TECHNICAL ASPECTS OF SITE INVESTIGATION.
VOLUME I (OF II)
OVERVIEW



Research and Development

Technical Report
P5-065/TR

ENVIRONMENT AGENCY

Technical Aspects of Site Investigation. Vol I (of II) Overview

R&D Technical Report P5-065/TR

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FOREWORD

This document is one of a range of guidance documents published (and in preparation) by the Environment Agency. Some of these are specific to the new contaminated land regime under Part IIA of the Environmental Protection Act 1990 (EPA 1990), and others are of a more generic nature and intended as guidance in a range of contexts. This document is the generic type and should cover any occasion where guidance on technical issues relating to site investigation is needed in relation to land contamination. It is a **supporting technical guidance document** within the framework of guidance being produced for land contamination (see below and Figure 1). An outline of where the document fits within this hierarchy is provided below and in Figure 1.

The Model Procedures for the Management of Contaminated Land (2000 in preparation) have been developed for the Department of the Environment, Transport and the Regions, and the Environment Agency. These incorporate existing good technical practice, including the use of risk assessment and risk management techniques, into a systematic process for making decisions about and taking appropriate action to deal with contamination. The approach contained in the Model Procedures is consistent with UK policy and legislative requirements. Therefore the model procedures set out a recommended good practice approach to managing land where contamination is, or may be, an issue.

The model procedures are part of a hierarchy of documents that provides a systematic approach to managing ground and groundwater contamination. The guidance within the documents increases in complexity and technical detail within each tier of the hierarchy. The four main tiers are:

1. **the process for managing ground and groundwater contamination** describing the overall approach and decision-making process within the UK legislative and policy frameworks;

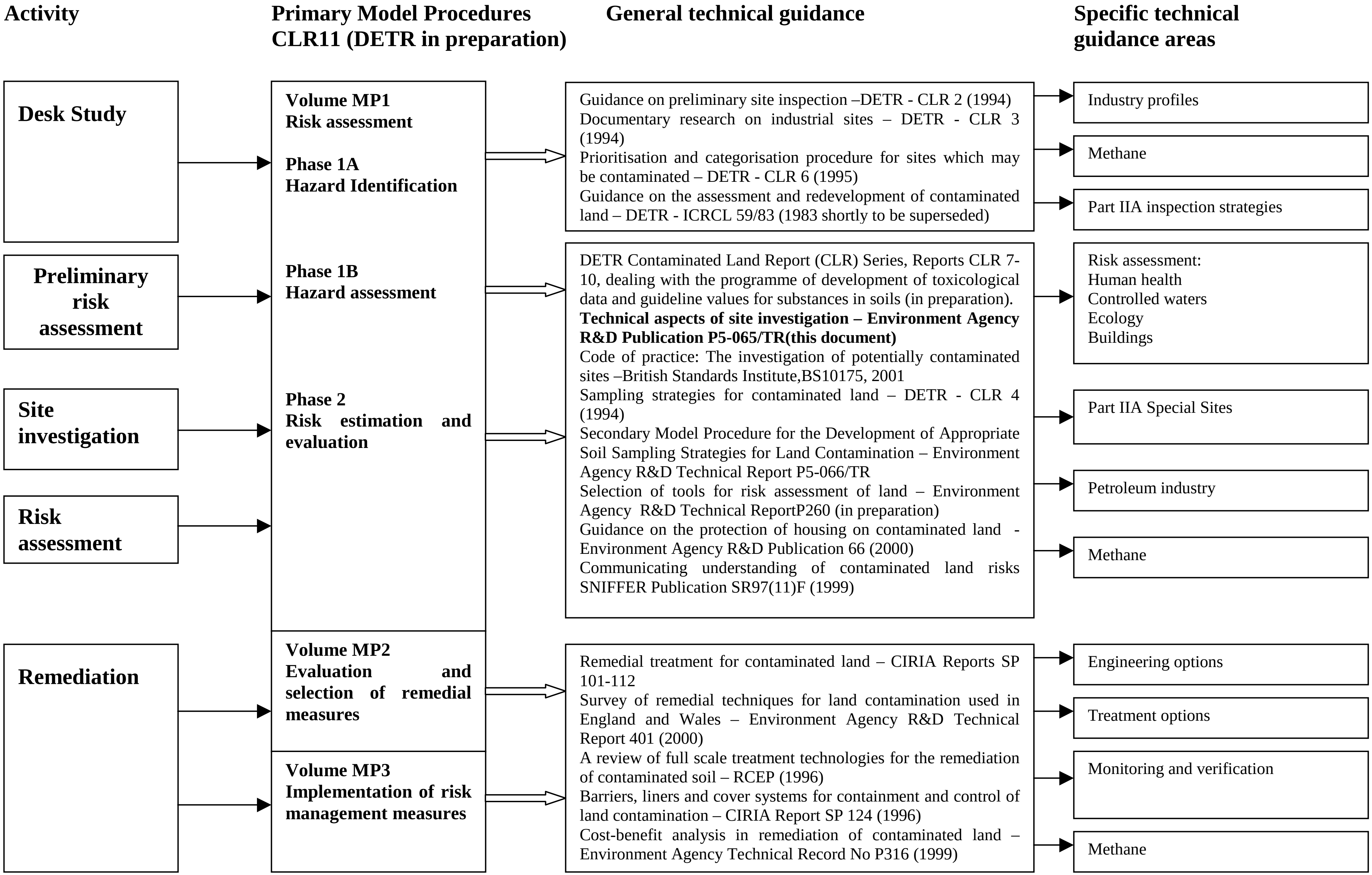
2. **primary model procedures** that describe the procedural approach for the main technical activities involved in managing land contamination, namely:
    - *risk assessment;*
    - *evaluation and selection of remedial measures;*
    - *implementation of risk management measures;*

3. **secondary model procedures** that describe the procedural approach for specific activities that support, or are part of, the three main technical activities covered by the primary procedures;

4. **supporting technical guidance** that describe technical aspects for specific activities (or sets of activities) that are part of the activities covered by the primary and secondary procedures.

This document is **supporting technical guidance** that is expected to be relevant to all parties involved in the assessment and management of contaminated sites, and in a variety of contexts. Users should establish a clear understanding of the purpose, context and requirements of any site investigation before using this guidance.

Figure 1 - Where this document fits in the overall scope of guidance on land contamination



1. INTRODUCTION

1.1 Intent and scope of the technical guidance document

This two-volume document provides technical guidance on the investigation of contaminated sites for use in a wide variety of contexts, including:

- Part IIA of the EPA 1990;
- the planning regime;
- the Pollution Prevention and Control (PPC) regime; and
- purchase/sale of land.

1.2 Target audience

The technical guidance document is intended to provide guidance principally to Environment Agency staff who are involved in the management of site investigation projects. The readership is expected to be wide ranging, including:

- Environment Agency and local authority officers;
- those who fall under the regulatory regime and need to understand the Environment Agency's approach and requirements in relation to the investigation of contaminated sites; and
- consultants and contractors engaged in site investigation projects.

The document is intended, primarily, to provide the target audience with the specialist technical information required when acting in a project management capacity dealing with investigation of contaminated sites. The variation in the level of existing expertise of the target audience has been recognised.

