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DEFENCE ESTATE ORGANISATION

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

PROJECT NO: 07686 - FINAL REPORT

Technical Report
June 1997
by
Aspinwall & Company Ltd

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REPORT RELEASE SHEET

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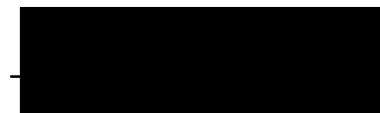
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Executive Summary

In February 1997 Aspinwall & Company (Aspinwall) was commissioned by Defence Estate Organisation (DEO) to undertake a Land Quality Assessment at RAF Upper Heyford near Bicester in Oxfordshire. A Phase One Desk Study had been undertaken at the site between August 1996 and March 1997 by ERM Enviroclean. The Desk Study identified a number of possible sources of contamination and recommended a phased intrusive investigation be designed to establish the likely nature, extent and significance of any contamination.

A Phase Two Investigation has been undertaken by Aspinwall which has concentrated on higher risk areas. It has involved the excavation of a series of trial pits and boreholes with subsequent chemical and radiochemical analysis of soil and groundwater samples in order to define the nature and extent of any contamination present at the site. This phase of work has also involved a soil vapour survey undertaken in areas of fuel storage and along the route of the petrol, oil and lubrication (POL) supply ring main. In addition, a survey was carried out to examine the nature of springs rising around the Upper Heyford base and to obtain water samples from these.

This interpretative report discusses the results of the site investigation. It must be read in conjunction with the factual report which contains detailed trial pit and borehole logs and chemical results. The intrusive investigations discussed in this report were undertaken to assess for the presence of contamination associated with areas deemed to represent a high potential contamination risk. All results refer to the assessment of these areas of the site and not the whole site. Areas not investigated are deemed a low risk and are unlikely to be contaminated.

The intrusive work undertaken as part of this phase of the Land Quality Assessment indicates that the high risk areas are largely free from significant contamination. The information gained from the Phase One study and other research indicates that there is unlikely to be significant contamination elsewhere on site. Minor hydrocarbon contamination exists in the former fire practice area and part of the weapons storage area adjacent to trial pit 124. Slight, but less significant, hydrocarbon contamination also exists in POL storage locations 20 and 21. In addition, elevated concentrations copper and zinc were identified around trial pit 113. Other isolated hot spots of hydrocarbons and phytotoxic metals exist in a limited number of locations on the site, although the extent of the contamination in these areas is likely to be restricted to the immediate vicinity of the source. Arsenic was found to be generally elevated across the site but not to such a degree that remediation measures are required. There remains a low risk that localised contamination may exist in areas not directly investigated during this study.

The results of analysis of samples of spring and groundwater from and around the site suggest that the underlying aquifer is not presently being affected by any of the contaminants listed above.

The hazards identified at RAF Upper Heyford have been identified for a number of different site conditions from current status to during redevelopment or remedial

Executive Summary *continued*

works, to after redevelopment. The risk to human health from chemical contamination is considered to be low or very low under present site conditions and during the course of any work proposed for redevelopment. The risk to the off site surface waters and the underlying aquifer from the isolated occurrences of hydrocarbon contamination at the site is also considered to be low to very low. However, the risk would increase during any physical works undertaken during redevelopment of the site, particularly if precautionary measures are not followed.

The site has been shown to be largely uncontaminated and therefore suitable for redevelopment for either housing or commercial / industrial use without the need for extensive remediation. Excavation and removal of hydrocarbon contaminated soil in the vicinity of the former fire practice area and part of the weapons storage area adjacent to trial pit 124 may be required before redevelopment occurs in this part of the site. Some remedial measures may be required to deal with hot spots of contaminants in other affected areas, such as POL's 20 and 21, if they are to be used for the locating of service runs or building footprints.

If a more sensitive end-use than for industrial purposes is proposed, then levels of phytotoxic metals and organic compounds will need to be considered during the locating of any areas of landscaping or gardens or during the laying of services. Certain areas of the site, especially in the vicinity of trial pits 113/113A would require a minimal amount of remedial work including removal and disposal of contaminated material to a licensed landfill.

The extent of any areas with broken / damaged asbestos sheet should be assessed as prolonged exposure to humans or other fauna may represent a health hazard and is currently a liability to MOD. Where the asbestos is in good repair the risk is of minor significance. The presence of asbestos-containing materials in the buildings on the site must be taken into consideration during any demolition activity and should be removed by a licensed contractor according to the relevant Health & Safety Executive Guidance.

Recommendations have been provided for two possible options for dealing with contaminated soil, either to remove it from identified areas in the near future, or for the Ministry of Defence to provide the information to potential developers to allow them to decide the level of remedial works required prior to any redevelopment of the site. The need to clean-up these areas will be driven by the viewpoint of the local regulatory authorities, and in particular The Environment Agency.

In order to provide costs for any such remedial works, a further phase of investigation has been proposed involving the excavating of additional trial pits and analysis of soils. Further analysis of samples of groundwater and spring water from the site has also been recommended as part of the same investigation.

Recommendations have also been provided for a full asbestos survey of all buildings at the site.

Background and Terms of Reference

1

Introduction

- 1.1 In February 1997 Aspinwall & Company (Aspinwall) was commissioned by the Defence Estate Organisation (DEO) to undertake an intrusive investigation as part of a Land Quality Assessment at RAF Upper Heyford near Bicester, Oxfordshire. Due to the large size of the site (494 hectares), the objective of this first phase investigation was not to undertake a comprehensive investigation across the whole site, but 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. Extensive investigation of low risk areas was not thought necessary at this stage.
- 1.2 This report is an interpretative document which discusses the results of the site investigation. It must be read in conjunction with the factual report which contains the rationale for the intrusive investigation, full trial pit and borehole logs, chemical results and details of the radiological survey and soil probing investigations.
- 1.3 Chapter 2 of this report provides an interpretation of the results of the site investigation indicating the nature and extent of contamination. In Chapter 3 the implications of the results obtained are assessed and Chapter 4 presents the conclusions and recommendations.
- 1.4 The terms of reference for the Phase Two study are included as Appendix 1 to this report. In summary the terms of reference required Aspinwall to:
- review existing documents and reports relating to the site;
 - make an initial assessment of potential hazards to enable the investigation work to proceed with safety;
 - design an intrusive investigation, and obtain quotes from site investigation contractors;
 - obtain quotes from analytical laboratories;
 - manage a programme of investigative trial pit and borehole excavations, with sampling, testing and analysis of results;
 - assess the potential health and environmental risks associated with the site;
 - report on the findings and make reasoned recommendations for any further action required;
 - provide factual and interpretative reports indicating the nature, degree and extent of contamination present;

Background and Terms of Reference

1

continued

- establish risks and hazards due to the contamination identified, assess potential contamination resulting from demolition works, and recommend further investigation and/or remedial works if necessary; and,
- produce a Land Quality Statement.

Interpretation of Results

2

Environmental Setting and Sensitivity

- 2.1 The site overlies a major aquifer which is used locally for water supply. Ground conditions are such that rainfall over the site will infiltrate the soil and generally move downwards to the water table. Permeability (slug) testing indicates that the aquifer can have a significant horizontal permeability, even where mudstones are present, such that groundwater may move relatively rapidly. The vertical permeability of the mudstones is likely to be much lower. Water levels indicate that the water table slopes radially outward such that groundwater moves from the site to the surrounding land where it rises to form a number of springs. These flow into three different stream/river systems whose water quality is generally defined as fair to good. The site is therefore located within an area which is sensitive to both surface and groundwater contamination. The results have been assessed with due regard to this environmental setting and also with regard to a number of potential end uses.

Assessment of Chemical Contamination

- 2.2 Due to the large spatial extent of RAF Upper Heyford the investigations undertaken were targeted towards areas perceived as being at high risk from contamination. The whole site has not been investigated in detail. The results, and in particular the assessment of the extent of contamination at the site, have therefore been interpreted within this context.

Guidelines

- 2.3 In order to put the analytical results into context, the data have in the first instance been assessed in relation to several sets of guidelines. For assessment of soils these include guidance notes issued by the Interdepartmental Committee for the Redevelopment of Contaminated Land (ICRCL) (Ref 1). This set of guidelines defines tentative trigger concentrations for various inorganic and organic contaminants for planned uses of differing sensitivity (allotments/domestic gardens through to buildings and hard cover).
- 2.4 For the majority of contaminants, two trigger levels are defined, a threshold concentration below which soils may be considered uncontaminated for defined end-uses; and an action level above which some form of remediation action is likely to be required or the form of the development changed. For contaminants which are phytotoxic (i.e. which prevent or inhibit plant growth but which are not normally hazardous to health), threshold concentrations are defined. The guidelines are designed to assist in the selection of the most appropriate end-use for a site and in deciding whether remedial action is required. The ICRCL guidelines are in the process of being updated by the Department of the Environment. Draft documents have been issued for consultation but have yet to be finalised.

Interpretation of Results *continued*

2

- 2.5 In the absence of ICRCCL guidelines being available for a parameter, guidelines produced by the Dutch Government (Ref 2) have been used. This guidance defines an Intervention Value which if exceeded suggests that there is a potential threat to the environment. If measured concentrations exceed these values, it is recommended that a more detailed risk assessment is undertaken to determine the actual degree of risk. The Dutch Intervention Values are based on determining the maximum tolerable risk from available toxicity and exposure data. A Target Value is also set which is relevant when undertaking remedial work, and forms the ultimate level of soil quality which the remediation should seek to achieve. They take into account the risk to the ecosystem as well as to human health.
- 2.6 In addition, sulphate concentrations have been compared with trigger concentrations produced by the Building Research Establishment (BRE) (Ref 3) in order to classify the soils and groundwaters with respect to the use of concrete. These guidelines provide guidance on whether sulphate resistant cement would be required in the event of redevelopment of the site.
- 2.7 Guidelines for the assessment of water contamination are included in the publication produced by the Dutch Government. The guidelines were developed as quality indicators of water in the Netherlands and should therefore be used with caution in assessing the significance of contaminated water in the UK. In the absence of a parameter being specified, guideline values set out in the EC Directive relating to the quality of potable water (Ref 4) are referenced. This directive was developed as an indicator of the quality of drinking water and therefore provides only a broad indication of quality of groundwater associated with contaminated land.

Soil Vapour Survey

- 2.8 A soil vapour screening survey was undertaken in those areas which were deemed to be at greatest risk from contamination by fuels and other volatile hydrocarbons. The results from this survey are shown in Appendix 2 of the factual report. They were used to locate trial pits, to confirm the results of trial pits and also in order to carry out a broad scale assessment of any leakage from the petrol, oil and lubrication (POL) supply ring main. As detailed in the factual report, of the 330 locations probed along the line of the ring main, its junctions and selected POLs only 3 had gas concentrations in excess of 100 ppm, that is, one of 1000 ppm, one of 6000 ppm and one greater than 10 000 ppm. The only other location where significant gas concentrations were encountered was around the fire practice area where gas concentrations in 3 out of 8 probe holes were greater than 10 000 ppm.
- 2.9 In addition limited soil vapour surveys were carried out at several locations where it had not been possible to excavate trial pits. Soil vapour survey (SVS) points 114 to 119 were installed around building 320 to examine the potential for contamination from above ground storage tanks (AST) which had only been partly

Interpretation of Results *continued*

2

assessed by trial pits 21,22, 28 and 29. SVS point 120 was installed next to a former AST adjacent to building 345, whilst SVS points 110 and 111 were installed next to buildings 221/255 in area C. SVS points 121 to 126 were installed as replacements for trial pits 37, 115, 48, 33, 114 and 30 respectively. In all instances no significant concentrations of flammable soil vapour were detected.

- 2.10 A number of soil survey points were also installed to confirm the results of the trial pitting. These included 34 points around POLs 17, 19, 20 and 23 in addition to 2 around the runway de-icing fluid underground storage tank. In all instances no significant concentrations of flammable soil vapour were detected, confirming the results of the trial pitting.

Results of Chemical Analysis on Soils

- 2.11 The full results of the chemical testing of the trial pit samples are contained in Appendix 4 of the factual report. Summary tables are presented in this chapter which indicate the range and mean values for each parameter for the areas investigated and compare these to the relevant guideline values.

Metals

- 2.12 The main hazards associated with contamination of soils by metals are:
- ingestion and inhalation of materials containing toxic metals such as arsenic, cadmium and lead which can give rise to acute or chronic harmful effects;
 - uptake of toxic metals such as cadmium and lead by crop plants, which can render crops unsuitable or unsafe for consumption;
 - the inhibition of plant growth by phytotoxic metals such as boron, copper, nickel and zinc; and,
 - the contamination of water resources by leaching of metals into surface waters and groundwater.
- 2.13 The results of the metal analyses are summarised in Table 2.1. This table also presents the locations where measured concentrations exceed the ICRL guidelines for fill and natural materials across the entire site. For toxic metals (Group A - Ref 1), the results have been compared with the threshold levels for both domestic housing and parks or open space. For phytotoxic metals (Group B - Ref 1), the results have been compared with the threshold values for areas where plants are to be grown. Because arsenic concentrations exceed the threshold for domestic housing at a large number of locations, these have been excluded from Table 2.1, but are summarised below.

Interpretation of Results *continued*

2

Group A Metals

- 2.14 From Table 2.1 it can be seen that only arsenic concentrations exceed the ICRCCL threshold for parks or open space, and then only at four locations, two of which (TP113 & TP113A) are adjacent to one another. The measured concentrations nowhere exceed double the above threshold concentration. The threshold for domestic gardens and allotments of 10 mg/kg is, however, exceeded at a large number of locations - 221 out of the 301 samples taken. The mean concentration across the site (assuming a worst case concentration of 1 where <1 has been recorded) is 17 mg/kg with a standard deviation of 10 mg/kg.

