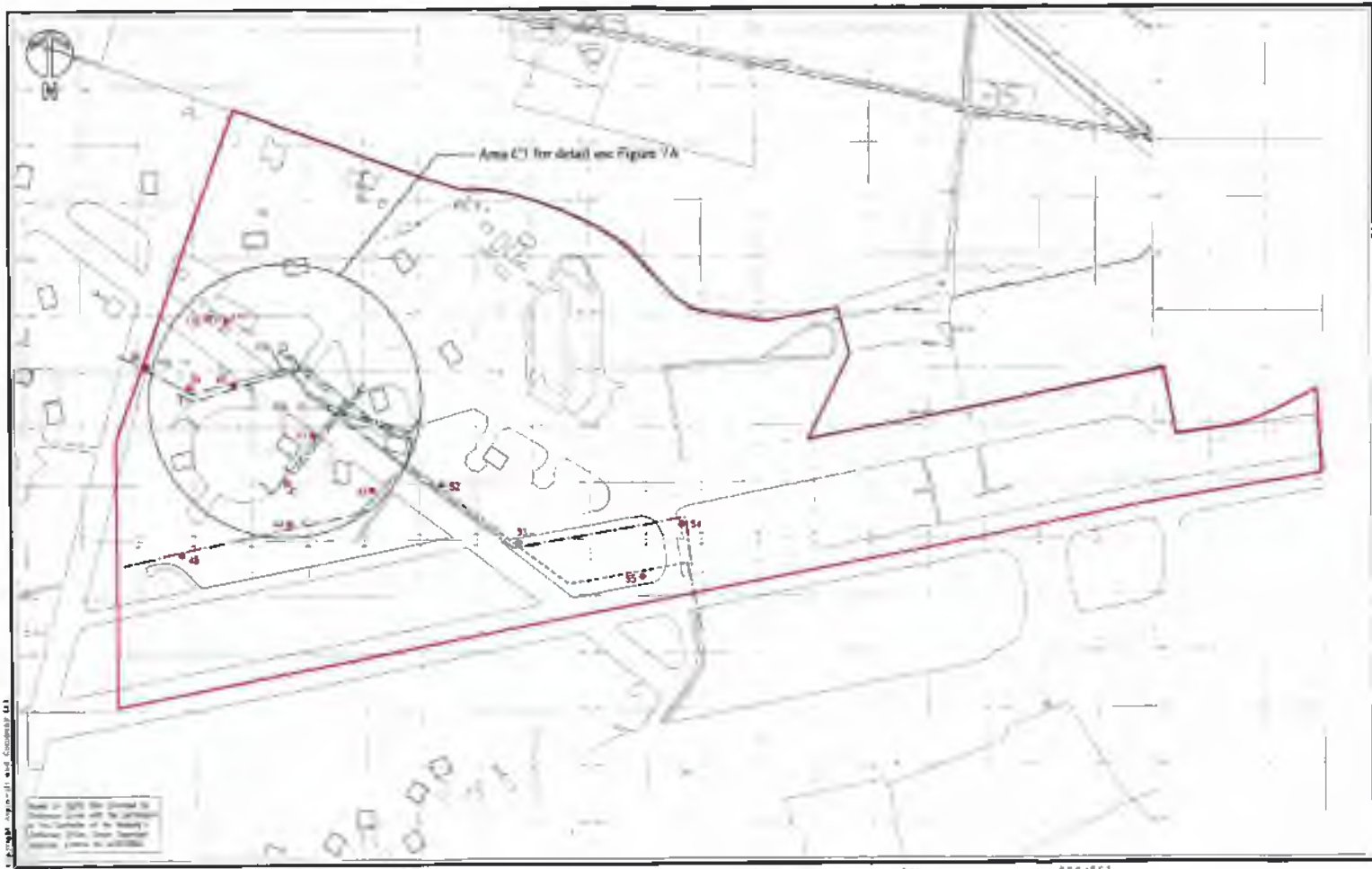
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FIGURE 6
AREA - B
SOIL VAPOUR SURVEY SAMPLING LOCATIONS

Figure

7, 7A

Soil Vapour Survey Sampling Points - Area C



RAF Upper Heyford, Gloucestershire G11

- Boundary of Area C
- Soil vapour survey point
- POI, supply ring main (taken from ERM desk study)
- POI, supply ring main re-routed from dpa previous location