The document should also assist in the development of a nationally consistent approach to site investigation projects in which the Environment Agency is involved by setting out what the Environment Agency believes to be the key issues relating to good site investigation practice.

In particular, the report serves as a supplement to, and should be used in conjunction with, other key guidance documents including:

- Model Procedures for the Management of Contaminated Land (2000 in preparation);
- Methodology for the derivation of remedial targets for soil and groundwater to protect water resources. Environment Agency R&D Publication 20;

- Environment Agency National Sampling Procedures Manual – Quality Management System for Environmental Sampling (internal Environment Agency guidance);

- British Standard BS 10175:2001 Code of Practice for the Investigation of Potentially Contaminated Sites;

- British Standard BS 5930:1999 Code of Practice for Site Investigations;

- Construction Industry Research and Information Association. Remedial treatment for contaminated land. Special Publication SP101-112 (Volumes I to XII). CIRIA (London), 1996.

1.3 What is and is not included in the technical guidance document

There is a considerable depth and range of published literature produced in respect of investigation of contaminated sites, both within the UK and internationally. This includes a broad range of technical guidance documents prepared by the Environment Agency for use in the context of Part IIA, EPA 1990. The technical guidance document is not intended to duplicate the other relevant guidance thus, it cross-refers to this where appropriate. A list of the most relevant references and sources of further information is included in Volume II of this document.

The technical guidance document includes an overview of good practice, technical information on the many individual investigation activities and provides a standard format for a site investigation report. The design/strategy aspects of site investigation are not dealt with in any detail within this document.

The completed document provides the benefit of collective past experiences combined with 'state of the art' technical developments. It is relevant to the investigation of different contaminant types in ground and groundwater on all sites where contamination investigation is an issue.

This document addresses site investigation as required in Phase 1a/1b and 2 of the Model Procedures, where the objectives of the investigation include:

- monitoring performance/effectiveness of remediation;

- verification testing; and

- site investigation to develop detailed remediation strategies or pilot treatments.

Further guidance can be obtained from:

- Guidance on Monitoring the Operations and Post-remediation Performance of Remedial Treatments for Land Contamination (in preparation for the Environment Agency);

- Guidance on the Assessment and Monitoring of Natural Attenuation of Contaminants in Groundwater, Environment Agency R&D Publication 95, 2000;

- Verification of Remedial Techniques (in preparation for the Environment Agency).

1.4 How to use the supporting technical guidance document

The information is arranged and presented so that it can easily be drawn upon when using other relevant guidance. It is split into two volumes:

- Volume I — The main text with links to text supplements in Volume II;

- Volume II — Text supplements that support Volume I (e.g. checklists, tables of information, figures, photographs, technical information sheets, box items, flowcharts, a standard reporting format for site investigations etc).

Volume I begins with an overview of good practice and further sections describe key issues in relation to the principal site investigation activities. The different chapters cross-refer to others within the technical guidance document where relevant. The format adopted aims to assist the reader in the practical use of the technical information by the strong links between the text in Volume I and the supplementary material in Volume II.

2. GOOD PRACTICE OVERVIEW

2.1 Introduction

This chapter provides a general overview of what is considered to represent current good practice in respect to the investigation of contaminated sites. Given the extensive detailed guidance that exists relating to the design and implementation of investigations into ground and groundwater investigations, the intention of this chapter is to summarise the key issues and to provide the reader with clear references to sources of more detailed guidance.

The reader should also be aware that the primary topic addressed in this document is intended to be the implementation of site investigations on contaminated sites rather than their design.

2.2 Key references

Key references are:

- Department of the Environment, Transport and the Regions **Model Procedures for the Management of Contaminated Land** (2000 in preparation) CLR 11 prepared by Stanger Science and Environment in association with Monitor Environmental Consultants Limited;

- Department of the Environment, Transport and the Regions**. Overview of Guidance on the Assessment of Contaminated Land** CLR 7 prepared by Chrisalis Environmental Consulting (in preparation);

- Harris M R and Herbert S M**. Contaminated Land: Investigation, Assessment and Remediation.** (1994) ICE Design Guide, Thomas Telford (London);

- Construction Industry Research and Information Association**. Remedial Treatment for Contaminated Land.** Volumes 1 to 12. CIRIA (London);

- British Standard BS 10175:2001 **Code of Practice for the Investigation of Potentially Contaminated Sites**.

Further reference material is listed in:

Text Supplement 2.11 "Further Reading" in Volume II

2.3 Approach and Objectives

In simple terms the approach which is adopted to the investigation of a contaminated site should reflect the dictionary definition of 'investigation':

- *to search or enquire into with care and accuracy.*

(Source: Chambers Concise Dictionary)

Consequently an investigation should never be viewed by the site staff involved as simply the need for recording mechanically the findings from a predetermined number of exploratory holes the design of which has been someone else's responsibility. Rather, good investigation staff should be constantly aware of the possible significance of what they are encountering within the ground and should make conscious decisions on the need to amend the investigation design to capture as much relevant information as possible.

Clear objectives need to be established for the investigation at the outset which the investigation should then aim to fulfil in an appropriate and reasonable manner. The objectives of an investigation can vary widely depending on the context. Some examples of investigation objectives are presented in Table 2.1.

2.4 Risk based framework for site investigation

The appropriate identification and management of the range of possible risks associated with contaminated sites can only be achieved once the hazards present on any site have been characterised sufficiently together with the physical and environmental context of the site. The quality and appropriateness of the site investigation is fundamental to this process. If undertaken competently, site investigation should provide the data for making appropriate judgements on both the range and significance of possible risks together with the measures that should be implemented to manage those risks effectively. Conversely, inappropriate or badly implemented site investigation, can result in a misunderstanding of the site conditions leading to a flawed assessment of risks and the selection of an inappropriate risk management strategy.

The generic approach to site assessment is set out in the Model Procedures for the Management of Contaminated Land (2000 in preparation). This document describes an approach based on the development and refinement of the conceptual model for a site as progress is made through the various stages of risk assessment. As described in greater detail within the Model Procedures the conceptual model should aim to identify all of the relevant pollutant linkages associated with the site. As the assessment progresses from the initial desk study stage to intrusive investigations the conceptual model should be reviewed and refined to provide a greater understanding of the conditions at the site. The requirements of the risk assessment process and the development of the conceptual model should therefore drive the data collection needs for the site.

The main phases of investigations together with a summary of the typical objectives and activities involved are summarised below in Table 2.1.

Table 2.1 - Principal investigation phases, typical objectives and activities

Phase of investigation	Objectives given in Model Procedures	Typical activities
Preliminary Investigation *(Model Procedures Phase 1a)*	To obtain sufficient information on the site to gain a preliminary understanding of its likely risk characteristics. To develop an initial conceptual model of the site.	Desk study. Site reconnaissance. Formulation of initial conceptual model (refer to Model Procedures for details).
Exploratory Investigation *(Model Procedures Phase 1b)*	To refine the conceptual model developed during Phase 1a (primarily by confirming the likelihood of pollutant linkages) and to provide a preliminary indication of potential chronic or short term risks to health or the environment To refine design of detailed investigation (including safety and environmental protection requirements).	Review existing information and carry out additional desk based research. Preliminary/limited ground investigation sampling and analysis. Refine conceptual model (refer to Model Procedures for details).
Main Investigations *(Model Procedures Phase 2)*	To provide sufficient information on which to base an estimate of risks posed by the site and evaluate the acceptability of those risks. To test and REFINE the conceptual model. To enable subsequent risk assessment and remediation design work to be undertaken. To obtain additional information needed to support risk assessment or remediation design work. To assess performance of remedial action.	Comprehensive investigation/sampling and analysis. Can include both intrusive and non-intrusive activities. Refine conceptual model (refer to Model Procedures for details). Further targeted investigations. Investigation and monitoring over appropriate time period.