Table 2.1 Trial Pits at Upper Heyford in which contaminant concentrations are greater than ICRCCL limits (all values in mg/kg)

	Group A						Group B			
	As*	Cd	Cr	Pb	Hg	Se	B	Cu	Ni	Zn
ICRCCL threshold - gardens *	10	3	600	500	1	3	3	130	70	300
ICRCCL threshold - parks	40	15	1000	2000	20	6				
trial pit 21				530						
trial pit 32	66									
trial pit 35	72						4			
trial pit 39				767						
trial pit 53						4				
trial pit 62							5			
trial pit 66							4			
trial pit 71		12						140		
trial pit 90										304
trial pit 113	49	4						1338		1365
trial pit 113A	76	4						1799		4563
trial pit 132		4								
<i>Summary statistics</i>										
No. of samples analysed	301	301	301	301	301	301	301	301	301	301
Maximum	76	12	187	767	< 1	4	5	1799	46	4563
Minimum	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	4
Mean	17	1	18	20	< 1	1	1	21	13	65
Standard Deviation	10	0.7	15	59		0.3	0.6	129	6	274

Note: arsenic concentrations are greater than 10 mg/kg in a large number of samples taken from trial pits on site and are therefore not included individually in the above table. Where measured concentration is less than the limit of detection, the latter value has been used for statistical calculations.

* For Group B metals the ICRCCL threshold is for areas where plants are to be grown.

- 2.15 The ICRCCL guidelines are in the process of being revised, with the currently drafted value for arsenic for residential houses with gardens being 175 and 200 mg/kg calculated at the 95th and 90th percentiles respectively for a soil pH of 7 (Ref 5). The concentrations measured at RAF Upper Heyford lie significantly below these guideline values, which are based on a risk assessment approach to exposure. It is considered that the concentration of arsenic measured in the soils at the site will not prohibit its redevelopment for residential purposes. In the majority of locations, the concentrations measured are those naturally occurring in the soils in the area rather than as a result of man-made contamination. Soils in

Interpretation of Results *continued*

2

the UK have background arsenic concentrations typically in the range 1 to 40 mg/kg.

- 2.16 Of the 301 samples taken the ICRCL threshold for gardens and allotments for cadmium of 3 mg/kg was exceeded at only four locations, three of which recorded 4 mg/kg, whilst the fourth was 12 mg/kg. The threshold for parks and open spaces is 15 mg/kg. The lead threshold of 500 mg/kg for gardens was only exceeded at two locations (trial pits 21 and 39), and then only by 30 mg/kg and 267 mg/kg, whilst the 3 mg/kg limit for selenium was only exceeded at 1 location, and then only by 1 mg/kg. The thresholds for chromium (total and hexavalent) and mercury were not exceeded at any location. For comparison, all Group A metals were either at, or below, the Dutch intervention values, except for the three arsenic values (at TP32, TP35 and TP113A) which were greater than the 55 mg/kg limit.

Group B Metals

- 2.17 From Table 2.1 it can be seen that the ICRCL guidelines for phytotoxic substances were exceeded in seven trial pits for either boron, copper or zinc, or a combination thereof. In five of these trial pits the limits were only just exceeded as follows: in trial pits 35, 62 and 66 the 3 mg/kg limit for boron was exceeded by only 1 or 2 mg/kg, whilst the 130 mg/kg limit for copper was exceeded by 10 mg/kg in TP71 and the 300 mg/kg zinc limit by 4 mg/kg in TP90. However, in trial pits 113 and 113A, adjacent to one another, the copper and zinc limits were exceeded by an order of magnitude. The samples in these trial pits were taken from metalliferous deposits within a layer of made ground. The threshold for nickel was not exceeded at any location.
- 2.18 For comparison, only the copper and zinc concentrations in TP113 & TP113A exceeded the respective Dutch Intervention Values.

Other Inorganic Determinands

- 2.19 Table 2.2 summarises the results for pH, total (acid soluble) sulphate and water soluble sulphate detected in soil samples from across the site.

pH

- 2.20 The soil at the site is neutral to alkaline in nature, as would be expected for soils overlying limestone. From the 301 samples analysed the highest recorded pH was 11.3, the lowest 6.9, with a mean of 8.2. The ninety five percentile pH was 8.6, while the 99 percentile pH was 10.3, indicating that little of the soil across the site is very alkaline. Such alkaline conditions are likely to be associated with degradation of concrete products. However, in TP53 where a pH of 11.3 was measured no concrete was encountered.

Interpretation of Results *continued***2*****Sulphate***

- 2.21 The results of sulphate analysis can be compared with guidelines issued by the BRE Digest 363 (Ref 3) which assesses sulphate results in relation to their ability to cause damage to concrete and is therefore important in respect of any redevelopment plans for the site. Total sulphate concentrations ranged from <0.01 to 2.2 %, with a mean of 0.06% across the site. Five samples of mainly near surface fill material were found to have concentrations in excess of the BRE guideline of 0.24%. Fill comprised a variety of material such as rubble and ash which are known sources of sulphate. One sample, from TP106, was of a sandy clay which also exceeded the BRE guideline.
- 2.22 The BRE Digest specifies that soils with a total sulphate concentration >0.24% should be classified on the basis of their water soluble sulphate content. Analysis of soil samples from the site for water soluble sulphate content gave results ranging from <0.003 to 3.2g/l, with a mean of 0.05g/l. For the majority of soils the water soluble sulphate concentrations were less than 1.2 g/l such that Class 1 concrete can be used. However, at trial pits 38 and 21 the water soluble sulphate concentrations exceed 1.2 g/l, such that Class 2 concrete maybe required within the vicinity, whilst at trial pit 121, 2.3 g/l is exceeded such that Class 3 concrete may be required. These locations do not have significantly elevated metal (lead is slightly elevated in TP21) or organic compound concentrations which would warrant remediation. Thus, excepting for construction reasons, these soils would not warrant removal.

Table 2.2 Summary of the Range of Selected Determinands Identified at Upper Heyford

	pH	Total sulphate (%)	Water soluble sulphate (g/l)
no. of samples	301	301	301
maximum	11.27	2.20	3.21
minimum	6.85	0.01	0.003
mean	8.15	0.06	0.05
Standard deviation	0.46	0.13	0.22
80 percentile	8.31	0.06	0.03
90 percentile	8.43	0.08	0.07
95 percentile	8.61	0.10	0.11
99 percentile	10.27	0.27	0.60

Interpretation of Results *continued*

2

Organic Determinands

Organic Screening

- 2.23 Solvent extractable material (SEM) provides a broad indication of the amount of organic matter (excluding volatiles) present in a sample. The extraction method will extract both natural and manmade organic components, and the amount of material extracted varies depending on the organic substance and the extraction efficiency of the solvent used. The solvent used for this analysis was a 10:1 dichloromethane (DCM)/ methanol mixture. This solvent was chosen because when used with the Soxtec extraction technique, it has been shown to extract a greater amount of organic matter than many other solvents.
- 2.24 SEM values for the 301 samples taken from across the whole site ranged from 42 to 10506 mg/kg with a mean value of 901 mg/kg (standard deviation = 1486). For RAF Upper Heyford, the majority of samples had SEM concentrations significantly below 5000 mg/kg. Only nine samples had concentrations in excess of 5000 mg/kg; these are summarised in Table 2.3.
- 2.25 Table 2.3 indicates that all samples except two are associated with made ground. In some instances it is clear what has caused the elevated SEM, however, in other further analysis was required as detailed below. At a number of locations where hydrocarbon odour was detected on site during excavation (Table 2.4) little correlation was found to the SEM analysis. This is because SEM is a good general indicator of organic contamination but does not extract and analyse for volatile compounds which are those which are more likely to be giving rise to the odours.
- 2.26 Many samples, including several of those detailed above, were also submitted for further screening analysis by thin layer chromatography with flame ionisation detection (TLC-FID) to determine the relative proportions of mineral oils, non-volatile aromatic hydrocarbons (an indication of total polyaromatic hydrocarbons - PAHs) and resins. As with SEM, this screening technique does *not* distinguish between natural and man made organic compounds. This technique can be used with a view to selecting appropriate methods for further detailed analysis.
- 2.27 The results obtained using TLC-FID showed that across the site mineral oil concentrations ranged from 0.01 to 8.5×10^3 mg/kg, with a mean concentration of 0.6×10^3 mg/kg (standard deviation = 1.6×10^3 mg/kg). There are no UK guidelines against which these results can be directly compared, the Dutch Intervention Value for mineral oil of 5×10^3 mg/kg being the most comparable guideline currently available, although this is based on a different method of analysis. For comparison however, only 2 samples had levels of mineral oil in excess of 5×10^3 mg/kg (Table 2.5).

Interpretation of Results *continued*

2

Table 2.3. Locations where soil samples with SEM >5000 mg/kg were encountered

Location	Depth (m)	SEM Concentration (x10 ³ mg/kg)	Ground Conditions
TP16 - POL 21	0.10	8.5	Made ground: sandy silt with a black, brittle, fibrous material
TP26 - Former AST	0.40	7.9	Made ground: silty sand with limestone, brick and ceramic fragments
TP27 - Former AST	0.30	10.5	Made ground: silty sand, limestone and asphalt
TP50 - Building 1443 (Hush House/AST)	0.10	7.1	Made ground: silty clayey sand with ash and clinker
TP57 - UST/AST	0.25	7.9	Made ground: silty sand with limestone and asphalt
TP118 - Former AST	0.95	5.9	Made ground: silty sand, limestone, bituminous material and roadstone
TP124 - Weapons storage area	1.70	6.4	Silty clay with limestone - hydrocarbon odour
TP124 - Weapons storage area	1.90	8.8	Silty clay with limestone - hydrocarbon odour
TP142 - Fire practice area	0.20	7.1	Made ground: sandy clayey silt with ash and clinker

AST - above ground storage tank, UST - underground storage tank.

Interpretation of Results *continued***2****Table 2.4. Locations where hydrocarbon odours were detected during trial pit excavation (SEM in x 10³ mg/kg).**

Trial Pit	Depth (m)	Odour Strength	SEM-1	SEM-2	SEM-3	SEM-4
2	0.8	strong	0.3	0.1	0.3	
14	0.4	faint	1.5	0.2		
15	2.5	odour	0.4	0.4		
42	1.7	odour	0.1	0.1		
61	1.0	strong	0.4	0.4		
75	1.4	very strong	0.7	1.0	0.5	
91	0.75	odour	0.2	0.8	0.1	
93	0.9	very strong	0.4	1.7	1.2	
100	1.4	odour	0.3	0.3	0.4	
105	1.2	odour	0.4	0.2	0.1	
109	1.2	odour	0.3	0.3	0.6	
124	1.7	strong	0.3	0.7	8.8	6.4
134	0.9	odour	1.2	0.4	0.1	
138	0.9	odour	1.5	4.5	1.2	
142	general	slight	7.1	0.1		
144	0.55	slight	0.6	0.5	0.2	
146	general	strong	1.3	0.6		
148	0.7	slight	0.6	0.3		
149	general	strong	0.1	1.6	0.2	

Note: SEM-1 is the solvent extractable material from sample 1 at this location, SEM - 2 from sample 2 etc.

Table 2.5. Details of samples with elevated Mineral Oil

Location	Depth (m)	Mineral Oil (mg/kg)	Total Non-Volatile Aromatics (mg/kg)	Resins (mg/kg)
TP124	1.7	5755	13	657
TP124	1.9	8473	9	290

Interpretation of Results *continued*

2

- 2.28 TP124 was located in the weapons storage area adjacent to the road. During excavation, a strong odour was detected with visible staining of the soil (see trial pit log in the factual report, Appendix 3). By comparison with the SEM data (Table 2.3), it can thus be illustrated that for these two samples mineral oil forms the greatest proportion of the organic matter present.
- 2.29 Results from TLC non-volatile aromatics analysis show that across the site, concentrations ranged from <1 to 556 mg/kg, with a mean concentration of 310 mg/kg. There are ICRL guidelines for total PAHs although these are based on a different analytical technique. However, for comparison, only 1 sample (from TP142 in the fire practice area) had a concentration which was just above the domestic garden action level for PAHs of 500 mg/kg and none above the open space action level of 10000 mg/kg.

Specific Organic Analysis

- 2.30 The SEM results were used as a starting point to specify more detailed organic analysis. The locations listed in Table 2.3 where SEM concentrations greater than 5000 mg/kg were observed were assessed as follows (note: abbreviations as detailed in Table 2.6 below):

- TP16 - black brittle fibrous material probably caused elevated SEM, further analysis required (PAH/PRO);
- TP26 - rubble material present, further detailed analysis required to determine source of elevated SEM (SVOCs);
- TP27 - asphalt probably caused elevated SEM. Further analysis required for confirmation (DRO/PRO/PAH);
- TP50 - ash and clinker probably caused elevated SEM. Further analysis required to determine source of contamination (PRO/PAH);
- TP57 - asphalt probably caused elevated SEM. Further analysis not required;
- TP118 - concentration only just greater than the 5000 mg/kg "limit" probably caused by bituminous material. Further analysis not required;
- TP124 - material did not appear to be made ground, but hydrocarbon odour evident. Further detailed analysis required (SVOCs); and,
- TP142 - elevated SEM probably due to ash, also slight hydrocarbon odour. Further analysis required to confirm nature of contamination (DRO/PAH/VOCs).

In addition, samples from selected locations at which odours were detected during excavation (Table 2.4) were analysed for a range of more detailed organic analyses.