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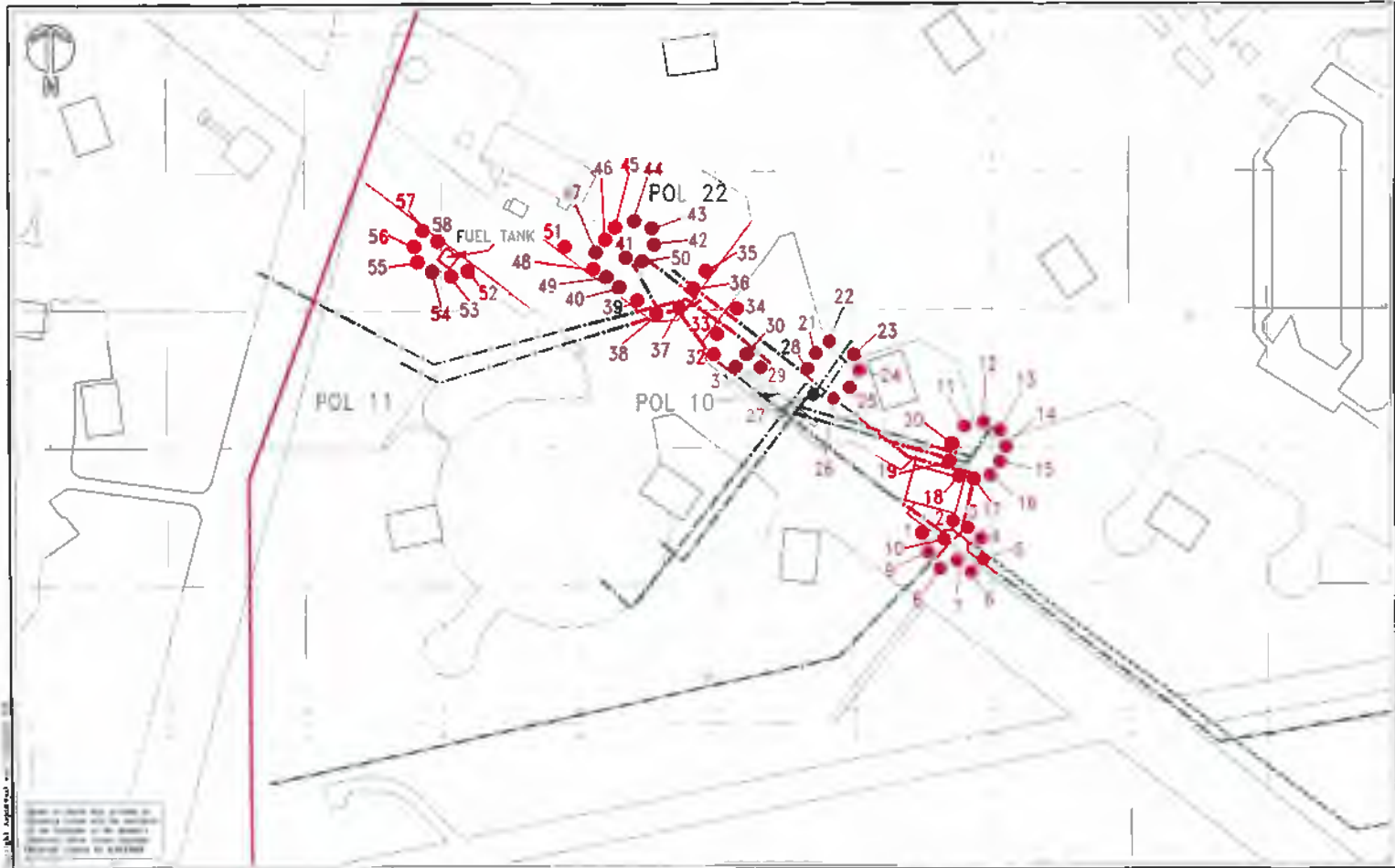
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FIGURE 7

**AREA C -
SOIL VAPOUR SURVEY SAMPLE LOCATIONS**



-  Boundary of Area C
-  Soil vapour survey point
-  POL supply ring main (taken from FRM desk study)
-  POL supply ring main re-routed from this previous location

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FIGURE 7A
DETAIL OF AREA C1 - SOIL VAPOUR SURVEY SAMPLE LOCATIONS

Figure

8, 8A

Soil Vapour Survey Sampling Points - Area D



- KEY**
- Boundary of Area D
 - Soil vapour survey point
 - PCL supply ring main (taken from ERM desk study)
 - PCL supply ring main re-routed from this previous location