2.5 Planning an investigation

2.5.1 Introduction

This section deals with the issues that should be addressed during the planning stage of a site investigation of a contaminated site. Effective planning of an investigation is essential to obtain the right information to assist in future decision making and to use resources in the most efficient manner. Considerable costs can be incurred in undertaking site investigations, hence the planning stage will need to consider the commercial as well as technical aspects to provide a cost-effective investigation.

Within this section the question ‘why is an investigation required?’ is examined followed by a summary of the main issues which should be considered during the planning stage. These are divided into those major issues which are likely to be central to the implementation stage e.g. selection of methods and those which may be relevant considerations in certain circumstances e.g. the need to consider ecological or archaeological issues.

2.5.2 Why is an investigation required?

Through the site investigation process a considerable amount of data relating to the site conditions will usually be generated. However, site investigation should under no circumstances be viewed solely as a data collection exercise and should always be aimed at fulfilling specific objectives (see Table 2.1). Principal objectives will frequently include the needs of the risk assessment process and the formulation or refinement of the conceptual model for the site.

Site investigation should be viewed essentially as a interim stage towards being able to answer specific questions about a site with a sufficient level of confidence. Depending on the circumstances involved, the questions that need to be answered will vary. However, whatever the circumstances in which the site investigation is to be undertaken, a clear understanding of why it is required and hence what type, quantity and quality of information is needed should always be established. Some possible questions that could trigger the need to investigate a potentially contaminated site are given in Text Box 2.1.

Text Box 2.1

Why is an investigation required?
Selected examples of common questions that may prompt site investigation

- What are the possible environmental liabilities associated with the site?
- Does the site fall within the statutory definition of contaminated land as contained in Part IIA of the Environmental Protection Act 1990 or constitute a liability under other regulations (e.g. works notices)?
- Is a Site Report needed to define baseline conditions as part of an IPPC application?
- Is information on land contamination needed to support an application to surrender a Waste Management Licence?
- Is the site likely to cause or currently be causing contamination of neighbouring properties?
- What is the likely value of the site?
- Is the site likely to be a good investment?
- Is the site suitable for its current use?
- Is there enough information to support a planning application or environmental statement?
- What, if any, are the ground contamination constraints for a specific type of development/reuse?
- What remedial measures are likely to be needed and how much will they cost?
- How can the performance of a remediation project be demonstrated?

2.5.3 Major issues to be considered

Summary and checklist

The key issues that need to be considered during the planning of a site investigation are summarised below in Checklist 2.1 below (for completeness this checklist is also included in Volume II). Additional detail on each of these aspects is given later in the text. The checklist provides a series of references to the relevant parts of the text.

Checklist 2.1 – Investigation planning – major issues

Issues	Tick	For more detail see
Objectives of the investigation		Chapter 2
Applicability of investigation techniques?		Chapter 4
Health and safety (investigation staff, other workers, neighbours)?		Chapter 11
Environmental impacts (water pollution, dust, vapours, waste disposal etc.)?		Chapter 12
Communications and emergency plans?		Chapter 11
Sample type and quality requirements		Chapter 5
Analytical requirements		Chapter 8
Level of confidence required		Chapters 2&8
Integration with other data needs (e.g. geotechnical)		Chapter 10
Programme (How much time is needed? How much is available?)		Chapter 4
Costs/budget available?		Not covered
Access for investigation equipment?		Chapter 4
Site ownership?		Not covered
Consents/permits required?		Chapter 13
Availability of water and power supplies?		Not covered
Below or above ground services?		Chapter 10
Presence of obstructions?		Chapter 10
Site operational constraints?		Chapter 13
Note: This checklist is also included in Volume II as Text Supplement 2.1		

2.5.4 Additional issues to be considered

Additional issues that may need to be considered, or considered in greater detail during the planning stage of an investigation depending on the individual site circumstances are presented below in Checklist 2.2 (for completeness this checklist is also included in Volume II). Additional detail on each of these aspects is given later in the text. The checklist provides a series of references to the relevant parts of the text.

Checklist 2.2 – Investigation planning – additional issues

Issues	Tick	For more detail see
Controlled Waters (surface, groundwater, coastal)		Chapter 12
Ecology		Chapter 12
Archaeology		Chapter 12
Topographic Survey Considerations		Chapter 9
Audit Trails and Record Keeping		Chapter 2
Special Reinstatement Requirements		Not covered
Note: This checklist is also included in Volume II as text Supplement 2.2		

2.5.5 Investigation design

A suitably experienced and competent specialist (see section 2.9 for details) should undertake the detailed design of site investigations. The main aspects that should usually be considered in the design process are listed in:

Text Supplement 2.3 "Investigation Design Checklist" in Volume II

2.6 Phasing of investigations

To provide the most efficient use of resources, it is usually preferable to phase site investigations. Adopting a phased approach should have the following advantages:

- investigation priorities can be established and refined;
- investigations can target any areas of concern that have been identified through development of the conceptual model and earlier phases of investigation;
- safe working practices can benefit from the results of earlier investigations;
- environmental protection requirements can be established with greater certainty;
- cost effectiveness can be maximised.

2.7 Preliminary investigations

This section covers the preliminary stages of site investigations i.e.:

- **desk study**; and
- **site reconnaissance**.

A desk study and a site reconnaissance should always be undertaken prior to the start of any intrusive investigations. Together, these should be able to provide essential information relating to both:

- the design of the intrusive investigation; and
- health, safety and environmental protection requirements.

Detailed information and guidance on how to undertake a desk study and site reconnaissance of a potentially contaminated site are provided in a number of published documents including:

- Department of the Environment, Transport and the Regions. Model Procedures for the Management of Contaminated Land (2000 in preparation);
- Department of the Environment (1994) CLR2, Guidance on preliminary site inspection of contaminated land. Report by Applied Environmental Research Centre Ltd. Volumes 1 and 2;
- Department of the Environment (1994) CLR3, Documentary Research on Industrial Sites. Report by RPS Group.
- British Standards Institution Code of Practice for Site Investigations. BS5930: 1999;
- British Standard BS 10175:2001 Code of Practice for the Investigation of Potentially Contaminated Sites;
- CIRIA Special Publication 103, Remedial Treatment of Contaminated Land: Site Investigation and Assessment. CIRIA 1995;

Information on the potential contamination that may be associated with particular industrial processes is contained in the series of Industry Profiles published by the former DoE (now DETR) in 1995.

2.7.1 Desk study

A desk study is a very important stage of site assessment as, properly carried out, it will provide an initial understanding of a site's risk characteristics. A summary of the sources of information that should be accessed in a desk study is presented in:

Text Supplement 2.4 “Summary of Desk Study Information Sources” in Volume II

The target information that should aim to be collected during a desk study is presented below in Table 2.2. Not all of this information will always be available depending on the specific circumstances of each study.