- 2.31 Eleven soil samples were submitted for analysis for volatile organic compounds (VOCs) by Gas Chromatography - Mass Spectrometry (GC-MS) as detailed in

Interpretation of Results *continued*

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Appendix 4 of the factual report. The concentration of VOCs based on these analyses are summarised in Table 2.6. Only at TP105 and TP149 were quantifiable concentrations of identifiable volatiles detected. Both comprised very low concentrations of benzene, toluenes, ethylbenzene and xylenes (BTEX), but in TP149 a large proportion of the total VOCs could not be identified with certainty. The concentrations of total VOCs present are not considered to be significant. At both locations hydrocarbon odours were noted during excavation. TP105 is located adjacent to a POL storage area and TP149 in the fire practice area.

2.32 Six samples from five trial pits (26, 53, 120, 124 and 138) were analysed by GC-MS for semi-volatile compounds (SVOCs). These are not detailed in Table 2.6 as it is not appropriate to sum the concentrations of the individual compounds detailed in Appendix 4 of the Factual Report. A number of SVOCs were tentatively identified in samples from trial pits 124 and 138. The former of these was excavated in the weapons storage area, whilst the latter was located adjacent to an underground storage tank. The SVOCs tentatively identified include a range of PAHs and aliphatic hydrocarbons typical of weathered petroleum hydrocarbons.

2.33 Further more detailed analysis of eight samples for PAHs by GC-MS was carried out. This analytical method is used to quantify the 16 PAHs identified by the United States Environmental Protection Agency (US EPA) as priority pollutants. Results ranged from < 10 to 415 mg/kg, expressed as total concentrations. The ICRC domestic garden action level for total PAHs is 500 mg/kg and for open space 10 000 mg/kg. None of the samples analysed exceeded these levels.

Total Petroleum Hydrocarbons (TPH)

2.34 Total petroleum hydrocarbons were analysed by two means. A number of samples were analysed for total petroleum hydrocarbons (TPH) - an "indicator" technique which can be used to identify samples with a high hydrocarbon loading. The results from this can then be used to specify more detailed analysis for diesel range and petrol range organics (DRO/PRO respectively).

2.35 Forty two samples were analysed for TPH (Table 2.6) with a range from 17 mg/kg to 8482 mg/kg and a mean of 689 mg/kg (standard deviation of 1578 mg/kg). Only two samples were identified with a TPH concentration greater than 5000 mg/kg, both from TP124 in the weapons storage area.

2.36 Four samples were analysed for PRO, all yielding concentrations less than the limit of detection of 10 mg/kg. Six samples were analysed for DRO, of which those from trial pits 14 and 16 in POL 21, trial pit 93 in POL 20 and trial pit 142 in the fire practice area were shown to contain weathered diesel, albeit at relatively low concentrations. The maximum measured diesel concentration was 871 mg/kg in trial pit 142. The maximum measured DRO concentration of 2050 mg/kg from trial pit 27 was ascribed to coal tars whose source is probably the band of asphalt at 0.3 m.

Interpretation of Results *continued*

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Table 2.6 Organics Analysis - Summary

Location TP	Depth (m)	DRO mg/kg	PRO ug/kg	PAH ug/kg	SVOC	VOC ug/kg	SEM mg/kg	TPH mg/kg	NSO mg/kg	TNVA mg/kg	Min Oil mg/kg	
2	1.1						112	25	86	8	17	
2	2						259	40	219	9	31	
14	0.4	62	<10	23271			1463	301	1159	174	127	
15	2.5						387	128	259	10	119	
16	0.1	108	<10	1071			8530					
18	1.6						174	49	125	8	41	
26	0.4				yes		7911					
27	0.3	2050	<10	415490			10506					
35	0.2					<1	1169	989	179	40	949	
35	0.5			4740			1021	524	494	259	265	
42	1.7						141	54	83	15	39	
50	0.1	392	<10	169591			7106					
53	1.9						3089	2817	269	34	2783	
53	2.6				yes		986	707	278	30	677	
57	0.25						7919					
61	1.1						406	99	306	13	86	
66	1.4						429	233	196	3	230	
66	1.45						167	67	99	<	1	
75	1.4						971	675	295	1	674	
75	1.9						505	280	291	45	168	
91	0.75					<5	219	74	145	36	38	
91	1.2			961			767	234	532	127	107	
91	2.3						146	37	109	7	30	
93	0.9	119		4623		<1	1671	1340	329	125	1215	
93	1.6						1158	1001	185	23	948	
99	1.9					<1	177	62	114	14	48	
100	1.4					53	299	57	242	17	40	
100	1.6						429	137	291	11	126	
105	1.2					43808	214	59	135	18	61	
105	3						107	17	90	3	14	
109	1.2						296	108	188	<	1	
118	0.95						5878					
120	0.75				yes		3296					
124	1.7				yes		6437	5768	657	13	5755	
124	1.9				yes		8780	8482	290	9	8473	
134	1					73	420	158	260	27	131	
134	1.6						160	52	108	14	38	
138	0.7				yes		4517					
138	1.5					4745	1165	770	394	36	734	
139	1.1						517	107	409	11	96	
142	0.2	871		1788		38	7124	1069	6048	556	513	
143	0.3						397	74	323	37	47	
143	0.45						237	22	215	6	16	
144	0.5						488	32	456	6	26	
144	1.1						183	30	203	7	23	
146	0.3					23	1304	538	764	16	522	
146	1.2						573	456	116	4	452	
148	0.8						626	128	496	18	110	
149	0.3						67	25	42	4	22	
149	0.5					22303	1550	1123	426	22	1101	
Number of samples							301*	42	42	42	42	42
maximum							10506*	8482	6048	556	8473	
minimum							42*	17	42	<	1	14
mean							901*	689	426	43	644	
standard deviation							1486*	1578	913	96	1579	
95 percentile							3920*	2743	759	172	2705	

DRO - diesel range organics, PRO - petrol range organics, PAH - polynuclear aromatic hydrocarbons
SEM - solvent extractable material, TPH - total petroleum hydrocarbons, NSO - NSO/resins
TNVA - total non-volatile aromatics, Min Oil - mineral oil, VOC - volatile organic compounds
SVOC - semi-volatile organic compounds. * - statistics are for all samples, not only those in Table 2.6.

2.37 In addition to the soil samples taken from trial pits, soil/rock samples were taken from the boreholes, essentially to allow geological descriptions to be completed. During this exercise a slight hydrocarbon odour was detected in two shallow

Interpretation of Results *continued*

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samples (0 to 1 and 1 to 2 m) from borehole 6. These were forwarded to the laboratory for analysis which indicated slight contamination by biodegraded diesels (0 to 1 m) and very slight contamination by PAHs (1 to 2 m). Neither the groundwater from borehole 6, nor nearby surface water from Spring I indicated any hydrocarbon contamination (see below) suggesting that the contamination is due to an isolated spillage.

Asbestos

- 2.38 Three samples were submitted for analysis for asbestos. Two of these were soil samples from TP113 and TP113A, neither of which contained any asbestos. A third sample was submitted of some broken material located on the ground surface near TP133 and which was tentatively identified on site as asbestos cement sheet. The laboratory determined that the material contained 12% chrysotile (white) asbestos which corroborates the on site observation.

Leachability of Soils

- 2.39 Although soils may be contaminated, this contamination may not be readily mobilised, especially for metals which are strongly pH dependent. In order to assess this further samples from trial pits 35, 113, 113A and 138 were submitted to Geochem for leaching test analysis. The resulting leachate was analysed for the same range of metals as analysed for above. The results indicated that neither arsenic, cadmium, chromium nor mercury was leached from the soil samples at a concentration greater than the limit of detection of 50 µg/l. Metals that were leached include lead, zinc and copper, but only from TP113A and TP138 and not at greatly elevated concentrations (especially from TP138 where all three determinands were less than four times the limit of detection). Nickel was also leached from soil from TP138 but again at a low concentration. Although the concentrations measured were above Dutch guidelines for groundwater (Ref 2), the laboratory leached samples are obtained by much more "aggressive" means than those due to natural leaching by rainfall. The laboratory results therefore considerably overestimate the concentration of contaminants that may occur due to natural leaching and so are not truly comparable with the guidelines.

Results of Chemical Analysis of Groundwater from Trial Pits

- 2.40 Water samples were taken from trial pits 38, 91, 106 and 138 and analysed for a range of determinands. Due to limited inflow of water only organic indicator analyses could be carried out on samples from three of these, however, metals and major ions were also analysed on the sample from TP138. The organic indicator analyses (Mineral Oil, Aromatics, NSO, TPH, SEM) are generally at or close to the limits of detection, excepting the sample from TP91 which has elevated SEM and

Interpretation of Results *continued*

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NSO, that from TP106 which has slightly elevated NSO and that from TP138 which has elevated TPH and mineral oil. These indicate that where shallow groundwater is present, be it due to perching of rainwater or localised leakage from water mains, it may be contaminated to a degree. However, excavations on site indicate that there are few locations where groundwater is present within unconsolidated material.

- 2.41 COD and BOD analyses of the water sample from TP138 were elevated confirming the presence of some contamination. Of the metals analysed arsenic, cadmium, chromium, nickel and lead were all elevated in comparison to drinking water standards (Ref 4). A GC-MS scan identified very few volatiles, with those that were present being at low concentrations.
- 2.42 Trial pit 138 was excavated near to the Walon petrol filling station (PFS) through made ground including ash and clinker. As detailed above and in Table 2.4 a hydrocarbon odour was noted during excavation, possibly due to a leaking UST (Walon personnel on site indicated that they were investigating the possibility of this). This is likely to have been the cause of the elevated TPH and mineral oil. It is likely that the elevated metals are due to leaching from the made ground.
- 2.43 In general the groundwater samples taken from trial pits were not representative of the general groundwater quality beneath the site as determined from analysis of samples from boreholes and springs (see below).

Results of Chemical Analysis of Groundwater from Boreholes

- 2.44 Table 2.7 indicates that the groundwater beneath the site is generally of good quality. It is of neutral to slightly alkaline pH with slightly elevated electrical conductivity (EC), indicative of a high total dissolved solids. This is not unusual given the nature of the geology beneath the site. However, excepting nitrate in Borehole 1B and sulphate in Borehole 2 none of the major ions exceed the EC maximum admissible concentration (MAC) in drinking water (where a value is given - Ref 4). The elevated nitrate may be due to local agricultural use, whilst the sulphate may be naturally derived from mudstone strata. Bicarbonate at Borehole 6 is also elevated, although the reason for this is unclear.
- 2.45 The major ions have been plotted as a piper diagram (Appendix 2) and indicate the similarity between the groundwater at all locations except borehole 2. The determinands are dominated by calcium and bicarbonate ions typical of limestone groundwaters. Borehole 2 is the exception as although calcium in the groundwater at this location is high, bicarbonate is low, whilst sodium, sulphate, phosphate and ammoniacal nitrogen are elevated compared to the other locations. This may be a facet of the nature of the borehole as much as the aquifer - limited water was encountered at this location, permeability was low and borehole purging/ development was not extensive. Of the metals for which analysis was

Interpretation of Results *continued***2**

undertaken, the majority were present at concentrations less than the limit of detection. The exceptions are discussed below.

- 2.46 Arsenic can be found naturally in groundwaters at concentrations in excess of 50 µg/l, although the norm is less than 1 µg/l (Ref 6). The concentration of 710 µg/l measured in Borehole 2 is therefore elevated in comparison, whilst the 2280 µg/l in Borehole 3B is greatly elevated. It can be much higher in geothermal waters, values of 40 mg/l being recorded in the US (Ref 7). No trial pits were dug in the close vicinity of Borehole 3 to indicate local soil concentrations.
- 2.47 Boron is greater than the limit of detection in Boreholes 1A, 2, 5 and 6, however, it was nowhere detected at a concentration greater than the EC guide level. Cadmium was only detected in Boreholes 5 and 6, at 0.1 and 0.2 mg/l respectively, only just greater than the limit of detection of 0.05 mg/l. The natural background concentration is around 1 µg/l (Ref 6). Chromium was not significantly greater than the limit of detection at any location.
- 2.48 Copper was only present at greater than the limit of detection at Borehole 3B and then not significantly greater than the EC GL. Mercury concentrations detected in Boreholes 1B, 4 and 6 are elevated compared to the EC MAC, but are less than twice the limit of detection and must therefore be interpreted with caution. The concentration of 140 µg/l measured at Borehole 1A is elevated compared to the MAC of 1 µg/l. No natural sources can be suggested for its origin, whilst analysis of shallow soils near Borehole 1 do not indicate elevated concentrations.
- 2.49 Nickel was only detected at greater than the limit of detection (and the EC MAC) in Borehole 3B. However, the concentration was only four times the limit of detection. Nickel can be found naturally occurring in groundwaters in the UK at over 0.1 mg/l, although typically concentrations are less than 0.01 mg/l (Ref 6). Nickel concentrations in soil across the site are very low.
- 2.50 Lead was detected at a concentration slightly greater than the limit of detection (and the EC MAC) at four locations, although only at one of these was the concentration slightly greater than four times the limit of detection. Natural concentrations of lead in groundwater are generally below 1 µg/l (Ref 6). Selenium was not detected at any location greater than the limit of detection.
- 2.51 Zinc was present at a concentration greater than the limit of detection at four locations, but only at Borehole 3B was the concentration significantly greater than the limit. There is no EC MAC for zinc, although the concentration exceeds the EC GL, but not the Dutch Intervention value.