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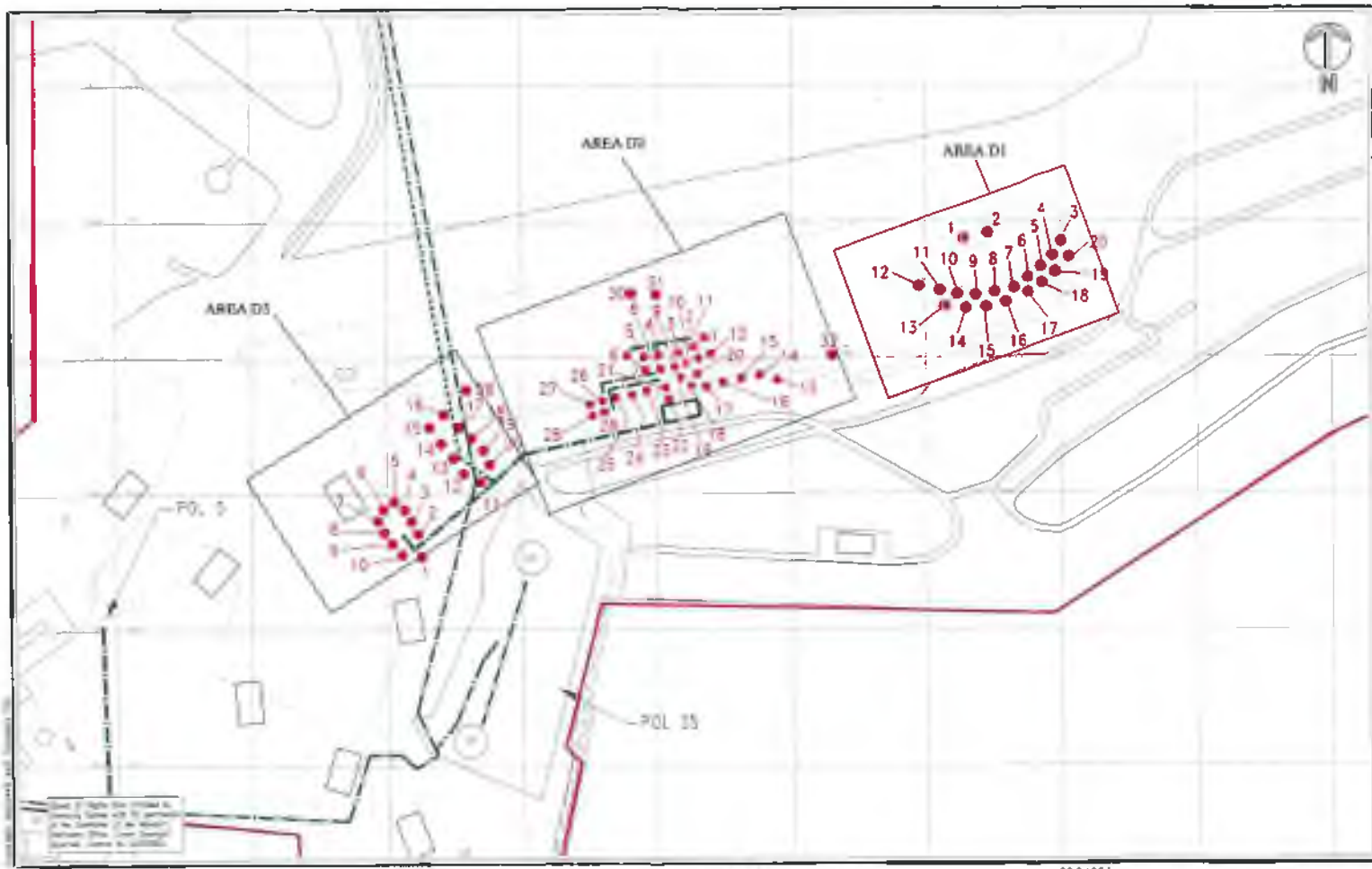
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DRAWN: **FIGURE 8**

AREA D - SOIL VAPOUR SURVEY SAMPLE LOCATIONS



- Boundary of Area D
- Soil vapour survey point
- POL supply ring main (taken from ERM desk study)
- POL supply ring main re-routed from this previous location