Table 2.2 - Typical target information available from a desk study

Item of information	**Examples**
Site location	Address, location plan (with scale and orientation) and OS grid reference
Site layout (as built both current and historic)	Plant components, building structures, drainage systems, process areas, material storage areas, energy supply plant, effluent treatment plant, gas treatment plant, waste disposal plant and areas, maintenance facilities, laboratories, site services
Design/construction modifications	Site layout, process train, materials
Nature/quantities of materials handled on site	Feedstocks, intermediates, products, wastes, reagents, maintenance materials
Nature of surrounding land use	Residential, hospitals, schools, nurseries, commercial/industrial, agricultural/horticultural, surface water/groundwater resources, ecology, protected habitats, presence of public utilities, environmental consents (e.g. IPPC authorisations, waste management licences etc.)
Physical features	Present and past topography, propensity for flooding
Previous history	Industrial use, incidence of major accidents (fires, spillages etc.), previous mining activity, environmental enforcement records
Geology/hydrogeology/hydrology	Solid and drift geology, mine workings, natural cavities, presence/status of surface and groundwater bodies and abstraction points, presence and sensitivity of surface waters, abstraction points and consented discharges
Ecological/geological status	Presence of sensitive ecological systems on or near to the site Presence of designated protected areas e.g. SSSI’s
Archaeological status	Presence of sensitive or protected archaeological features
Source: CIRIA Special Publication 103 Note: This table is also included in Volume II as text Supplement 2.5	

2.7.2 Site reconnaissance

A site reconnaissance or 'walkover' survey is essential, as part of an initial site appraisal, to confirm that the current status of the site is consistent with the other findings of the initial assessment i.e. site history etc. Prior to undertaking a site reconnaissance, safety considerations should be taken into account based on the findings of the historical research and the desk study, and appropriate safety precautions should be taken.

This initial visit to the site may well disclose evidence of otherwise unrecorded events and those that post-date the recorded history of the site. Wherever possible, historical plans of the site should be available for the site visit together with a current plan at a suitable scale which can be annotated with relevant site observations.

Important observations can also be made on the general status of the local area in environmental terms and the presence of potentially contaminative neighbouring or nearby operations. A photographic record of the site including all key features should be made for future reference.

On developed sites there may well be very little opportunity to observe the ground conditions and the developed surface of the site can be a very poor indication of the underlying ground conditions.

Additional guidance on undertaking initial site reconnaissance visits is given in DoE Contaminated Land Research Report CLR Report No 2. Guidance on Preliminary Site Inspection of Contaminated Land. DoE 1994.

A checklist for undertaking an initial site reconnaissance and a proforma of a site visit record sheet are included in:

Text Supplement 2.6 "Site Reconnaissance Information Checklist" in Volume II and

Text Supplement 2.7 "Example of a Site Visit Record Sheet" in Volume II

2.8 Exploratory and main site investigations

This section covers all stages of intrusive site investigations and the use of non-intrusive techniques on site referred to in Table 2.1 including:

- **exploratory investigations**;
- **main investigations**, which may include:
  - the primary detailed investigation of a site;
  - supplementary investigations; and
  - validation investigations.

Typical objectives for each phase of the investigation are illustrated earlier in this chapter in Table 2.1.

The investigation of a contaminated site is a potentially hazardous activity for the personnel involved as well as other people present either on or adjacent to the site. Consequently the activity needs to be carefully planned in respect to health and safety issues (see Chapter 11), environmental protection (see Chapter 12) and any operational constraints (see Chapter 13). A desk study and site reconnaissance should always be undertaken prior to any intrusive investigation, in part to allow as much information as possible to be obtained on the potential hazards and risks involved during the course of the investigation work.

Staff involved in undertaking all stages of investigations should always have a clear understanding of the objectives of the investigation and should have the skills and experience both to recognise and respond to emerging conditions. In many instances the findings of the investigation will vary from the assumptions which were made at the design stage. For example, the investigation may encounter evidence of below-ground structures such as tanks, pipes and basements that were not anticipated. In such circumstances it may be appropriate for the investigation to be amended to establish the full extent of such features including their size, depth and contents. Such knowledge will often be crucial both to establishing the level of risk associated with the site and the subsequent remedial requirements.

Where specific underground features need to be located and characterised the use of trench excavations or geophysical techniques can be highly advantageous as compared to a series of conventional boreholes or trial pits providing that suitable access is available.

Where possible plant and equipment which is selected for the investigations should be both appropriate to the anticipated ground conditions and also able to operate effectively in at least some unforeseen conditions. For example plant which is selected for excavating trial pits on potentially contaminated former industrial sites should be sufficiently powerful to deal with a reasonable level of obstructions in the ground (see also Chapter 10). Hence the use of a more powerful excavator which can more readily overcome obstructions may be appropriate (see also Chapter 4).

On completion of the investigation the final condition of the site investigation locations should be left as safe as possible to minimise the risks to potential site users (including any trespassers). In some circumstances this may need special measures to be taken which could include the need for the importation of clean cover materials.

2.8.1 Site investigation reports

All pertinent information gathered during a site assessment should be included in the site investigation report in a clear, logical and structured format. A standard format for a site investigation report is given in:

Appendix A "Standard Format for a Site Investigation Report" in Volume II

2.9 Professional competence

The success of any site investigation will be highly dependent on the professional competence of the staff involved at all levels. All of the activities involved in site investigation should be undertaken by competent and suitably qualified staff to ensure that:

(i) the work is of an appropriate technical quality;

(ii) potential health and safety risks which exist on many potentially contaminated sites are minimised; and

(iii) potential environmental risks which could arise during the site investigation are minimised.

A summary of the main factors that should be considered in selecting both consultants and investigation contractors/laboratories is presented below in Text Box 2.2.

Text Box 2.2

Selection of specialist advisors and contractors

- Demonstration of a breadth of suitable skills and experience;
- familiarity with published guidance and regulation;
- suitably qualified and experienced staff at a range of levels;
- adequate resources;
- operation of a quality management system;
- operation of a comprehensive health and safety management system and a demonstrable track record;
- independent accreditation for testing procedures (contractors);
- availability of adequate Professional Indemnity Insurance, Public Liability Insurance and other insurances.

Note: This Text Box is also presented in Volume II as Text Supplement 2.7

Further details on the selection of appropriate specialists are given in the DoE Contaminated Land Research Report CLR 12 A Quality Approach to Contaminated Land Consultancy, 1997.

Levels of professional competence for professional staff undertaking investigations of contaminated sites (and other related tasks) are provided in:

Text Supplement 2.9 "Definitions of Professional and Technical Staff" in Volume II

2.10 Audit trails and record keeping

It is frequently the case that a third party needs to review a site investigation. This may be, for example, in the context of reviewing the adequacy of proposed (or already implemented) risk assessment and risk management measures. A Secondary Model Procedure for Verification of Risk Assessment and Risk Management Measures (*working title - document* *still in preparation)* is being developed by the Environment Agency. This procedure is to assist those who need to make judgements about, or use information from, the work carried out by others to assess the level of confidence they may place in the work. Checklists included provide a basis for both non-technical and technical verification and reference should be made to this to gain an appreciation of the issues that a third party will wish to address.