Interpretation of Results *continued*

Table 2.7 Summary of Groundwater Analysis

BH	EC	pH	Na	K	Ca	Mg	Cl	NO ₃	Phos	SO ₄	Ammon	ALK	HCO ₃	COD	BOD	TOC	As	B	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn	M.Oil	NVA	NSO	TPH	DCM	TSE	DRO		
GL	mS/cm		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	ug/l		
MAC	0.4		20	10	100	30	25	25	0.17	25	0.03						0.05	1	0.005	0.05	0.1	0.001	0.05	0.05	0.01	0.065	0.05								
TV			175	12	50	50	50	2.2	250	0.3							0.06		0.006	0.03	0.075	3E-04	0.075	0.075	0.8	0.6									
1A	0.645	7.27	40	6	178.2	11.97	30	23.3	0.12	101	0.04	480	480	478	11.1	2	<0.05	0.12	<0.05	<0.05	<0.05	0.14	<0.05	0.06	<0.1	<0.05	2	<1	1	2	3	3	<10		
1B	0.549	7.25	12	<3	197.8	2.87	19	93.4	0.06	56	<0.01	330	330	<10	20.5	2	<0.05	<0.05	<0.05	<0.05	0.08	<0.05	<0.05	<0.05	<0.1	<0.05	1	<1	1	2	2	2	<10		
1B*																																			
2	1.029	8.11	96	7	115.3	8.13	46	52.6	0.63	324	0.26	90	90	30	1.2	7	0.71	0.37	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.1	<0.05	<1	<1	3	<1	3	2	77		
3A	0.572	7.38	14	<3	124.4	2.46	13	41.3	0.07	53	<0.01	480	480	14	0.7	2	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.06	<0.1	<0.05	<1	<1	2	<1	2	2	<10		
3B	0.614	7.21	12	<3	164	2.13	13	14.1	0.18	42	0.08	400	400	10	<0.5	5	2.28	<0.05	<0.05	<0.05	0.13	<0.05	0.21	0.11	<0.1	<0.05	<1	<1	3	<1	3	3	<10		
4	0.557	7.43	21	3	113.4	6.58	15	<0.5	0.03	58	<0.01	280	280	<10	<0.5	9	<0.05	<0.05	<0.05	<0.05	0.06	<0.05	<0.05	<0.1	<0.05	<1	<1	<1	<1	<1	<1	<1	<10		
4*																																			
5	0.624	7.21	14	<3	141.8	2.71	53	<0.5	0.02	29	<0.01	300	300	<10	<0.5	5	<0.05	0.22	0.07	<0.05	<0.05	<0.05	0.23	<0.1	0.15	<1	<1	1	<1	1	1	1	10		
5*																																			
6	0.602	7.32	19	5	152.5	9.31	5	<0.5	0.11	82	0.02	1400	1400	77	2.8	6	<0.05	0.08	0.1	<0.05	<0.05	0.09	<0.05	<0.1	0.06	<1	<1	<1	<1	<1	<1	<1	<1	<17	
7	0.587	7.14	12	<3	135	2.78	10	<0.5	0.02	10	0.04	400	400	<10	<0.5	5	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.09	<0.1	0.08	<1	<1	<1	<1	<1	<1	<1	<1	<10	
7*																																			

Notes: * - bailed sample, GL - EC Guide Level, MAC - EC Maximum Admissible Concentration, TV - Dutch target value, IV - Dutch Intervention Value
 EC - electrical conductivity, Ammon N - ammoniacal nitrogen, ALK - alkalinity, COD - chemical oxygen demand, BOD - biochemical oxygen demand, TOC - total organic carbon, M.Oil - mineral oil/paraffin, NVA - total non-volatile aromatics
 NSO - NSO/resins, TPH - total petroleum hydrocarbons, DCM - DCM/MeOH extract, TSE - total soluble extract, DRO - diesel range organics, Phos - phosphate (note MAC & GL expressed as P).

Interpretation of Results *continued*

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- 2.52 Although at the majority of locations the metal concentrations in groundwater do not exceed the limit of detection there are a number of instances where this does occur. In general the concentrations are not significant being only up to four times the limit of detection. Furthermore comparison has been made to guideline concentrations for potable water which are not necessarily applicable to contaminated land assessments such as this. The only exception is in Borehole 3B where arsenic appears to be anomalously high.

Organic Determinands

- 2.53 A number of screening tests were undertaken in order to identify, in broad terms, if organic contaminants were present in the groundwater. These included COD, BOD, TOC, Mineral Oil, TPH and NSO/resins. In addition, analysis for diesel range organics (DRO) was carried out to improve the detection limits for hydrocarbons.
- 2.54 COD was only elevated in Borehole 1A at 478 mg/l and slightly elevated in Borehole 6 at 77 mg/l. The cause of the very high concentrations in Borehole 1A could not be determined by the laboratory and was not paralleled by elevated concentrations of any other "indicator" tests, including TOC and BOD. COD is generally used as an indicator of the presence of "polluting" material, although in this instance such material could not be identified.
- 2.55 BOD was slightly elevated in Borehole 1B, although not to an extent to cause any great concern. Of the remaining "indicators" used, all were less than, at, or close to, the limit of detection, indicating that the groundwaters are not significantly contaminated by organic material. The analysis for diesel range organics also indicates no significant contamination.
- 2.56 The DRO analysis indicates that the groundwater sampled from the boreholes is not contaminated by hydrocarbons. The slightly elevated concentration measured in Borehole 2 is not significant, especially given that it was not possible to effectively purge the borehole due to the slow groundwater inflow rate.

Results of Chemical Analysis of Spring Water

Inorganic Determinands

- 2.57 The spring water chemistry is detailed in Table 2.8. This indicates good quality water with a neutral pH and slightly elevated EC typical of groundwater from oolite strata. As with the borehole waters the major ion concentrations are generally less than the MAC for potable water (where a value is given). The exceptions are from springs C2 and D where nitrate concentrations of 119 and 97

Interpretation of Results *continued***2**

mg/l respectively were measured. These are probably associated with inputs from agricultural sources.

- 2.58 The piper plot (Appendix 2) indicates that the springs are all of a similar chemical type, as with the borehole waters, being dominated by calcium and bicarbonate ions. Only spring I appears to have a slightly different chemistry with calcium, chloride and sulphate being generally lower. This is likely to be a reflection of the conditions under which spring I was sampled (i.e. following heavy overnight rain) compared to all other locations (stable conditions).
- 2.59 There are slight differences in the chemistry of the borehole and spring waters. The spring waters tend to have higher calcium, potassium, chloride, and ammoniacal nitrogen concentrations and lower magnesium and sodium. This may be a reflection of bedrock quality variations, groundwater residence times in the aquifer, and equilibration of dominant ionic species.
- 2.60 Of the metals, all except lead and zinc at Spring I are less than the limit of detection. The concentrations at spring I are less than or equal to twice the limit of detection and should therefore be treated with caution. In both instances, if the values are true, they are not significant in terms of environmental contamination.

Organic Determinands

- 2.61 All of the indicators of organic contamination are either less than the limit of detection, or close to it, suggesting that there is not significant pollution of spring water. Although DRO was detected at greater than the limit of detection at three locations these concentrations are not considered to be significant.

Other Data

- 2.62 The geological memoir for the area (Ref 8) cites borehole and spring water quality for the Lias and Middle Jurassic strata. The results for the Lower Lias indicate that the water quality is markedly different to the Middle Lias and Middle Jurassic, the Lower Lias groundwater being dominated by sodium/potassium cations and sulphate/chloride anions. The Middle Lias and Middle Jurassic groundwaters are similar in chemistry to the groundwater samples taken at Upper Heyford, i.e. dominated by calcium and bicarbonate ions.
- 2.63 The National Rivers Authority (NRA, now The Environment Agency) have historically monitored spring/surface water quality in the vicinity of Upper Heyford, the results of which, for March 1995, are presented in Annex F of the Desk Study (Ref 9). These indicate calcium/bicarbonate dominated, neutral to slightly alkaline groundwaters with no significant organic contamination.

Interpretation of Results *continued*

Table 2.8 Summary of Spring Water Analysis

Spr	EC mS/cm	pH	Na mg/l	K mg/l	Ca mg/l	Mg mg/l	Cl mg/l	NO ₃ mg/l	Phos mg/l	SO ₄ mg/l	Amn N mg/l	ALK mg/l	HCO ₃ mg/l	COD mg/l	BOD mg/l	TOC mg/l	Aa mg/l	B mg/l	Cd mg/l	Cr mg/l	Cu mg/l	Hg mg/l	Ni mg/l	Pb mg/l	Se mg/l	Zn mg/l	Mn mg/l	NVA mg/l	TPH mg/l	DCM mg/l	TSE mg/l	DRO ug/l	
GL	0.4		20	10	100	30	25	25	0.17	25	0.03						0.05	0.005	0.005	0.05	0.001	0.001	0.05	0.05	0.01	0.1							
MAC			175	12	50	50	50	50	2.2	250	0.3						0.01	4E-04	0.001	0.015	5E-05	0.015	0.015	0.065	0.065	0.06							
TV																	0.06	0.006	0.03	0.075	3E-04	0.075	0.075	0.8	0.8								
IV	0.685	7.52	16	<3	173	2.26	25	27.5	0.02	44	0.49	300	300	<10	<0.5	2	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.1	<0.05	<1	<1	1	1	<10		
B*	0.658	7.72	24	<3	228	2.95	59	119.1	0.02	35	0.85	233	233	<10	<0.5	3	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.1	<0.05	<1	<1	1	1	24		
C2	0.919	7.79	18	10	298	3.69	54	97.2	<0.01	69	0.05	300	300	<10	<0.5	3	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.1	<0.05	<1	0.53	<1	17			
D																																	
D'																																	
G1	0.791	7.83	15	<3	248	3.33	28	30.1	0.02	71	0.61	400	400	<10	<0.5	2	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.1	<0.05	<1	<1	1	1	<10		
I	0.362	7.87	13	<3	58	1.37	17	4.7	0.04	17	0.04	550	550	<10	<0.5	6	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.07	<0.1	<0.05	<1	<1	<1	<1	<10		
L	0.654	7.76	20	<3	184	2.96	64	3.8	0.07	27	0.05	260	260	<10	<0.5	3	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.1	<0.05	<1	<1	0.33	<1	31		
M	0.667	7.36	16	<3	177	2.05	35	31	0.01	47	0.09	250	250	<10	<0.5	3	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.1	<0.05	<1	<1	0.46	<1	<10		
P1	0.796	7.94	22	8	215	3.72	34	36	0.02	77	0.08	367	367	<10	<0.5	3	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.1	<0.05	<1	1	1	1	<10		
R2	0.798	7.32	12	<3	246	3.19	18	17.7	<0.01	69	0.18	433	433	<10	<0.5	1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.1	<0.05	<1	2	2	2	<10		

Notes: * - second sample taken following heavy rain, GL - EC Guide Level, MAC - EC Maximum Admissible Concentration, TV - Dutch target value, IV - Dutch Intervention Value
 EC - electrical conductivity, Amn N - ammoniacal nitrogen, ALK - alkalinity, COD - biochemical oxygen demand, BOD - biochemical oxygen demand, TOC - total organic carbon, Mn - mineral oil/paraffin, NVA - total non-volatile aromatics
 NSO - NSO/resins, TPH - total petroleum hydrocarbons, DCM - DCM/MethOH extract, TSE - total soluble extract, DRO - diesel range organics, Phos - phosphate (note MAC & GL expressed as P).

Interpretation of Results *continued*

2

Results of Radiological Investigation

- 2.64 The results of the radiological investigation indicate that radioactivity is unlikely to be a significant issue at the site.

Summary of Findings

- 2.65 Significant findings from the investigation include:
- of the 355 SVS investigation points only 6 locations had flammable gas concentrations greater than 100 ppm. Three of these were within the former fire practice area (all > 10 000 ppm), and three along sections of the POL supply ring main (1000, 6000 and > 10 000 ppm);
 - the concentrations of toxic metals recorded do not represent significant contamination. Although arsenic is elevated above ICRCCL guidelines across much of the site this is not considered to be a significant risk;
 - only trial pits 113 and 113A recorded concentrations of the phytotoxic metals copper and zinc significantly in excess of published guidelines. These metals also exceeded the guidelines in TP71 (copper) and TP90 (zinc), but by less than 10% in both cases. Guidelines for boron, also a phytotoxic metal, were exceeded in three trial pits, TP62, TP66 and TP35;
 - sulphate concentrations at the locations sampled across the site were generally less than BRE guidelines in relation to the use of Class 1 concrete. However, at two locations Class 2 concrete would be required, with Class 3 required at one location;
 - organics in soils:
 - only 8 trial pits (9 samples) across the whole site had SEM values in excess of 5 000 mg/kg;
 - 1 trial pit (TP124) had mineral oil concentrations in excess of the Dutch Intervention value of 5 000 mg/kg;
 - no samples were analysed with significant concentrations of VOCs, SVOCs, PRO or PAHs;
 - weathered diesel, albeit at low concentrations, was identified in four trial pits (TP14 and TP16 in POL 21, TP93 in POL 20 and TP142 in the fire practice area);
 - two samples, both from TP124, had elevated concentrations of TPH;
 - olfactory or visual evidence of hydrocarbon contamination was tentatively identified in 19 trial pits, although this was not always borne out by the results of analysis;

Interpretation of Results *continued*

2

- results from the borehole water and spring water sampling indicate that the underlying aquifer is not being significantly affected by the isolated instances of soil contaminants described above; and,
- the radiological investigation did not indicate the presence of any radioactive material in the areas investigated.

It must be remembered that these results relate to a targeted investigation designed to assess possible contamination in areas perceived as having a high risk. They do not relate to the whole site, although the areas of the site not investigated are perceived as being of a lower risk.