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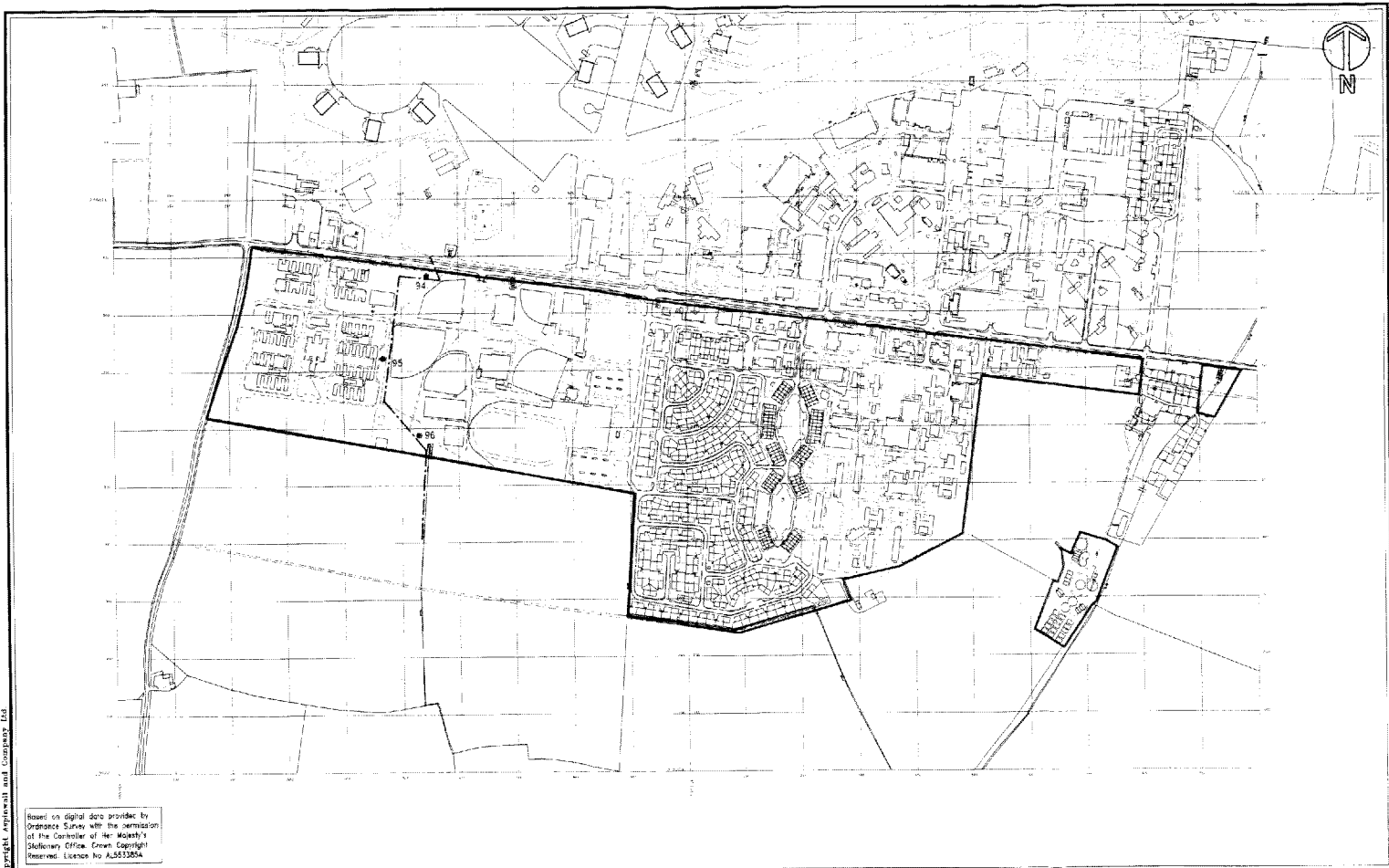
FIGURE 8A
**DETAIL OF AREA D -
 SOIL VAPOUR SURVEY SAMPLE LOCATIONS**

Figure

9




Soil Vapour Survey Sampling Points - Area E

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KEY

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-  Soil vapour survey point
-  POL supply ring main (taken from ERM desk study)

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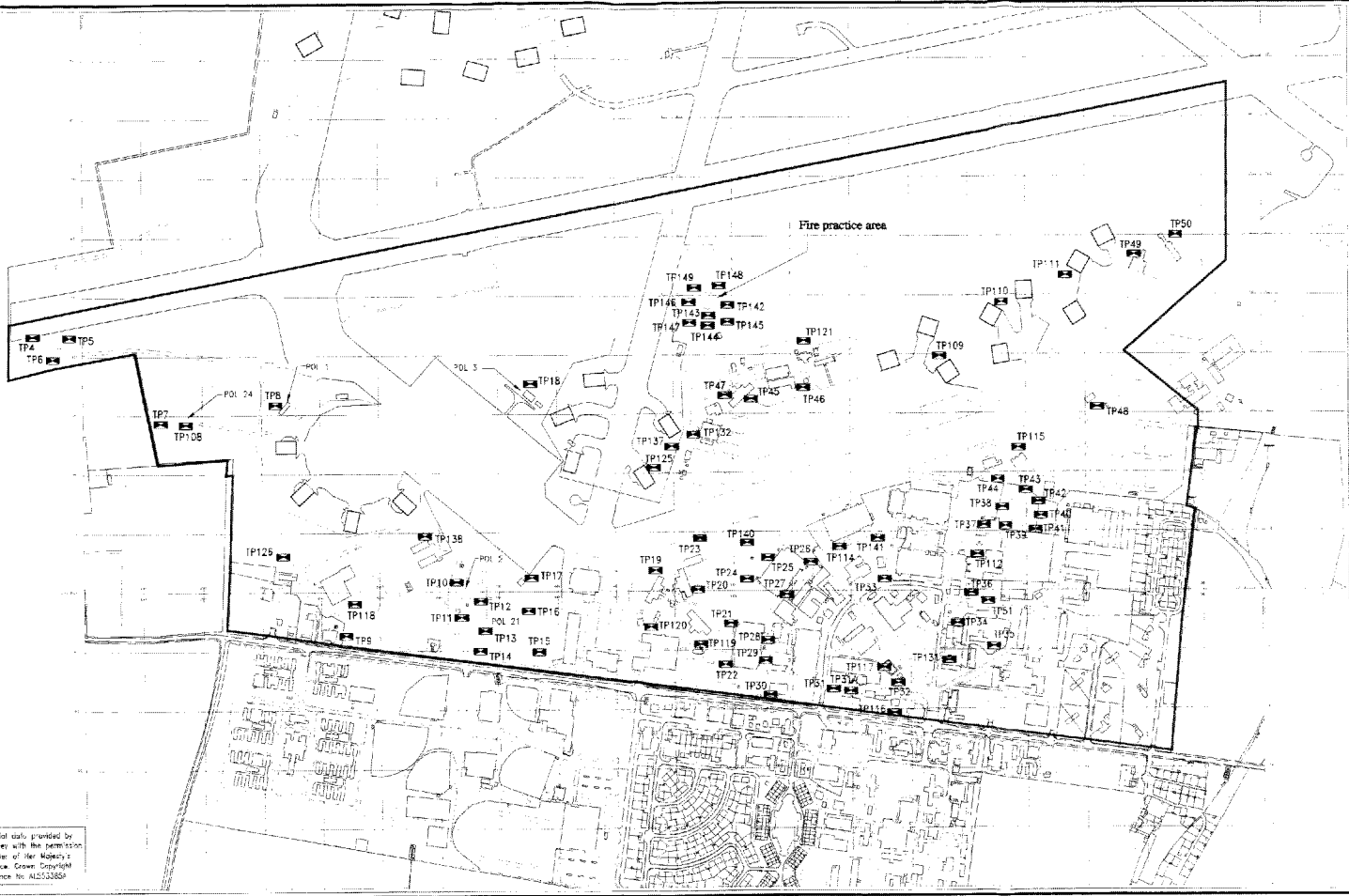
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DRAWING
FIGURE 9
AREA E -
SOIL VAPOUR SURVEY SAMPLE LOCATIONS