Providing an audit trail means, in essence, carrying out and documenting work in such a manner that a third party is able to undertake verification and gain confidence in what has been done.

There is frequently an implied measure of trust that what is reported to have been done has actually been done, with the emphasis focusing on the logic trail presented. For example, it is frequently accepted that samples were stored appropriately and analysed within an acceptable elapsed period. However, this position is changing with laboratories now increasingly reporting, as a matter of routine, when samples were received and the date they were analysed as a requirement under the system for which they have UKAS accreditation.

Where work is being done in the context of possible legal action, being able to provide a high degree of confidence in what was carried out by means of an audit trail is particularly important. Indeed, failure to be able to inspire confidence in the procedures adopted could lead to results being viewed as unreliable. In the above context and when deciding how extensive an audit trail may be appropriate, consideration should be given to the issues summarised in:

Text Supplement 2.10 "Audit Trails and Record Keeping – Issues on Which Confidence May be Required" in Volume II

3. SITE CHARACTERISATION RECORDS AND DATA MANAGEMENT

3.1 Introduction

This section provides guidance on recording the findings of site investigations. The preparation of site records of an appropriate quality is of vital importance in ensuring that all relevant information and observations are captured during the investigation. Site records will form the basis of a series of judgements relating to both the risks associated with the site as well as the possible need for and scope of remedial measures. Consequently they form the foundation of all ground contamination projects.

3.2 Key references

In general site investigation records should be produced in accordance with the requirements of the following:

- British Standards Institution **Code of Practice for Site Investigations**. BS5930: 1999.

Other key references are:

- Department of the Environment (1994) CLR 5. **Information systems for land contamination**. Report by Meta Generics Ltd.

- Environment Agency R&D Technical Report P241, 1999, **Recommendations for the Processing and Presentation of Groundwater Quality Data;** and

- BGS/Environment Agency 2000, **Some guidance on the use of digital environmental data.** BGS Technical Report WE/99/14, NGWCLC Technical Report NC/06/32.

Further reference material is listed in:

Text Supplement 3.2 "Further reading" in Volume II

3.3 Precision and accuracy of site records

The levels of both precision and accuracy required for site records will vary depending on the specific objectives of the investigation. Usually an increase in either of these parameters will result in an increase in costs. Whilst the cost implications of producing site records which are 'fit for purpose' need to be recognised, under no circumstances, should such commercial issues detract practitioners from making the correct technical judgements.

In most circumstances the acceptable levels of precision and accuracy will vary for different aspects of site records as illustrated below. The definitions of precision and accuracy are given below in sections 3.3.1 and 3.3.2 respectively. During the planning and design of the investigation careful consideration should be given to levels of precision and accuracy which are required. An illustration of selecting appropriate levels of precision and accuracy is given below as Scenario 3.1.

Scenario 3.1

Appropriate levels of precision and accuracy

Precision

In order to assess long term trends in groundwater quality or small fluctuations in groundwater levels over time, a high level of precision (and of accuracy) is likely to be required. Where the objective is simply to provide an initial assessment of groundwater quality or to establish the direction of groundwater flow a lower level of precision may well be acceptable.

Accuracy

The measurement of heavily contaminated shallow soils on a gasworks site for total PAH content could be acceptable to within an accuracy level of ±1000 mg/kg where concentrations are in excess of 10,000 mg/kg and the visual description of the sample gives explicit evidence of tarry contamination. In these circumstances whether a true result of 10,000 mg/kg is expressed as 9,000 mg/kg or 11,000 mg/kg is unlikely to change either the assessment of risk or the remedial strategy.

The measurement of PAH concentrations in an important aquifer that underlies the site, and has the potential to be used for potable supply, is likely to require the measurement of total PAH concentrations to an accuracy level of less than 0.1 µg/l in order to allow an assessment to be made of the suitability of the aquifer as a potable supply.

A further relevant factor relates to the selection of analytical detection limits. In choosing detection limits an important consideration should be whether or not the detection limits will be sufficiently sensitive to allow comparison with established standards e.g. drinking water standards. The level of sensitivity (and accuracy) must be such that comparisons against the most stringent relevant standards can be made. For example if a detection limit of say 5 mg/l is selected it clearly will not allow comparison with a standard of say 1 mg/l when the measured result is below the detection limit.

3.3.1 Precision

The term precision relates to the reproducibility of multiple measurements. It is inversely related to the variability among results obtained by repeatedly applying the same measurement process.

The precision of a result should generally be increased by increasing the number of measurements made. However, in respect to analytical data, for example, the precision of an analytical result may be better at higher concentrations where the analytical method is not being pushed to the limit.

A measurement process of high precision is one which when repeated will produce either the same or very similar results. However, the results produced can still be inaccurate when repeating the same measurement process using an inappropriate technique (sampling or measurement bias).

3.3.2 Accuracy

The accuracy of a measurement is how close the result of a measurement is to the true value.

Accuracy relates to the quality of a result, and is distinguished from precision, which relates to the quality of the operation by which the result is obtained. Determining the accuracy of a measurement usually requires calibration of the measurement tool (e.g. ruler, analytical instrument etc.) with a known standard.

Key features of precision and accuracy are given below in Table 3.1.

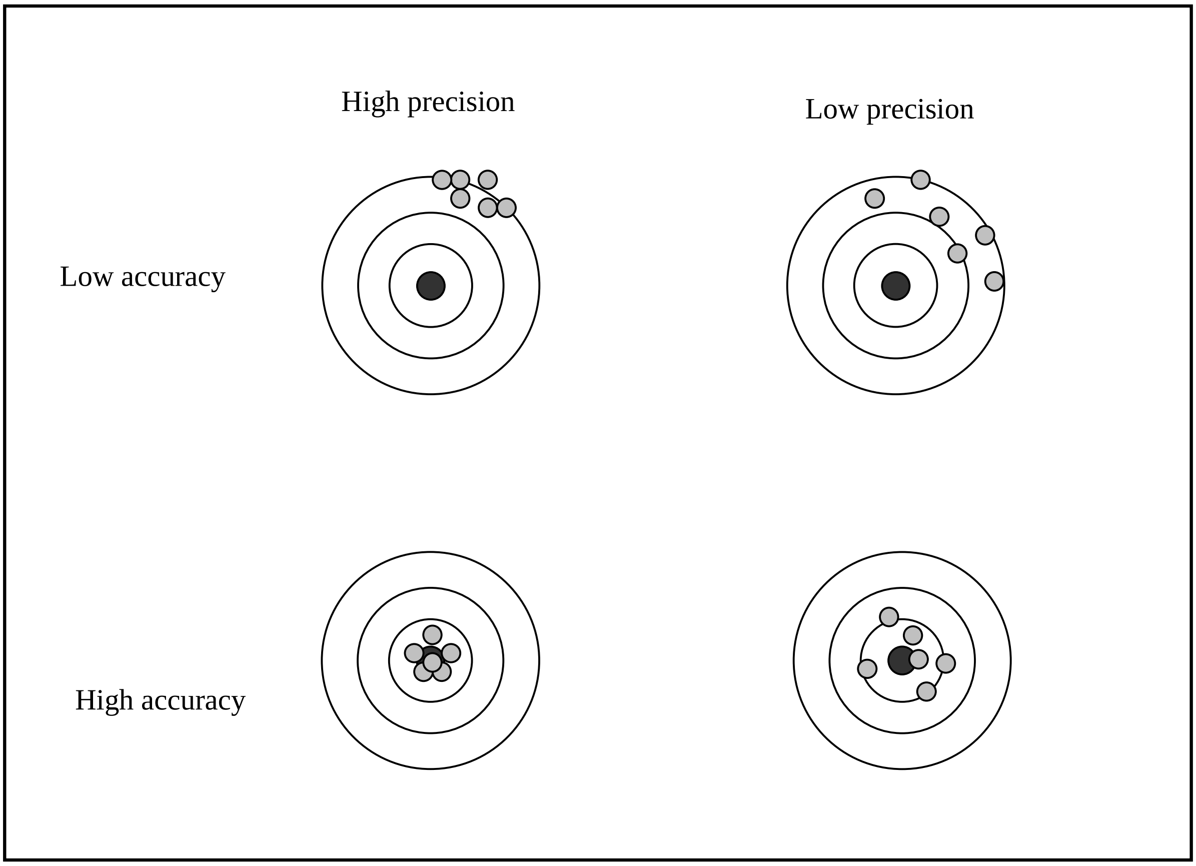
Table 3.1 - Key features of precision and accuracy