Environmental Appraisal

3

Introduction

- 3.1 Health, safety and environmental considerations at RAF Upper Heyford are addressed below by a site-specific risk assessment. The assessment considers the present state of the site, risks associated with future demolition and remediation activities and risks following redevelopment or site re-use.

Qualitative Risk Assessment

- 3.2 Risk assessment is the process of collating known information on a hazard or set of hazards in order to estimate actual or potential risks to receptors. The receptor may be human health, a water resource, a sensitive local ecosystem or even future construction materials. Receptors can be connected with the hazard under consideration via one or several exposure pathways (e.g. the pathway of direct contact). Risks are generally managed by isolating or removing the hazard, isolating the receptor, or by intercepting the exposure pathway. Without the three essential components of a source (hazard), pathway and receptor, there can be no risk. Thus, the mere presence of a hazard at a site does not mean that there will necessarily be attendant risks. The following risk assessment thus focuses on the parts of the site where hazards have been identified and is not general to the whole site.

Identified Hazards

- 3.3 The investigation has identified a number of contaminants on-site at concentrations which exceed published guideline values. These chemical contaminant groups are described in Chapter 2. Individual sources of hazard include:
- soil bound phytotoxic metals: significantly elevated copper and zinc concentrations in two locations close to one another;
 - organics in soil: including petroleum hydrocarbons and mineral oils at a limited number of locations across the site; and,
 - asbestos within construction materials in buildings.

Pathways

- 3.4 The mere presence of chemical contamination does not infer a risk. The exposure pathway determines the dose delivered to the receptor and the effective dose determines the extent of the adverse effect on the receptor. The pathway which transports the contaminants to the receptor or target generally involves conveyance via soil, water or air.

Environmental Appraisal *continued*

3

3.5 Potential environmental fate and exposure pathways specific to the site are:

- direct contact, incidental ingestion or inhalation of contaminated soils;
- uptake of contamination by plant roots;
- leaching of soluble contaminants to groundwater;
- migration of contamination into on-site drains via surface water run-off and leaching;
- migration of hydrocarbon vapours through permeable strata; and,
- physical contact with explosive ordnance.

Receptors

3.6 The varying effects of a hazard on individual receptors depend largely on the sensitivity of the target. Receptors include any people, animal or plant populations, or natural or economic resources within the range of the source and connected to the source by the transport pathway. Receptors can, in addition, extend to remediation processes and future construction materials that may be adversely affected by on-site contamination. In general, however, receptors can be divided into a number of groups dependent on the final use of the site. The potential receptors identified include:

- **Humans:** present site occupants and visitors, personnel involved in site remediation and redevelopment activities, and future site users;
- **Flora and fauna:** present vegetation does not appear to be suffering from distress, although sensitive species planted in future may be at risk. No information is available regarding fauna present, although the rabbit population appears considerable. Extensive grassed areas are currently used for grazing sheep and horses - no adverse effects to these have been reported;
- **Groundwater:** this is present within a layered aquifer beneath the site. The upper layers are most at risk due to infiltration of rain water and leaching of soils. Lower layers of the aquifer system are protected to a degree by low permeability mudstone strata, although leakage can occur through these;
- **Surface water:** there are no surface water courses on the site, however storm water drains discharge to watercourses at the site periphery. It is thought that this system also collects former springs present prior to development of the base. There are also a number of springs which rise off site but which may be fed by groundwater from the site;

Environmental Appraisal *continued*

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- Buildings and services: the existing buildings on site do not appear to be suffering any signs of corrosive damage, although buildings to be developed in future may be sensitive receptors.

Exposure Assessment

- 3.7 By considering the source, pathway and receptor, an assessment is made for each contaminant on a receptor by receptor basis with reference to the significance and degree of the risk. In assessing this information, a measure is made of whether the source contaminant can reach a target or receptor, determining whether it is of a major or minor significance. The risks are assessed against the present site condition, conditions during any demolition and remediation, and following redevelopment and further occupation. The options for redevelopment include use of the land for a range of purposes including gardens, parkland, residential and industrial. The results of this assessment are presented in Tables 3.1, 3.2 and 3.3.
- 3.8 It is evident from Tables 3.1 to 3.3 that for the majority of hazards under the different site conditions from present state through to redevelopment, the risks can be categorised as low or very low. The exception to this is under present site conditions in any areas where asbestos sheet is broken or damaged. This notwithstanding, the period when environmental risks require most careful management is during site demolition and redevelopment.
- 3.9 Concentrations of toxic metals determined in soils at the site are not considered to present a significant risk to current or future site users or to site workers involved in any physical works undertaken at the site. Phytotoxic metals are limited to a very few isolated occurrences and will only be a risk in the event that sensitive species are planted in those areas affected.
- 3.10 The presence of isolated occurrences of organic contamination of soils in some areas of the site, may present a low risk to the underlying aquifer and off site spring fed watercourses, in the event that the source of contamination is disturbed. The main areas affected include the former fire practice area (trial pits 142 and 149) and within the weapons storage area (trial pit 124). Additional, but less significant organic contamination was found in POL 20 (trial pit 93) and POL 21 (trial pits 14 and 16). If left undisturbed, the threat to the underlying aquifer appears minimal. If the ground in affected areas were to be disturbed by physical works, however, any low or semi-permeable layers which may have restricted vertical migration would be disrupted, and would provide an enhanced pathway for contaminants to reach the underlying aquifer and hence off site watercourses. Mitigation measures to prevent contamination of the underlying aquifer would therefore be required for physical works during any redevelopment of the affected areas of the site.
- 3.11 The concentrations of organic contaminants present also pose a health risk, albeit limited, to site workers or future site users who may come into contact with soils in

Environmental Appraisal *continued*

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the areas affected. Underground services such as plastic water pipelines may be at risk if laid directly through contaminated strata. Similarly, buildings with void spaces below ground level may be at risk from the migration of flammable gas.

- 3.12 There remains a possibility that buried ordnance is present at the site, although all searches to date have indicated no live munitions to be present.
- 3.13 Although the asbestos materials used in buildings throughout the site are generally intact and in good condition there are isolated areas with damaged sections of asbestos cement sheet present (e.g. adjacent to TP133). In such areas there is a current risk to health if the period of exposure is significant, but elsewhere the risk is low. Even in areas where asbestos containing materials are in good condition damage and dust generation will undoubtedly occur in the event of demolition. All demolition works on buildings containing asbestos will have to be carried out under carefully controlled conditions by specialist contractors appropriately licensed for asbestos removal with particular attention to dust suppression and the health and safety of site workers.
- 3.14 We recommend that an asbestos survey of the site is carried out to update available information and to ensure its completeness. Furthermore, such a survey would identify any asbestos materials which are present in a friable condition which could pose a threat to site users with a sufficient level of exposure to it.
- 3.15 There is the potential for the presence of radioactive material in areas not assessed by DRPS in their 1995 survey. However, their assessment indicates this not to be a significant issue for the areas they investigated.

Environmental Appraisal *continued*

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Table 3.1 : Risks Associated with RAF Upper Heyford under Present Site Conditions

Source	Pollutant	Receptors	Pathways to Receptor	Associated Hazard	Risk (Likelihood) of Occurrence	Potential Significance
Soil bound toxic metals	Arsenic, cadmium, lead, selenium	Humans and other fauna	Direct contact, ingestion, inhalation	Health risk if ingested	Very low	Concentrations very localised. Current site use may result in direct contact with ground for contractors working on drains/services or building foundations. No adverse effects to animals using grazing areas reported. E : Minor significance, no remediation likely to be required
		Watercourses (off site)	Movement via groundwater	Contamination of nearby surface water	Very low	Localised concentrations. Elevated soils results not mirrored in groundwater. E : Minor significance, no remediation likely to be required
Soil bound phytotoxic metals	Zinc, copper, boron	Groundwater	Percolation through ground	Contamination of underlying aquifer	Very low	Localised concentrations. Elevated soils results not mirrored in groundwater. E : Minor significance, no remediation likely to be required
		Flora	Root uptake	Toxicity effects on plants	Very low	Elevated concentrations localised and site vegetation shows no distress. E : Minor significance, no remediation likely to be required
Organics in soil and groundwater	Hydrocarbons (including petroleum based fuels and lube oils)	Humans	Direct contact, ingestion, inhalation	Health risk if ingested Irritation may arise on dermal contact	Very low	Elevated concentrations localised and current site use unlikely to involve direct contact with ground. E : Minor significance, no remediation likely to be required
		Watercourses (off site)	Movement via groundwater	Contamination of nearby surface water	Very low to low	Elevated concentrations localised and pathways to surface waters limited, although may be facilitated if ground is disturbed by physical works. E : Minor-significance, no remediation likely to be required

Environmental Appraisal *continued*

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Table 3.1 : Risks Associated with RAF Upper Heyford under Present Site Conditions

Source	Pollutant	Receptors	Pathways to Receptor	Associated Hazard	Risk (Likelihood) of Occurrence	Potential Significance
Organics in soil and groundwater	Hydrocarbons (including petroleum based fuels and lube oils)	Groundwater	Percolation through ground	Contamination of underlying aquifer	Moderate	Elevated concentrations localised. Migration may be facilitated if ground is disturbed by physical works. E : Minor significance, no remediation likely to be required
Organics in soil and groundwater	Flammable soil vapours	Buildings and buried services	Soil vapour migration	May cause build up of flammable gas in service ducts or below ground building structures	Very low	Elevated concentrations of flammable gas very localised. E : Minor significance, no remediation likely to be required
Organics in soil and groundwater	Hydrocarbons (including PAHs, petroleum based fuels and lube oils)	Buildings and buried services	Contact and percolation through ground	May influence integrity of plastic materials	Very low	Elevated concentrations localised. E : Minor significance, no remediation likely to be required
Hazardous construction materials	Asbestos	Humans	Inhalation	Health risks if inhaled	Low to High	Asbestos identified within fabric of buildings but reported to be in generally good condition. Isolated occurrences of asbestos cement sheet in poor condition. C. Moderate remediation liability to E : Minor significance, no remediation likely to be required
Areas of Radioactive materials	Radioactive isotopes	Humans and other fauna	Contact and percolation through ground	Health risk if exposed	Very low	Uncertainty in uninvestigated areas. No evidence of radioactive materials in trial pits excavated across the site. E : Minor significance, no remediation likely to be required
Areas of buried ordnance storage	Explosives (range of organic and inorganic contaminants depending on ordnance present)	Humans	Direct contact	Health risk if exploded	Very low	Uncertainty over uninvestigated areas. No evidence of ordnance in trial pits excavated across the site. E : Minor significance, no remediation likely to be required

Environmental Appraisal *continued*

3

Table 3.2 : Risks Associated with RAF Upper Heyford Identified During Demolition and Site Re-development

Source	Pollutant	Receptors	Pathways to Receptor	Associated Hazard	Risk (Likelihood) of Occurrence	Potential Significance
Soil bound toxic metals	Arsenic, cadmium, lead, selenium	Humans	Direct contact, ingestion, inhalation	Health risk if ingested	Very low	Concentrations very localised. Provided suitable health and safety procedures adopted. E : Minor significance, no remediation likely to be required
		Watercourses (off site)	Movement via groundwater	Contamination of nearby surface water	Very low	Concentrations very localised and elevated results in soils not mirrored in groundwater. E : Minor significance, no remediation likely to be required
		Groundwater	Percolation through ground	Contamination of underlying aquifer	Very low	Concentrations very localised and elevated results in soils not mirrored in groundwater. E : Minor significance, no remediation likely to be required
Soil bound phytotoxic metals	Zinc, copper, boron	Flora	Root uptake	Toxicity effects on plants	Low	May require limited remedial action in isolated areas only, especially if planting copper and zinc sensitive species. E : Minor significance, no remediation likely to be required
Organics in soil and groundwater	Hydrocarbons (including petroleum based fuels and lube oils)	Humans	Direct contact, ingestion, inhalation	Health risk if ingested Irritation may arise on dermal contact	Low	Provided suitable health and safety procedures adopted. Risk only exists if source is disturbed. D : Minor liability
		Watercourses (off site)	Movement via groundwater	Contamination of nearby surface water	Low	Mitigation measures may be required during redevelopment to prevent migration of contaminant to off site surface waters. Risk only exists if source is disturbed. D : Minor liability

Environmental Appraisal *continued*

3

Table 3.2 : Risks Associated with RAF Upper Heyford Identified During Demolition and Site Re-development

Source	Pollutant	Receptors	Pathways to Receptor	Associated Hazard	Risk (Likelihood) of Occurrence	Potential Significance
Organics in soil and groundwater	Hydrocarbons (including petroleum based fuels and lube oils)	Groundwater	Percolation through ground	Contamination of underlying aquifer	Low	Mitigation may be required during redevelopment to prevent migration of contaminant to groundwaters. Risk only exists if source is disturbed. Environment Agency may require remedial action as part of redevelopment scheme. D: Minor liability or E: Very minor liability depending on attitude of Environment Agency
Organics in soil and groundwater	Flammable soil vapours	Buildings and buried services	Soil vapour migration	May cause build up of flammable gas in service ducts or below ground building structures	Very low	In areas not affected by organic contamination risk is negligible. Elsewhere gas protection measures may be required for buildings in absence of ground remediation. D: Minor liability
Organics in soil and groundwater	Hydrocarbons (including PAHs, petroleum based fuels and lube oils)	Buildings and buried services	Contact and percolation through ground	May influence integrity of plastic materials	Very low	In areas with no organic contamination risk is negligible. Where contaminants are present, materials used for water pipelines may need to be resistant. D: Minor liability
Hazardous construction materials	Asbestos	Site workers	Inhalation	Health risks if inhaled	Low	Providing suitable health and safety precautions adopted D: Minor liability if carried out to appropriate procedures
Areas of Radioactive materials	Radioactive isotopes	Humans and other fauna	Contact and percolation through ground	Health risk if exposed	Very low	Uncertainty in uninvestigated areas. No evidence of radioactive materials in trial pits excavated across the site. D: Minor liability
Areas of buried ordnance storage	Explosives (range of organic and inorganic contaminants depending on ordnance present)	Humans	Direct contact	Health risk if exploded	Very low	Uncertainty over uninvestigated areas. No evidence of ordnance in trial pits excavated across the site. D: Minor liability