Figure

10

Trial Pit Locations - Area A



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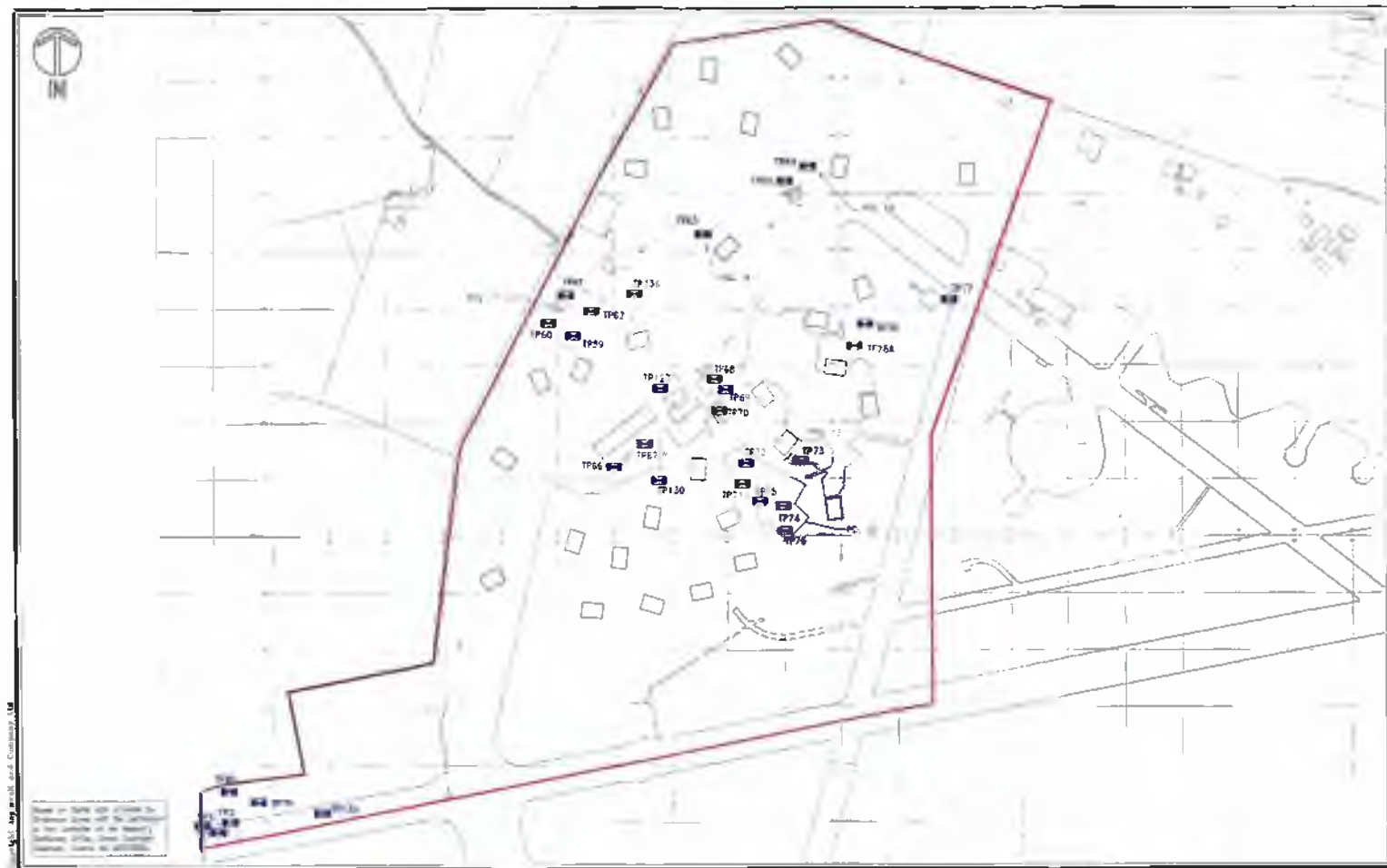
Copyright: Aspinwall and Company Ltd.