Feature	Precision	Accuracy
conformity	The degree of mutual agreement among repeated measurements.	The degree of conformity of a measured or calculated value to a standard or true value.
characterisation	Precision is high if the standard deviation, standard error and confidence interval are low.	Accuracy is high when bias is low.
factors	Precision is affected by random errors (e.g. factors which change during the period when repeat measurements are taken).	Accuracy is affected by systematic errors (e.g. selection of an inappropriate sampling or analytical method).

3.3.3 Illustration of precision and accuracy

If a true value is represented as a bull's eye on a target, a group of measurements of that value characterised by closely grouped points have a high level of precision. If the group of measurements is also near to the centre, it is highly accurate as well. Therefore, on a bull's eye, accuracy is a function of how close a hit is to the bull's eye, and precision is a function of how closely grouped the shots are (see Figure 3.1 below).

Figure 3.1 – Illustration of precision and accuracy



3.4 Descriptions, observations and photographs

When on site, observations should be recorded in as much detail as possible, since subsequent assessment and the formulation of remediation strategies may rely on this information. Information, which might initially appear as being of little relevance, could be crucial to further investigation and remediation strategies. Key investigation information is often contained within trial pit and borehole "logs" that are used to record ground and groundwater information at investigation locations. Whether these follow the style set out in BS5930, or another suitable for the technical requirements of the project, these should be clear and note anything that is observed that may help in subsequent interpretation (e.g. odours, staining, technical details of the investigation method etc.).

Detailed notes are particularly important if a follow-up site visit is not possible or if further work will be carried out by another person who will rely solely on the previously supplied site records. A site diary can be a very useful means of recording information in a systematic fashion during longer site investigations. An example proforma for a daily site diary is provided in:

Text Supplement 3.1. "Example of a Daily Site Diary" in Volume II

As many relevant photographs as possible should be taken during an investigation. Photographs are the means of documentation with the least loss of information. However, they are only meaningful when properly labelled and with reference to the location at which they were taken. Therefore, make a note of the location and number of photograph each time a photo is taken together with a description of the subject of the photograph. Photographs of trial pits or excavated soil should also include a date, scale, and unique location reference. Good quality photographs of excavated trial pits are notoriously difficult to produce, usually as a result of problems caused by the contrast in light levels between the ground surface and at depth within the trial pit. Consequently it is also important to take photographs of excavated materials in stockpiles to supplement the 'down hole' trial pit photographs. Photographs should not be the sole solution to a visual site inspection, since colours and small details may not be sufficiently resolved in a photographic print. The production of dimensioned sketches can also be very useful in this respect.

3.5 Laboratory data

Units of measurement for data from analytical laboratories should always be checked on receipt. It should not be assumed that all data are reported in the same units. So, for example, the majority of soil quality results will often be reported in mg/kg whilst a small proportion of results will be reported in a different unit e.g. µg/kg.

Additionally results may be presented in the same units but expressed in a different form. So, for example, results for soils may be expressed as dry weight, wet weight and with or without 'inerts' included in the calculation of contaminant concentrations.

Particular care must be taken with units when the data are sent electronically, and are going to be imported into other spreadsheets or electronic packages for statistical evaluation or modelling. If this is not done, the data may be used further without respect to their different units, since statistical packages, spreadsheets and mathematical models operate on a unit-less basis and just consider the value itself. Thus, the error may be carried over and remain unrecognised when looking at and interpreting the final result. This may result in significant errors in the final assessment of site conditions.

The differences between two units often comprise three orders of magnitude. This is illustrated below in Scenario 3.2.

Scenario 3.2

Units of measurement – getting it right

Concentration units can easily be mistaken for one another. Note that:

1g/l	equals	1000mg/l
1mg/l	equals	1000µg/l
1µg/l	equals	1000ng/l
1ng/l	equals	1000pg/l

Hence, for example, a measurement recorded incorrectly as 7.5µg/l, which was actually a reading of 7.5mg/l actually should be 7500µg/l.

In the case of a benzene concentration in groundwater such a difference in units of measurement as illustrated above, if undetected, could make a significant difference to the evaluation of risks and hence to the remediation strategy.

Laboratory data should always be reviewed critically for outliers and unexpected or abnormal results and the laboratory should be asked to confirm such results.

3.6 Data model design

During any given ground investigation, the data collected may quite validly be recorded in different formats and stored separately. For instance, the borehole location, surface level and depth may be recorded in one table. The geology for that borehole may be stored in another, and the soil chemistry and water chemistry in two others. Scattering of data in this way, usually involving different computer files may impact on how, if at all, any software package can then analyse those data. It is vital that an adequate data model is designed at an early stage of the project that streamlines the flow of information in line with the project requirements. In designing the data model a number of issues should be addressed including:

- What questions are going to be asked of the data?
- What will be the best way to present the data to aid understanding?
- How much data will be generated?
- How quickly are the data needed? Do they need to influence and inform the investigation work on site?
- Who will need to have access to the data and what are their requirements? e.g. other designers? regulators? the client?
- Will the site be subdivided into zones (see section 5.5.3 for further details)?
- Can the data records be questioned directly on both physical and chemical characteristics, or does the structure of the data model prohibit this? For instance, can data on soil chemistry be interrogated according to depth of sample?
- Will time-related data be generated e.g. from gas and groundwater monitoring programmes?
- What sort of data outputs will be required?

Unless these questions are resolved at the outset of the project the data sets may need to be re-input possibly into different software to provide the required outputs. A well-designed data model should prevent this from happening.

Selection of software packages to be used on the project should take into account the skill base of the project team i.e. whether or not the project team is spreadsheet/database/GIS literate. The availability of training may have a bearing on the ultimate decision, but any change in current practice should be managed with care. Consideration should also be given to:

- who will be supplying the data and in what format;

- the methodology and format which will be used to present the results (e.g. SURFER, CAD, GIS, customised logging package such as HoleBase).