Environmental Appraisal *continued*

3

Table 3.3 : Risks Associated with RAF Upper Heyford Identified Following Site Re-development

Source	Pollutant	Receptors	Pathways to Receptor	Associated Hazard	Risk (Likelihood of Occurrence)	Potential Significance
Soil bound toxic metals	Arsenic, cadmium, lead, selenium	Humans	Direct contact, ingestion, inhalation	Health risk if ingested	Very low	Concentrations very localised. Provided suitable precautions are taken in affected areas. E : Minor significance, no remediation likely to be required
		Watercourses (off site)	Movement via groundwater	Contamination of nearby surface water	Very low	Concentrations very localised and elevated results in soils not mirrored in groundwater. E : Minor significance, no remediation likely to be required
		Groundwater	Percolation through ground	Contamination of underlying aquifer	Very low	Concentrations very localised and elevated results in soils not mirrored in groundwater. E : Minor significance, no remediation likely to be required
Soil bound phytotoxic metals	Zinc, copper, boron	Flora	Root uptake	Toxicity effects on plants	Very low	Assuming appropriate remedial action taken in gardens / landscaped areas. E : Minor significance after redevelopment
		Humans	Direct contact, ingestion, inhalation	Health risk if ingested Irritation may arise on dermal contact	Very low	Elevated concentrations localised. Assumes remedial action taken if affected areas are used for sensitive end-uses E : Minor significance after redevelopment
Organics in soil and groundwater	Hydrocarbons (including petroleum based fuels and lube oils)	Watercourses (off site)	Movement via groundwater	Contamination of nearby surface water	Very low (if remedial action undertaken) Low to moderate (if no action taken)	Elevated concentrations localised and pathways to surface waters limited although may be facilitated if no remedial action and ground is disturbed by physical works. E : Minor significance after redevelopment

Environmental Appraisal *continued*

Table 3.3 : Risks Associated with RAF Upper Heyford Identified Following Site Re-development

Source	Pollutant	Receptors	Pathways to Receptor	Associated Hazard	Risk (Likelihood of Occurrence)	Potential Significance
Organics in soil and groundwater	Hydrocarbons (including petrol based fuels and lube oils)	Groundwater	Percolation through ground	Contamination of underlying aquifer	Very low (if remedial action undertaken) Moderate (if no action taken)	Elevated concentrations localised. Migration may be facilitated if remedial action not undertaken and ground is disturbed by physical works. E: Minor significance
Organics in soil and groundwater	Flammable soil vapours	Buildings and buried services	Soil vapour migration	May cause build up of flammable gas in service ducts or below ground building structures	Very low	Assuming soil gas precautions adopted in buildings constructed in affected areas in the absence of ground remediation being undertaken. E: Minor significance
Organics in soil and groundwater	Hydrocarbons (including PAHs, petroleum based fuels and lube oils)	Buildings and buried services	Contact and percolation through ground	May influence integrity of plastic materials	Very low	Assuming precautions adopted for pipework laid in affected areas. E: Minor significance
Hazardous construction materials	Asbestos	Humans	Inhalation	Health risks if inhaled	Very low	Following removal of all source material from site and appropriate disposal. E: Minor significance
Areas of Radioactive materials	Radioactive isotopes	Humans and other fauna	Contact and percolation through ground	Health risk if exposed	Very low	Uncertainty in uninvestigated areas. No evidence of radioactive materials in trial pits excavated across the site. E: Minor significance
Areas of buried ordnance storage	Explosives (range of organic and inorganic contaminants depending on ordnance present)	Humans	Direct contact	Health risk if exploded	Very low	Uncertainty over uninvestigated areas. No evidence of ordnance in trial pits excavated across the site. E: Minor significance

Conclusions and Recommendations

4

Conclusions

- 4.1 A targeted site investigation has been undertaken at RAF Upper Heyford focusing on those areas considered to be at high risk from potential sources of contamination. This phase of work involved preliminary soil vapour surveys, a trial pit investigation and construction of nine groundwater monitoring points at seven locations. The aim of this investigation has been to focus on higher risk areas. There remains a low risk, therefore, that other localised areas of contamination exist in parts of the site not directly covered by this site investigation. Any localised areas of contamination, occurring for instance below buildings, would be most appropriately investigated and dealt with as part of any demolition and redevelopment work.
- 4.2 Examination of background information, combined with analysis of soil samples from areas deemed a high potential contamination risk and groundwater samples from boreholes beneath the site and springs draining the site indicates that the majority of RAF Upper Heyford is uncontaminated and therefore suitable for either housing or industrial use without the need for extensive remediation.
- 4.3 Contamination identified at the site by this investigation is limited to two main areas as follows:
- former fire practice area where elevated concentrations of petroleum hydrocarbons have been detected in soils (trial pits 142 and 149); and,
 - the weapons storage area (trial pit 124).

In addition, hydrocarbon contamination, albeit at relatively low concentrations, was identified in POL 20 (trial pit 93) and POL 21 (trial pits 14 and 16). These areas are shown on Figure 1. It should be emphasised that, other than for the former fire practice area, the extent of the areas contaminated by the compounds listed above is likely to be limited to the immediate vicinity of the source of the contamination.

- 4.4 Analysis of samples from several other areas of the site indicate the presence of contaminants at elevated concentrations, however, these locations are excluded from the above list for a number of reasons. These locations and the reasons for their exclusion are as follows:
- the sample from trial pit 50 (adjacent to Hush House 1443) had an elevated SEM but further analysis indicated that PRO was less than the limit of detection, whilst the DRO of 392 mg/kg could not be ascribed to hydrocarbons. Although some PAHs were detected their concentration was substantially less than the ICRL domestic garden action level. It is

Conclusions and Recommendations

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continued

likely that the elevated SEM is due to local contamination in the ash and clinker sampled at this location;

- the sample from trial pit 27 had elevated SEM and DRO (both the highest of all the samples tested) and PAHs were detected, albeit less than the domestic garden action level. The elevated DRO was ascribed to coal tars. These, and the elevated SEM, are probably derived from asphalt which was associated with the sample taken at 0.3 m depth (see trial pit log in Appendix 3 of the Factual Report); and,
- the area around trial pit 105 is excluded from the list of contaminated areas as although VOCs were detected, they were not present at significant concentrations.

- 4.5 The presence of phytotoxic metals at the site is limited to six locations (treating TP113 & TP113A as one area). Boron is slightly elevated at three locations and copper and zinc at two. At TP113/113A both copper and zinc are present at significantly elevated concentrations. These metals are associated with the made ground present at this location. Given the presence of healthy vegetation in all of the above areas, such concentrations are not thought to pose a serious risk, unless the areas are to be replanted with particularly sensitive plants species.
- 4.6 Asbestos fibres were not detected visually in the ground excavated at any location. Isolated pieces of broken asbestos cement sheet were identified on the ground adjacent to TP133.
- 4.7 The site is known to be in a sensitive location with respect to both groundwater and surface water. The Great Oolite Limestone which underlies the site is a major aquifer used for local water supply. In addition, discharges from the aquifer support surface water courses via a number of springs. These flow to three drainage systems: the River Cherwell, the Padbury Brook and the Gallos/Gagle Brook. These water courses are generally of fair to good quality.
- 4.8 The results of chemical analysis on groundwater samples taken from both springs and boreholes suggest that the underlying aquifer is not presently being polluted to any significant extent by any of the contaminants listed above. However, the attitude of The Environment Agency to sources of contamination which are present on sites situated in locations of high environmental sensitivity such as Upper Heyford is becomingly increasingly stringent. There is a possibility therefore that The Environment Agency may require some form of remediation of organic contamination in affected areas of the site, particularly as part of any redevelopment scheme.
- 4.9 Although the asbestos materials used in buildings throughout the site are generally, though not entirely, intact and in good condition damage and dust generation will undoubtedly occur in the event of demolition.

Conclusions and Recommendations

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continued

Recommendations

- 4.10 The concentrations of metals and organic compounds present in most areas of the site are not considered to be sufficiently elevated and extensive to warrant any form of immediate remedial works. Areas that may require remedial works are the fire practice area, part of the weapons storage area and the area with elevated copper and zinc around trial pit 113. It may also be, although this is less likely, that remedial works will be required in POL 20 and POL 21.
- 4.11 In their current state, and provided that the sources of contamination are not disturbed (by ground excavations for building foundations, service trenches etc.), then it is considered that the above areas pose only a low risk to water resources in the area, and on this basis are unlikely to require immediate remediation. Where excavations as part of redevelopment do take place then provided suitable control measures are employed the potential contamination risks can be minimised. However, the regulatory authorities and, in particular The Environment Agency, may wish to adopt a more stringent line to a source of contamination in an area of high water resource sensitivity. It may be the case that The Environment Agency would require remedial works to be undertaken to deal with the petroleum hydrocarbons which have been shown to exist in some of these areas, particularly in the event of any redevelopment work at the site.
- 4.12 MOD have two possible options for dealing with the contamination:
- Option 1** Remove contaminated soils from the various areas; or
- Option 2** Provide all available information to potential developers to allow the sources of contaminants identified to be addressed in redevelopment plans for the site.
- It is recommended that Option 2 is followed by the MOD.
- 4.13 If the site is to be redeveloped for a sensitive end-use such as housing, then there are certain areas of the site which would require a limited amount of remedial work. This would include removal and disposal at a licensed landfill of hydrocarbon contaminated soils identified by this study as detailed above. In addition some remedial measures may be required for other end uses. This may include remediation of hot spots of contaminants in areas which are to be used for the locating of service runs or building footprints.
- 4.14 If gardens or landscaped areas were to be positioned in areas where phytotoxic metals have been detected, then fill materials in such areas should be removed or covered with clean imported topsoil.
- 4.15 It is recommended that a full asbestos survey of all buildings at the site is undertaken to ensure that there are no possible sources of asbestos which have not

Conclusions and Recommendations

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continued

been identified in the site asbestos register and to assess the extent of any broken or damaged areas of asbestos sheet. During demolition, asbestos-containing materials identified should be removed by a licensed contractor according to the relevant Health and Safety Executive guidance. A full survey would allow the quantities of asbestos-containing materials to be established and therefore the costs for their removal and disposal.

Further Work

- 4.16 In order to provide costs for remedial work for the two main contaminated areas it would be necessary to undertake a further phase of investigation at RAF Upper Heyford which would fully define the areas of ground affected. Such investigations would involve the following at each of the fire practice area and weapons storage area (in the vicinity of TP124):
- excavation of up to 10 trial pits, with subsequent analysis of soils for petroleum and diesel range compounds; and,
 - production of an addendum report detailing the nature and extent of contamination in each area.

Prior to any work being undertaken in the fire practice area, Walon should be requested to clear all cars to allow ease of access to the whole area.

- 4.17 In addition to the hydrocarbon contaminated areas, the extent of the copper and zinc contaminated area adjacent to trial pits 113 and 113A should be defined either by trial pitting or by cored soil probing.
- 4.18 As part of further visits to site, monitoring and sampling for laboratory analysis could be undertaken to confirm the quality of groundwater beneath the site and that rising as springs from the site. This is important as the sampling to date was undertaken during a short period associated with the ground investigation. The results are therefore very much limited a "snap shot" of groundwater quality. In order to provide a greater degree of confidence as to the quality of the groundwater, and to assess groundwater quality under different groundwater conditions, a second set of samples should be taken. Although failure to undertake such works will not impinge upon the current site assessment, the availability of additional background groundwater quality data will further support our assessment of the groundwater prior to any re-development works on site.
- 4.19 The total cost of the additional work including production of an addendum document to this Phase Two report would be in the order of £5 000 (excluding VAT) for the groundwater and spring water sampling and £9 000 (excluding VAT) for the investigations around the fire practice area, weapons storage area and phytotoxic contamination around trial pits 113/113A.

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Appendices

Consultants Directive

1

MINISTRY OF DEFENCE

DEFENCE ESTATE ORGANISATION (WORKS)

**LAND QUALITY ASSESSMENT - PHASE TWO: INTRUSIVE
SURVEY**

Project No. 07686

CONSULTANTS DIRECTIVE

RAF UPPER HEYFORD

Client's Representative:

[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
RAF Benson
Wallingford
Oxfordshire
OX10 6AA

DEO(W) Task Officer:

[REDACTED]
Environmental Engineer
Defence Estate Organisation (Works)
Blakemore Drive
Sutton Coldfield
W Midlands
B75 7RL

Date: March 1997
DEO Project Ref: D/DEO(W)27/104/82/5
Clients Ref: [REDACTED]/6239/Pol3

LAND QUALITY ASSESSMENT - PHASE TWO: INTRUSIVE SURVEY

RAF UPPER HEYFORD

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1	BACKGROUND
5	LOCATION
6	Additional Information
7	PROJECT OBJECTIVE
8	SCOPE OF THE WORKS
	REQUIREMENTS OF THE STUDY
14	HAZARD ASSESSMENT
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A	Location Plan of Site
B	RAF Upper Heyford Phase One Reports
C	Environmental Risk Assessment: Summary Table
D	Report Standard Framework

LAND QUALITY ASSESSMENT - PHASE TWO: INTRUSIVE SURVEY

RAF Upper Heyford

BACKGROUND

1. RAF Upper Heyford is no longer required by the MOD and in order to release the site for sale the MOD needs to know more details of the land quality on the site and the health & environmental risk that any contamination may present in association with changing the use of the land.
2. MOD propose to achieve this by undertaking a phased investigation of the site as described in DWS Technical Bulletin 95/28 entitled Land Quality Assessment Management Guide.
3. A Desk Study has already been undertaken and is included at Annex B. The report comprised a desk study and reconnaissance which assessed the potential for contaminated land to exist on the site. It also recommended the further action necessary to confirm the conclusions presented within the report.
4. The next phase of the investigation aims to address the recommendations made in the Desk Study and to identify the actual extent and implications of any contamination on the RAF Upper Heyford site. This Directive initiates this second phase of the study.