<p>KEY</p> <p> Boundary of Area A</p> <p> Trial pit location</p>	<p>CLIENT</p> <p>DEFENCE ESTATE ORGANISATION</p> <p>CONSULTANTS</p> <p>Aspinwall & company CONSULTANTS IN ENVIRONMENTAL MANAGEMENT</p>	<p>SCALE</p> <p>1:6000</p> <p>DRAWN</p> <p></p> <p>CHECKED</p> <p></p>	<p>PROJECT</p> <p>RAF UPPER HEYFORD PHASE TWO INVESTIGATIONS</p> <p>FIGURE 10 AREA A - TRIAL PIT LOCATION</p> <p>DATE</p> <p>JUNE 1997</p>
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Figure

11

Trial Pit Locations - Area B

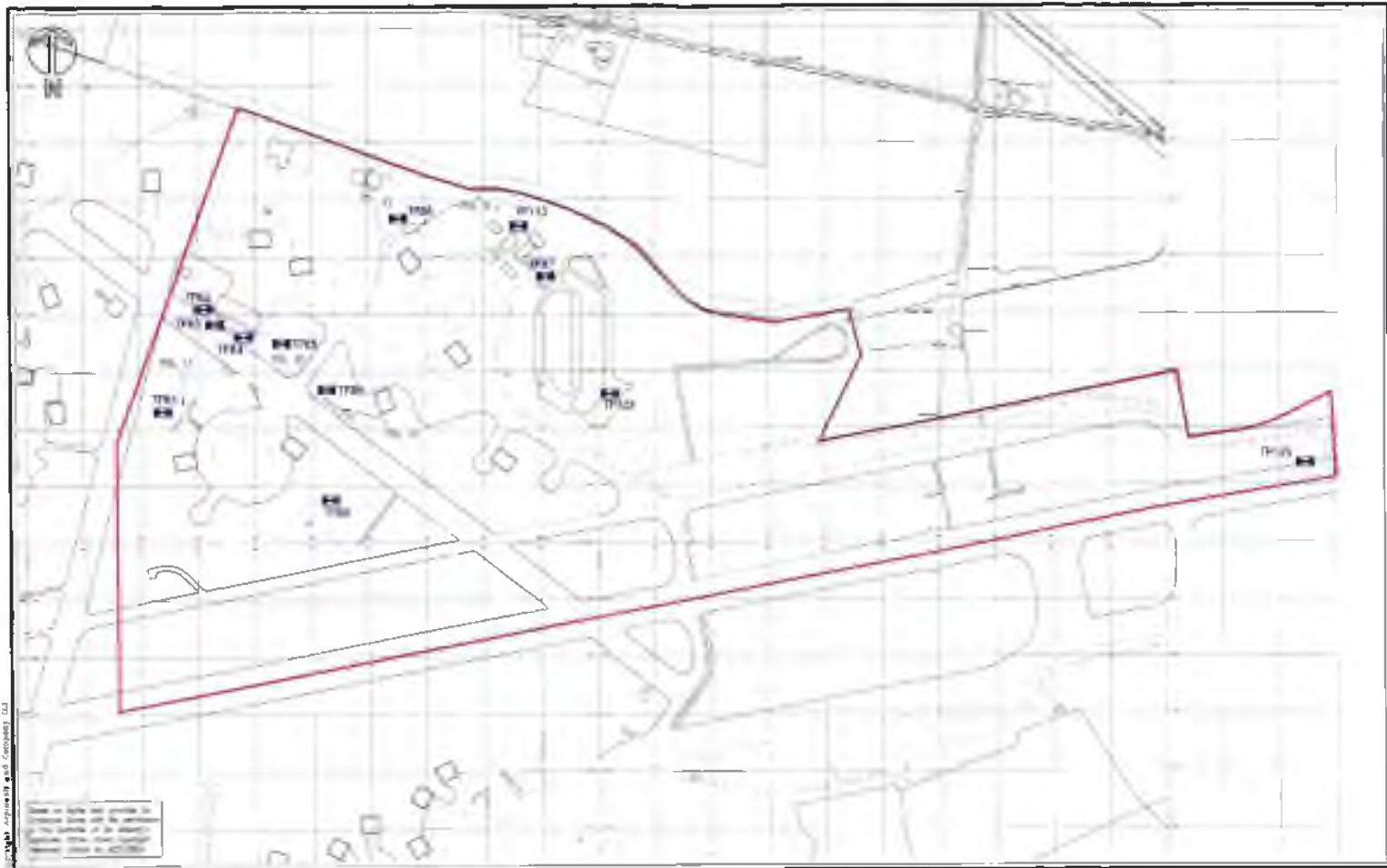


KEY Boundary of Area B Trial pit location	CLIENT DRPENCE ESTATE ORGANISATION	SCALE 1:8000	CAN MB3333A	PROJECT RAF UPPER HEYFORD - PHASE TWO INVESTIGATIONS OF 19/92
	CONSULTANTS Aspinwall & Company CONSULTANTS IN ENVIRONMENTAL MANAGEMENT	DATE JUNE 1997	FIGURE 11 AREA - B TRIAL PIT LOCATION	