These questions should help to decide which software package is used for data input and management. Table 3.2 below summarises the main advantages and disadvantages of the principal methodologies currently available.

Table 3.2 - Generic data input packages

Software	Advantages	Disadvantages
Spreadsheets; e.g. Lotus 1-2-3, Excel	Used by many engineers and laboratories.	Control of data not formalised.
Databases; e.g. Access, Oracle	Can be customised to ensure more rigorous input/data control. Preferable for handling very large volumes of data efficiently.	Not widely used in the geoenvironmental community.
GIS	A wide range of analysis and mapping functionality, linked with internal databases.	Internal database may not be able to cope with large datasets; check that package can interface with external databases, such as Access, or with spreadsheets, such as Excel.

In designing the data model, careful consideration should be given to how the boreholes, trial pits and samples are to be referenced (see section 5.5). Use of punctuation marks within the sample references may not be acceptable for importation into an electronic database. Careful consideration should be given to how to handle multiple records at one location – the sample logs could contain a field for the log number, or incorporate the log number within the unique sample number. This should be reflected within the data model, as it will impact upon how access can then be gained to associated data, such as location information. Definitions of key database terminology are given below in Text Box 3.1.

Text Box 3.1
Database terminology

Databases store descriptive information for a feature, such as a borehole or trial pit in a tabular data file in which a *record* stores all the information about a particular feature, and the *field* stores one type of information (i.e. attribute or characteristic) for all the features in the database.

Problems frequently arise in relation to how locations are recorded. A local co-ordinate system can be used, or the survey may be linked to the national grid system. Whichever is the case, a check should be made on what information will be required to set up the co-ordinate or mapping system on the computer. The data model should enable the sample records to be linked back to the co-ordinates for the borehole/trial pits. Care should be taken that depths are recorded consistently; i.e. depth from ground surface, modified level, etc. and in a manner that ensures they can be accurately linked back to the topographic survey of the site surface.

Consistency in all the data fields to be gathered is vital. It is important to anticipate how the information is to be used. For instance, how is the geology defined? Is it unambiguous, or does it involve simplification or qualitative interpretation which will limit its use further down the line (e.g. interpretation of 'silt' may vary between an environmental scientist and a geotechnical engineer)? It is important to ensure that site staff are appropriately trained, for instance, with regard to material descriptions to suit geotechnical requirements, to BS5930: 1999. If a customised logging package is used, such as HoleBase, then the specific data input fields required need to be established in advance and checked against the proposed data log sheets. It should also be established whether or not the AGS format is to be adopted (refer to: Electronic Transfer of Geotechnical and Geoenvironmental Data (3rd Edition), Published by Association of Geotechnical Specialists. 1999. ISBN 0 9519271 8.3).

An explicit decision should be made on how to record a null observation, and what format this should be in. This should refer back to what is acceptable within the data model.

The data model should define the permitted length and format of the record. Data fields should be formatted to allow for accurate recording to an agreed precision (see section 3.3). Many software packages can not accept < values, and careful consideration needs to be given to how these data are going to be handled. Gilbert (1999) suggests reporting actual values where data are below formal detection limits e.g. if a field measurement of 0.5 is registered on a monitoring instrument this value is recorded even if the formal detection limit of the instrument is 1.0. Current practice includes adopting zero value, the detection limit, or a fraction of the detection limit. Where data are then interpolated (as during contouring), treatment of such values should be made explicit so that an assumed value can clearly be differentiated from a measured value. Care needs to be taken in the treatment of zero values particularly where they are subject to statistical analysis such as the calculation of means.

If a contour map is one of the intended outputs, consideration should be given to whether or not there are enough appropriately spaced sampling points to support interpolation of contours. This decision will tie in with what method is adopted to create the contours. If gridding is to be adopted, a general rule of thumb is to make the grid cells half the size of the minimum distance between the sample points. Sample coverage should ensure a satisfactory level of understanding of what is happening around the site boundaries. This can be particularly important if the site is elongated, as this can affect how the contouring package interprets the results. It is important that the operator has a clear knowledge of what the contouring package is doing. For example, it is possible to make a perfectly planar surface from the roughest of terrain. Hence the designer needs to decide what interpretations he/she wants the computer to make. These, and many other relevant issues are discussed in greater detail in Burrough and McDonnell (1998) Principles of Geographic Information Systems, Oxford University ISBN 0 19 823366 3.

If three-dimensional models are to be constructed, the way in which different layers are to be interpreted, and how discontinuities should be treated needs to be decided. Where geological strata are recorded, records should include both the top and bottom of stratum. Where the base of a stratum is not reached in an exploratory excavation this should also be noted. This will assist with later geological modelling. If only top of stratum is recorded, assumptions must subsequently be made about what occurs below; do the observed strata occur in sequence? If there are no further observations below this level, does the last observed stratum continue to the bottom of the log, and beyond?

3.7 Presentation of data

The way in which the analytical/measurement data are presented should, as far as possible, be anticipated at the start of the project, so that the correct data model can be adopted. Questions to be asked at this stage include:

- Do trial pit/borehole records need to be presented purely as a series of logs, or is there a requirement to summarise the site observations in plan form?
- Is there a requirement to analyse the site in three dimensions, requiring contour maps/cross-sections of surface topography, geology, soil chemistry, soil physical properties, and water chemistry?
- Is there a requirement to map the character of the site, thematically, by physical/chemical properties, as a function of depth, or of geology?

How the data are presented will depend, to a large extent, on the software package available. But however sophisticated the package, it should not be considered as a substitute for a clear understanding by the appropriate technical staff of the site conditions. Rather it should be considered as a tool that can assist in this process. It is possible, through manipulating the data, to tell any number of stories about a particular site. For example, by changing the parameters within a contour package, you can smooth a very rugged site to an aesthetically pleasing, smooth, or in the extreme, flat surface if you wish, but is it portraying an accurate picture? Consequently whoever is operating the software package should have a good understanding of the algorithms which are being utilised to interpret the three dimensional surface.

Within any report which incorporates the output electronic data manipulation packages the following information should also be given:

- Full details of the software package used (including the version number);
- A justification for the parameters which have been selected for presentation;
- A listing of and justification for the data which have and have not been included;
- A summary of how the data have been manipulated together with a discussion of possible bias that may be highlighted in a particular from of data output e.g. contour plots.

Further details on the output capabilities of commonly used software packages are presented below in Table 3.3.

Table 3.3 - Generic graphical data output packages

Software package	Advantages	Disadvantages
Contouring packages (SURFER)	Full range of interpolation techniques, with easy-to-use interface.	Limited functionality beyond contouring/cross-sections
GIS e.g. ArcView, MapInfo	Depending on the specific package, a wide range of functionality, which may allow for thematic mapping, contouring, cross sections. User-friendly, cost-effective packages available on the market.	Handling of three dimensions can be cumbersome – depends on the package, and the degree of customisation that can be done in-house.
Mining packages e.g. VULCAN	Good three dimensional handling	Expensive, often require considerable training.
Customised packages e.g. HoleBase	Depending on the specific package, may exactly address the project need, providing for data input sheets, analysis and output	May lack flexibility.

Site data may also need to be available in a format that can be used for environmental modelling using a range of models including Landsim, Consim, Contaminated Land Exposure Assessment (CLEA) Model and Groundwater Vistas.