LOCATION

5. RAF Upper Heyford is located at the following address:

RAF Upper Heyford

A site location plan is provided in Annex A

Additional Information

6. MOD held information pertinent to the study is available through the Site Liaison Officer and may include:-
 - RAF Upper Heyford LAND QUALITY ASSESSMENT - PHASE ONE: DESK STUDY
 - Plans, maps and technical/process drawings (all available dates).
 - Deeds and other estate records.
 - Asbestos Register
 - Existing aerial and other photographs.
 - Some records/files detailing former and current uses/activities on the site.
 - Anecdotal evidence from former and present employees.

PROJECT OBJECTIVE

7. The objectives of the study are to provide information, in the form of reports, relating to the environmental quality of the ground and groundwater conditions present on the establishment. Information should also be gathered relating to the potential for future ground contamination occurring as a result of demolition of the existing buildings. Assessment is to be made of the potential health and environmental risks at the site and the degree of confidence in the assessment. If this assessment shows that there may be a significant risk to health and safety or the environment then options for remediation of contamination should be provided.

SCOPE OF THE WORKS

8. The assessment is to consider the land and buildings on the whole of the RAF Upper Heyford site (ref the Site Plan at Annex A) and also its interaction with neighbouring land.

9. The objective is to appraise the existing information and undertake the further work necessary to produce a reliable assessment of the Land Quality and Environmental Risk at the site and how this may be affected by different types of change of use.

10. An investigation should also be carried out into contamination of buildings on the site and any health or environmental risk that may be associated with their re-use or demolition.

11. Options are to be provided for the future management of the land or building contamination on the site together with an assessment of the financial, environmental and other consequences of accepting each option. A recommended option should be identified.

12. An assessment of potential remediation requirements should be given together with cost and timescale implications of the remediation work.

13. The scope of work also includes the provision of Collateral Warranties.

REQUIREMENTS OF THE STUDY

HAZARD ASSESSMENT

14. All Land Quality Assessment intrusive investigations have the potential to reveal hazardous substances. The Consultant must therefore ensure that adequate Health and Safety safeguards are employed by his personnel at all times.

15. On military establishments there may also be a potential risk from buried ordnance. The site operates a permit to dig system and the consultant must ensure that intrusive investigation only takes place on areas certified as clear of ordnance. Even after ordnance clearance a residual risk exists and hence utmost vigilance should be employed at all times. Should anything suspicious be located all work should cease, the area be evacuated and the assistance of the Explosive Ordnance Disposal (EOD) team be enlisted.

Known Hazards

16. Not used.

ASSESSMENT MANAGEMENT REQUIREMENTS

17. The Term Consultant for the assessment is to act in the role of Lead Consultant and as such is required to employ and supervise the specialist sub-contractors required for the study. The Lead Consultant is also ultimately responsible for all technical aspects of the site investigation design, supervision, interpretation and recommendations arising from this study.

Collateral Warranty

18. The Land Quality Assessment and Statement (LQA and LQS) produced under this directive will be used by MOD's selling agent and may be relied upon by purchasers. It will therefore be necessary for the Lead Consultant and all specialist sub-consultants, contractors and laboratories employed to provide Collateral Warranties regarding their professional work if required by purchasers or their funders. All parties involved must therefore indicate a willingness to provide collateral warranties if required at a future date. The Warranties must be assignable to purchasers or their funders as required by MOD.

Specialist Sub - Consultants

19. Radiological contamination assessments should be undertaken in close co-operation with the Defence Radiological Protection Service (DRPS). The Consultant should approach DRPS to consult and arrange this

liaison. Any work undertaken by DRPS should be incorporated into the LQA and completed to the satisfaction of the Consultant with the intention of it being covered by the Consultants collateral warranty.

Ground Investigation Contractor

20. At least three competitive tenders are to be obtained for the contracting aspects of the site investigation. Sub-contractors must be experienced in the appropriate field of environmental site investigation and preferably should work to accredited quality assurance standards. The Lead Consultant should produce a short report on the tender exercise in order to identify the Best Value Tender. Task Officer approval should be obtained before the Specialist Sub-Contractor is engaged.

Laboratory Analysis

21. At least three competitive tenders should be obtained for the laboratory analysis aspects of the assessment. Laboratories must work to quality assured standards and all laboratories asked to quote rates must have extensive NAMAS accreditation for relevant analytical procedures. Laboratories must also participate in the CONTEST and/or the WRc AQUACHECK schemes and the Lead Consultant should ensure that tendering laboratories have performed satisfactorily under these schemes. The Lead Consultant should produce a short report on the tender exercise in order to identify the Best Value Tender. This report should include information on the CONTEST performance of the laboratories. Task Officer approval should be obtained before the specialist laboratory is engaged.

RECONNAISSANCE

22. An initial walk over reconnaissance of the site should be undertaken by the Consultant in order to gain an understanding of the establishment and all matters pertaining to the Land Quality Assessment This is likely to include an appraisal of the site infrastructure, drainage, services and site operating procedures past and present. Any environmental issues requiring urgent attention should be reported immediately.

23. Information should also be gathered relating to the potential for future ground contamination occurring as a result of any demolition or re-furbishment of the existing buildings.

DOCUMENT REVIEW

24. The Consultant should review the existing Desk Study together with any further information which is available. He should undertake any further desk investigation he considers necessary and if required shall identify (via the Site Liaison Officer) and interview persons with long standing knowledge of the site. Consideration should be given to the recommendations of the Desk Study report.

INTRUSIVE INVESTIGATION

25. The Consultant should propose his preferred excavation and sampling regime for the site which should employ industry's best practice for investigation, sample extraction and preservation.

26. At all times the objective is to undertake any investigation on a logical and rational basis in order to achieve both economy in the expenditure of resources and confidence in the end result.

27. Information collected should include geotechnical soil properties relevant to contamination transport and remediation effectiveness.

28. During the course of the investigation the consultant should make reactive adjustments to the investigation process in the light of information obtained during the investigation. Written approval of the DEO(W) Task Officer to either expand or reduce the scope of the investigation shall however be obtained prior to any changes to the overall scope of works.

29. The Consultant (with his Specialist Sub-Consultants where appropriate) should supervise and administer all the work of his Contractors and should provide a competent Environmental Engineer on site at all times during the physical investigation in order to supervise the works.

30. The Consultant shall ensure that all disturbance to the ground caused by himself or the Contractor is made good at the earliest opportunity.

PRESENTATION OF INFORMATION

31. Information from the Investigation should be provided by way of three separate reports . The first report; The Land Quality Assessment (LQA) Factual Report, should comprise the factual information and other evidence gathered relating to the environmental quality of the site. The second report; The LQA Interpretive Report, should comprise interpretation and opinions on liability, costs, remediation and disposal options. It should include the Land Quality Statement, the Environmental Risk Assessment and an Option Study into future handling of the site. The third report; The Land Quality Statement, should comprise a short non-technical summary of the environmental condition of the site.

FACTUAL REPORT

32. The factual report should comprise the following minimum information:

- * Summary of factual elements of the Desk Study Assessment
- * A description of the work carried out during the intrusive site investigation.
- * A coloured Site Plan identifying the location of all exploratory work and any other pertinent information.
- * The Environmental Engineer's signed logs of exploratory excavations and boreholes etc. with accompanying level information and photographs where appropriate. Detail and presentation of logs should conform with BS 5930:1981.
- * Details of the samples taken and the techniques used.
- * In situ test results.
- * Presentation of laboratory results including information on preservation methods and analytical procedures used and the qualitative and quantitative results.
- * Full details of the quality assurance procedures employed.

INTERPRETIVE REPORT

33. The interpretive report should aim to develop a contamination model of the site. This should identify and where possible quantify the contaminated and uncontaminated areas of the site. Information should be shown on plans and sections etc. and where applicable should include contamination concentration isolines.

Environmental Risk Assessment

34. The Consultant should incorporate into the Land Quality Assessment a Health and Environmental Risk Assessment. This should consider individual hazards pathways and receptors for different types of after use. The mobility of contaminants should be addressed together with the acceptability of the contamination at source and at sensitive receptors. The key objective is to identify issues which may lead to significant harm or a significant possibility of such harm or pollution or likely pollution of controlled waters. Hence all areas of potential contamination should be prioritised in terms of health and environmental risk. This information should be shown on a clear plan and related to a summary table as outlined in Annex C.

35. Not used.

36. Where the Health or Environmental Risk is considered to be high then recommendations should be made regarding any remediation required to meet different types of future land use. This should include outline costs and timescales of any remediation for each scenario. Remediation options should include consideration of source removal, pathway disruption or receptor protection. The consultant should take into consideration the most likely future use of the site.

37. Costs should be estimated in sufficient detail to provide a reliable basis for identifying a recommended option. This should include a financial risk assessment and whole life costing.

Environmental Impact of Remediation

38. The Environmental Impact of remediation options should be addressed and an indication of the Best Practicable Environmental Option given.

Conclusions

39. The report should conclude with discussion and recommendations relating to the land quality issues and the most appropriate way to release the site from MOD ownership.

Financial Appraisal

40. A reliable Order of Cost Estimate (OCE) is required for each option, and shall be carried out in accordance with DWS Technical Bulletin 6/94, entitled Order of Cost Estimates, dated February 1994. Costs are to be current quarter price levels without inflation and the relevant cost index and its source should be quoted. VAT and fees should be itemised clearly. The OCE should include a Financial Risk Analysis, carried out and presented in accordance with DWS Technical Bulletin 7/94, entitled Estimating using Risk Analysis, dated February 1994. Costs for both "Average Risk" and "Maximum Likely Risk" cases are required and full details of the risks and their individual contribution to the risk element shall be identified in the Report.

LAND QUALITY STATEMENT

41. The model developed above should be used to form the basis for an environmental Land Quality Statement. This statement should summarise in layman's terms the environmental condition of the site, its suitability for re-use and the effects of any contamination on development potential. It should also include a brief summary of the sources of information together with a site boundary plan and other useful summary plans. The LQS should also form the basis for an executive summary within the main Interpretive report.

LIMITATIONS AND STANDARDS

CONSTRAINTS

42. The following constraints must be taken into consideration:-
- a. The site operates a permit to dig system which must be adhered to at all times.
 - b. A photographic pass will be needed before site work commences.
 - c. Prior to any work commencing on site, a Method Statement is to be provided for approval by the Client, in consultation with Defence Estate Organisation (Works). Health and safety risk assessments are to be completed in advance of all stages of the work.
 - d. Any investigations must be undertaken at such times and in such a manner as to avoid disruption to routine operation and maintenance of the Site.
 - e. Although the survey will take place mainly within the establishments boundaries it shall be undertaken in such a manner as to avoid concern to the general public. In the event of any approach by the press or broadcasting media they are to be referred immediately to the Clients Representative and no comment whatsoever shall be made.

CONTACT WITH THE ENVIRONMENT AGENCY

43. Any contact with the Environment Agency must be made only after receiving the written approval of the Water and Environmental Engineering Branch of Defence Estate Organisation (Works).

ENVIRONMENTAL IMPACT OF INTRUSIVE INVESTIGATIONS

44. It is MOD policy to minimise the adverse environmental affects of its projects and operations. Recycled or recyclable products are to be used whenever feasible.

45. All work undertaken in relation to this project shall employ the Best Available Techniques Not Entailing Excessive Cost to minimise the environmental impact of the project.

46. In particular, the Consultant shall ensure that:

- * Intrusive investigations are only undertaken using methods which do not create pollution transfer pathways.
- * The excavation of trial holes, boreholes or other excavations do not risk contamination of the groundwater regime.
- * Polluted soil arisings and water emanating from boreholes or trial pits is disposed of without causing environmental damage and in accordance with the waste management duty of care.
- * Noise from plant is kept within acceptable limits.
- * The emission of pollutants, harmful radiation or ozone depleting chemicals is minimised.
- * The use of energy is minimised.
- * Products which contribute to the destruction of rain forests or endangered wildlife are not used.
- * The use of noxious substances, especially DOE "Red List" and EC list 1 substances is minimised.

47. The specific written authorisation of the Project Sponsor is required before use or emission of any product, pollutant or substance which affects any of the above clauses.

HEALTH AND SAFETY

48. This Intrusive Site Investigation is to be undertaken in accordance with all relevant Health and Safety Legislation.

49. In cases where the Construction (Design and Management) Regulations 1994 are applicable. The Lead Consultant shall undertake the roles of both "Planning Supervisor" and "Principal Contractor".

50. All members of the study team are to be suitably briefed and a written Method Statement and risk assessment shall be agreed before any site work is undertaken. All MOD regulations and instructions concerning safe working procedures shall be rigorously adhered to. This is likely to include a permit to dig system.

51. Recommendations made concerning remediation shall comply fully with all relevant Health and Safety Legislation.

52. The Study shall identify any special health and safety hazards which should be considered when operating on the Site.