Figure

12

Trial Pit Locations - Area C



 Boundary of Area C
 Trial pit location

DEFENCE ESTATE ORGANISATION


Aspinwall & Company
 CONSULTANTS IN ENVIRONMENTAL MANAGEMENT

SCALE 1:6000

DATE

COLLECT

CAD MD33324

EX-FILE AJC0096A

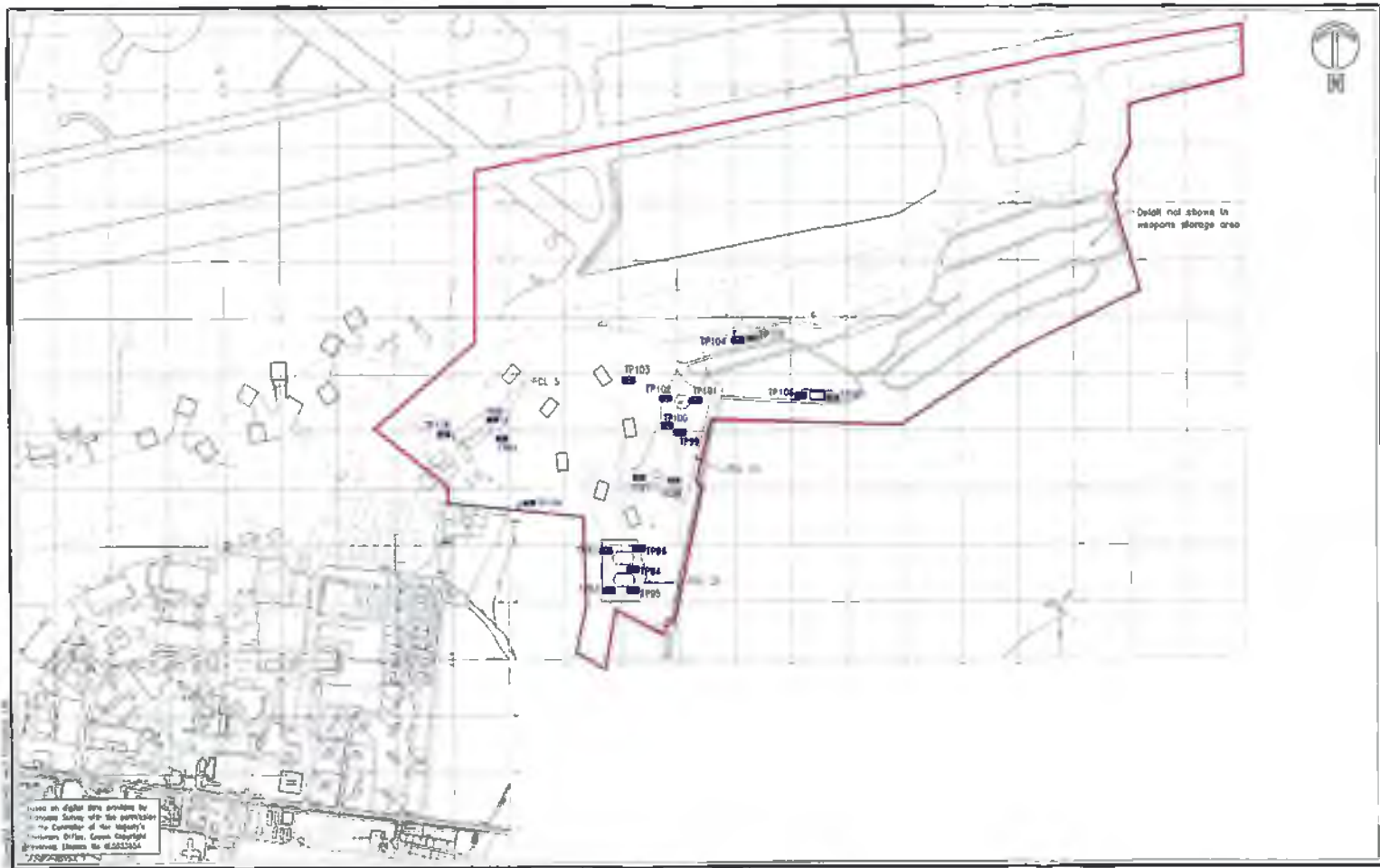
DATE

PROJECT
**RAF UPPER HEYFORD -
 PHASE TWO INVESTIGATIONS**
 DESIGN
FIGURE 12
**AREA C -
 TRIAL PIT LOCATIONS**

Figure

13

Trial Pit Locations - Area D



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-  Boundary of Area D
-  Trial pit location