DELIVERABLES

TIMESCALE

53. 4no copies of the First Draft Land Quality Assessment Factual, Interpretive and Land Quality Statement reports are to be delivered by 30 July 1997 for discussion at a meeting to be arranged. Interim reports are also to be provided as and when significant information becomes available. The target for issue of the final Land Quality Assessment Reports is 31 August 1997.

DISTRIBUTION

54. 8 no. copies of the Final Reports for each site are to be delivered to the Task Officer for distribution.

FORMAT OF STUDY REPORT

55. The format of the report for this Contaminated Land Investigation Desk Study is to conform with the DEO(W) "Standard Framework", attached at Annex D. When the DEO(W) Task Officer is satisfied that this commission has been completed, the Report is to be signed by both the Consultant and the Task Officer.

ADMINISTRATION OF THE STUDY

SECURITY

56. This assessment is classified as RESTRICTED - COMMERCIAL. The Factual Report and the Land Quality Statement are however unrestricted but should only be discussed with staff nominated by the Client's Representative. Each page of the Interpretive report should be marked RESTRICTED - COMMERCIAL.

57. The names of individual MOD staff connected with this project should not appear within the body of the report but should instead be provided in a letter to accompany the report. It is acceptable for post titles to be mentioned within the main text of the report.

ACCESS

58. Entry to RAF Upper Heyford is strictly controlled, and all personnel requiring access must be in possession of MOD Security Clearance.

59. When the Consultant wishes to visit the Site all study team members are required to obtain visitor's passes for each visit, notwithstanding any security clearances already held, and to give prior notice of intended visits to the Site Liaison Officer.

POINTS OF CONTACT

60. Details of the MOD staff connected with this project, their duties and their responsibilities are provided in an accompanying letter.

LOCATION PLAN FOR RAF UPPER HEYFORD

RAF UPPER HEYFORD - LAND QUALITY ASSESSMENT PHASE ONE REPORTS

LAND QUALITY ASSESSMENT: ENVIRONMENTAL RISK ASSESSMENT: SUMMARY TABLE

AREA / BUILDING	POTENTIAL POLLUTANT	LIKELIHOOD OF POLLUTANT OCCURRING	ASSOCIATED HAZARD	POTENTIAL RECEPTORS	POTENTIAL PATHWAYS TO RECEPTOR	POTENTIAL CONSEQUENCES OF HAZARD-RECEPTOR LINKAGE	LIKELIHOOD OF HAZARD-RECEPTOR LINKAGE	SIGNIFICANCE
		Indication of probability, volume, concentration, percentage area etc.	Specific to pollutant	Specific to pollutant (may vary for different land use options)	Specific to pollutant (may vary for different land use options)	e.g. health, safety, environmental effects. Time & Cost implications etc.	Certain High Medium Low Very Low Negligible	Combination of potential consequences and likelihood of occurrence

REPORT - STANDARD FRAMEWORK1. Content

- a. Terms of Reference A copy of the Client's written instruction to DEO(W) to carry out an Investigatory Study should be included, along with the scope of the Study.
- b. Background Brief details of the site, or sites, giving location(s), MOD. unit, any environmental constraints, including details of any historical listings, any anticipated geotechnical problems and any operational, time or security needs stipulated by the Client. Where the aspects can be more clearly shown in the drawn form then drawings and/or diagrams should be included.
- c. Summary of Options A very brief comparison of advantages and disadvantages of each option considered presented on one page, including the cost.
- d. Conclusion and Recommendation Giving clear cut recommendations. the option preferred and the operational and economic advantages (including timescales) that justify the recommendation(s).
- e. Options Each option dealt with in depth, including the costs and the contractual approach (if any) inherent in each option. Drawings sufficient to explain the option(s) to those unfamiliar with the site should be included.

2. Face Sheet

This should contain:

- a. DEO(W) title "DEFENCE ESTATE ORGANISATION (WORKS)" centred at the top of the sheet.
- b. Name and address of the relevant DEO(W) office in the bottom left hand corner of the sheet.
- c. Title as shown on the Directive in the centre of the sheet, with the Project No immediately below.
- d. The legend "Prepared by (the Consultant's name) for the Ministry of Defence, Defence Estate Organisation (Works), under commission (number)" in the bottom right hand corner of the sheet along with the month and year in which the Study was produced.

3. Size

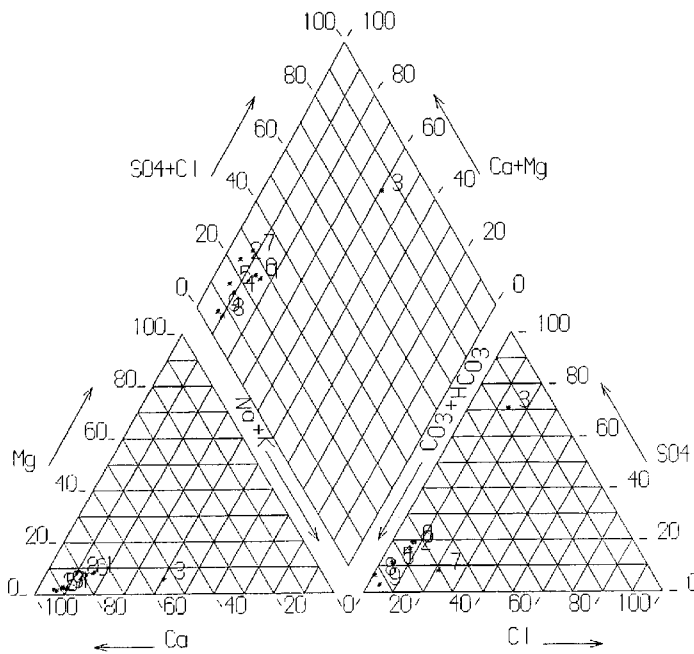
This should always be A4 vertical format, but may contain folded A3 or larger sized sheets in clear A4 pocket inserts in the case of the Summary of Options and drawings.

**Piper Trilinear Diagrams for Springs and
Groundwaters**

2

#	Date	Zone	Well I.D.
	DDMMYY		

1	060597	1,3,5	BH1A
2	060597	1,3,5	BH1B
3	060597	1,4,9	BH2
4	060597	1,3,5	BH3A
5	060597	1,3,5	BH3B
6	060597	1,3,5	BH4
7	060597	1,3,5	BH5
8	060597	1,3,5	BH6
9	060597	1,3,5	BH7



KEY:

SCALE	CAN	MD3333A
DRAWN	DWG FILE	PPH
CHECKED	DATE	JUNE 1997

CLIENT
DEFENCE ESTATE ORGANISATION

CONSULTANTS

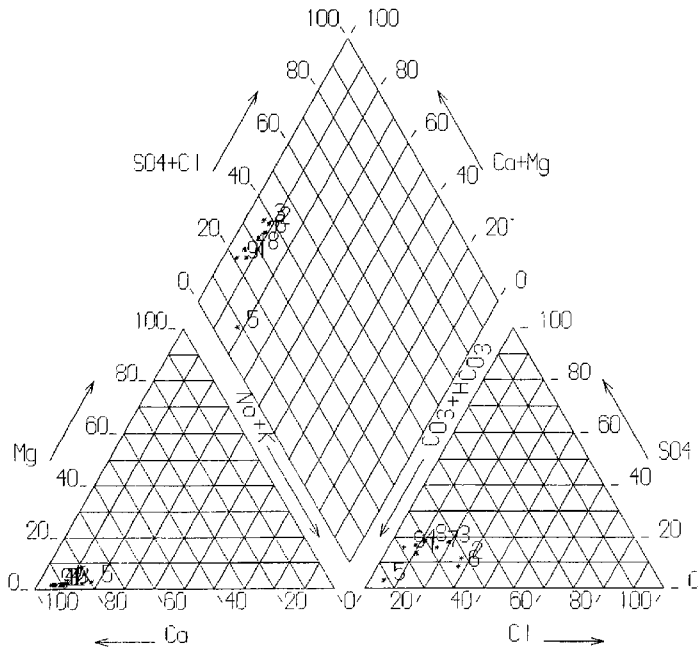
Aspirwall & company
CONSULTANTS IN ENVIRONMENTAL MANAGEMENT

PROJECT
RAF UPPER HEYFORD - PHASE TWO INVESTIGATIONS
DRAWING

APPENDIX 2A
GROUNDWATER QUALITY - BOREHOLES


Date Zone Well I.D.
DDMMYY

1	060597	1,3,5	SPRING B
2	060597	1,3,5	SPRING C2
3	060597	1,3,5	SPRING D
4	060597	1,3,5	SPRING G1
5	060597	1,3,5	SPRING I
6	060597	1,3,5	SPRING L
7	060597	1,3,5	SPRING M
8	060597	1,3,5	SPRING P1
9	060597	1,3,5	SPRING R2



KEY:

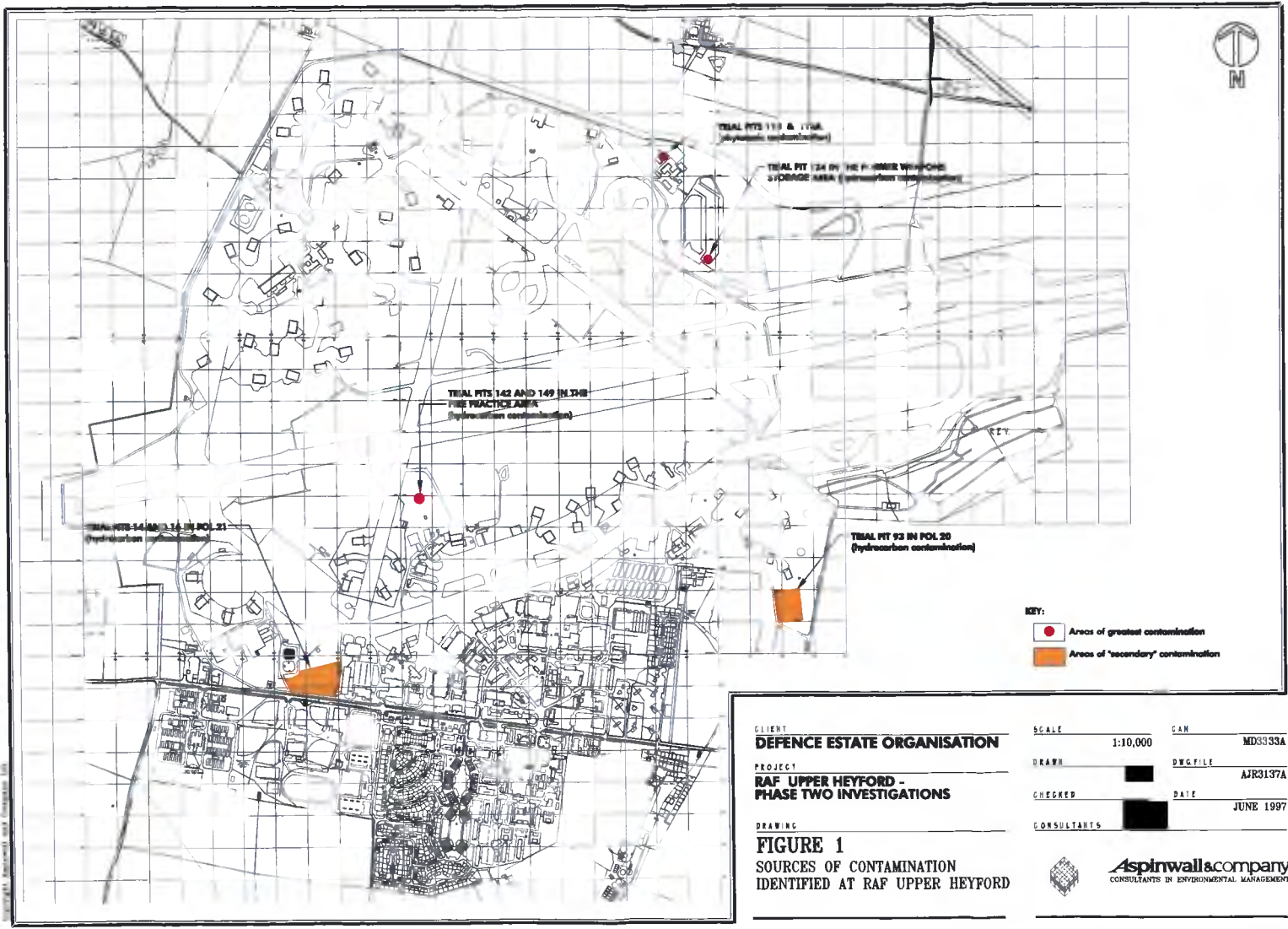
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JUNE 1997

CLIENT _____
DEFENCE ESTATE ORGANISATION
CONSULTANTS _____
 **Aspirinwall & company**
CONSULTANTS IN ENVIRONMENTAL MANAGEMENT

PROJECT _____
RAF UPPER HEYFORD - PHASE TWO INVESTIGATIONS
DRAWING _____
APPENDIX 2B
GROUNDWATER QUALITY - SPRINGS

**Sources of Contamination Identified at RAF
Upper Heyford**

1



CLIENT
DEFENCE ESTATE ORGANISATION

PROJECT
**RAF UPPER HEYFORD -
 PHASE TWO INVESTIGATIONS**

DRAWING
**FIGURE 1
 SOURCES OF CONTAMINATION
 IDENTIFIED AT RAF UPPER HEYFORD**

SCALE 1:10,000
 DRAWN [redacted]
 CHECKED [redacted]
 CONSULTANTS [redacted]

CAN MD3333A
 DWG FILE AJR3137A
 DATE JUNE 1997

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 CONSULTANTS IN ENVIRONMENTAL MANAGEMENT

Aspinwall & company Ltd