DEFENCE ESTATE ORGANISATION

PROJECT

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CONSULTANTS IN ENVIRONMENTAL MANAGEMENT

SCALE

DRAWN

CHECKED

DATE

D.R.C. FILE

DATE

PROJECT
RAF UPPER HEYFORD -
PHASE TWO INVESTIGATIONS

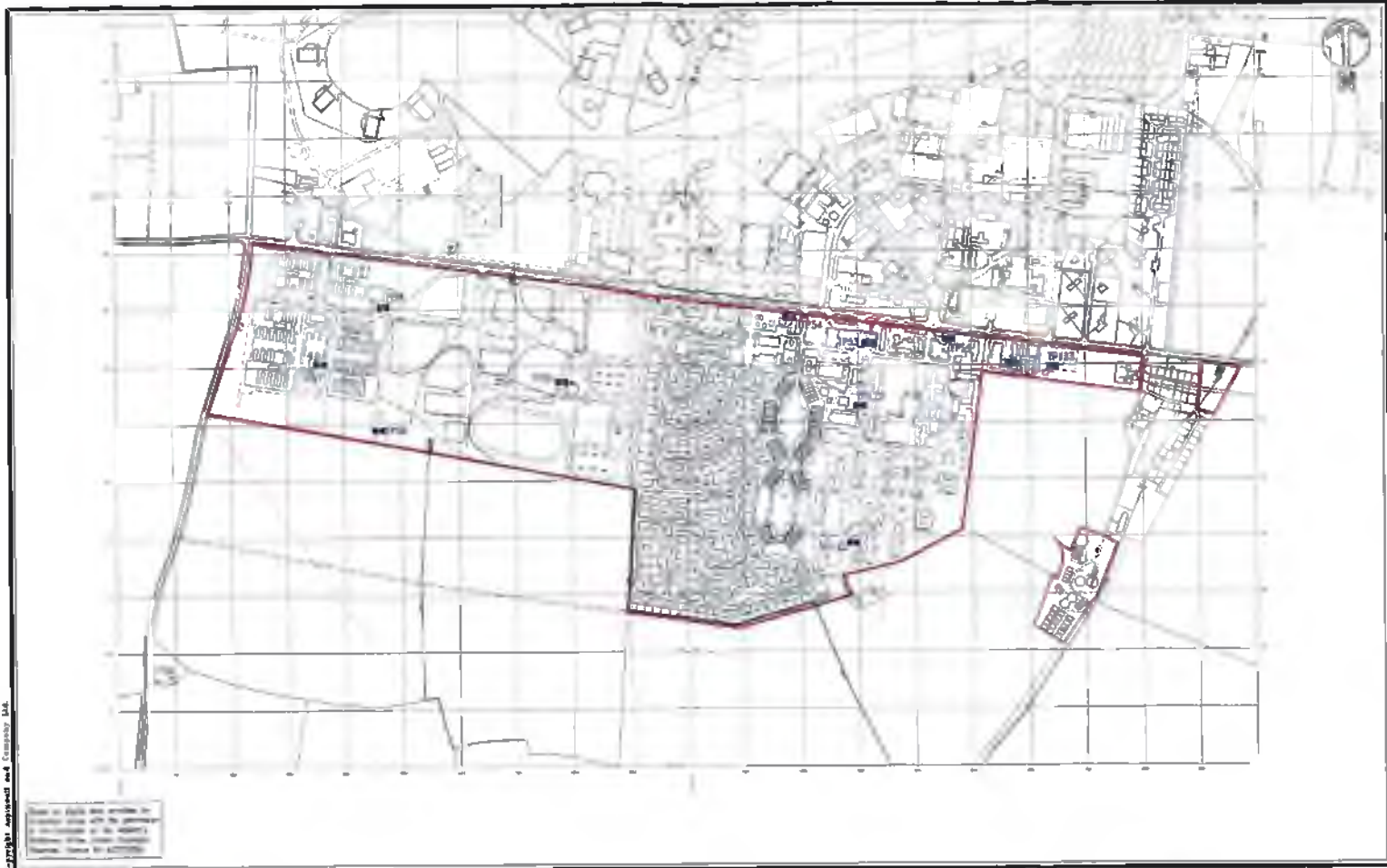
FIGURE 13
AREA D -
TRIAL PIT LOCATIONS

Figure

14

Trial Pit Locations - Area E

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	Boundary of Area E
	Trial pit location

CLIENT
DEFENCE ESTATE ORGANISATION

CONSULTANTS
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SCALE
 1:0000

DRAWN

CHECKED

GEN
 MR0333A

DWG FILE
 AJR3097A

DATE
 JUNE 1997

PROJECT
**RAF UPPER HEYFORD -
 PHASE TWO INVESTIGATIONS
 DRAWING**
FIGURE 14
**AREA E -
 TRIAL PIT LOCATION**