4. INTRUSIVE AND NON-INTRUSIVE INVESTIGATION METHODS

4.1 Introduction

A wide range of intrusive and non-intrusive investigation methods are available for characterising contaminated sites. This chapter, together with the Investigation Method Summary Sheets in Volume II (text supplement 4.2) that accompany it, provide technical information on the principal methods currently available and guidance in their applicability.

4.2 Key references

- Environment Agency R&D Project P2-178 **Review of Non-intrusive Groundwater Investigation Techniques for Groundwater Pollution Studies** (in production);

- Environment Agency (in preparation) **Guidance on Monitoring the Operational and Post-remediation Performance of Remedial Techniques**. R&D Project record P5-044.

- CIRIA (1995). **Remedial Treatment for Contaminated Land**. Volume III: Site Investigation and Assessment;

- **Guidance Document for Combined and Geotechnical Investigation**. 2000. Association of Geotechnical Specialists.

- British Standards Institution **Code of Practice for Site Investigations**. BS5930: 1999.

- British Standard BS 10175:2001 Code of Practice for the Investigation of Potentially Contaminated Sites.

Further reference material is listed in:

Text Supplement 4.6 "Further Reading" in Volume II

4.3 Intrusive methods

Intrusive methods include trial pits, boreholes and hand boring i.e. invasive techniques that allow soil and groundwater samples to be obtained, the ground profile to be inspected and monitoring installations to be established. At least one of these techniques will usually be employed during the investigation of a contaminated site. A wide range of drilling methods and techniques can be utilised and excavations can be carried out by hand to shallow depth or, and more conventionally, by different types of excavator. The principal methods that may be useful for the investigation of contaminated sites in the UK are:

- **Trial Pits** (synonyms include “Trial Holes”, “Trial Trenches”, “Test Pits” and “Test Holes” - hand dug and mechanically excavated);

- **Continuous Flight Auger** and **Hollow Stem Auger Boreholes** (the acronyms CFA/HSA are commonly used);

- **Cable Percussive Boreholes** (synonyms include “Shell and Auger”);

- **Rotary Cored Boreholes**;

- **Window Sampling and Probing**;

- **Hand Augers** and **associated methods** (e.g. Post-Hole Borer, Piston Sampler);

- **Rotary Drilling** (synonyms include “Rock Roller” and “tricone”);

- **Down the Hole Hammer** (acronyms DTH and DTHH are commonly used).

Of these, the first five methods have greatest application in UK ground conditions for the investigation of contaminated sites (which generally focus on the shallower ground rather than deep bedrock). The others, although less commonly used, are potentially useful in certain situations. For example Rotary Drilling and DTH are drilling techniques suitable for highly consolidated conditions (i.e. hard rock). Conversely, most hand augering methods are suitable for only relatively soft very shallow ground and are not used to great extent in the UK. Nevertheless, all these methods have their application in the investigation of contaminated sites.

4.4 Non-intrusive methods

A range of methods that are non-invasive are also available and can play a valuable role in site investigation. These image the ground without intrusion into it and thus can be used without changing the ground and contaminant profiles (see also Chapter 7) and with much reduced exposure of personnel to contaminants and physical hazards (see also Chapter 11). If used appropriately, these techniques can:

- help to check the validity of desk study indications;

- help to focus intrusive work in appropriate areas;

- provide information on changes over time e.g. where successive surveys are used to plot plume movement; and

- give advanced warning of hazards that may be encountered during such work.

While there are literally scores of geophysical and other non-intrusive techniques available, six principal types of geophysical method that can all be applied to the investigation of contaminated sites are included in this technical guidance document, i.e.:

- **Seismic**;
- **Gravity**;
- **Electrical**;
- **Electromagnetic**;
- **Magnetic**; and
- **Ground Penetrating Radar** (the acronym GPR is frequently used).

Many other non-intrusive techniques such as satellite imagery, aerial photography, thermal imaging etc are included in Environment Agency R&D Project P2-178 Review of Non-intrusive Groundwater Investigation Techniques for Groundwater Pollution Studies (in production) and are not discussed further here.

4.5 Investigation method summary sheets

An "Investigation Method Summary Sheet" has been produced for each of the intrusive and geophysical investigation methods listed above. These are presented as:

Text Supplement 4.1 "Investigation Method Summary Sheets" in Volume II

Each Investigation Method Summary Sheet includes the following information:

- a basic description of the method;
- a typical sequence of events when the method is deployed;
- key applications and limitations in relation to the investigation of contaminated sites;
- key cost factors;
- personnel requirements;
- key operational parameters;
- practical safety and environmental issues; and
- selected further reading.

A selection of photographs illustrating equipment commonly used for the investigation of contaminated sites is included in:

Text Supplement 4.2 "Selected Photographs of Investigation Methods" in Volume II

4.6 Selection of site investigation methods

The choice of which methods will be most appropriate for a site investigation will depend on a wide range of factors including:

- site ground conditions;
- special situations (e.g. where there is the need to drill into an underlying aquifer);
- specific technical requirements (e.g. the need for robust and high quality groundwater monitoring installations and sampling needs);
- site specific operational issues (e.g. accessibility, proximity to non-involved persons etc);
- presence of sub-surface features (e.g. tanks, voids and archaeological features - great care will need to be taken whether the intention is that these are found or avoided);
- time available;
- cost.

The Investigation Method Summary Sheets in Volume II illustrate the applicability of each specific intrusive method in relation to the above issues.

A guide to choosing an appropriate intrusive investigation technique is provided in:

Text Supplement 4.3 "Choosing an Intrusive Investigation Method" in Volume II and

Text Supplement 4.4 "Worked Example" in Volume II

In selecting the most appropriate technique for a specific site, particularly in respect to drilling techniques, advice should be sought from a specialist contractor with experience of the local ground conditions.

Given the wide range and very large number of geophysical techniques that are available, advice should be sought from a specialist contractor or consultant on the selection of the most appropriate method.

4.7 Site investigation preparation and implementation issues

All of the issues discussed in the section on planning for site investigations in Chapter 2 should have been considered and addressed before an investigation is scheduled and a contractor is engaged. However, good preparation for the investigation itself can make a significant difference to its success and smooth operation during implementation, particularly where there are several parties/individuals involved and a wide range of logistical and technical items that have to be arranged.

Issues that may need to be addressed when preparing and implementing a site investigation include:

- client and site communications;
- specific health and safety needs;
- operational and technical details, including pollution prevention and environmental protection; and
- division of responsibilities between the Project Manager and other involved staff.

A checklist is provided in:

Text Supplement 4.5 "Site Investigation Preparation and Implementation Checklist" in Volume II

In practice, a project manager may choose to delegate the organisation of the detail of the issues to the scientists and engineers attending site. However, *all* issues should be considered initially by the project manager as they may have project management and logistical implications with knock-on effects on other project aspects.

5. SAMPLING

5.1 Introduction

The purpose of this section is to provide a useful summary of the key issues that should be considered in developing a sampling strategy.

5.2 Key references

Much guidance referring to sampling strategies already exists and this technical guidance document does not attempt to reproduce this. Key references on sampling strategies and methods include:

- Environment Agency (2001). **Secondary Model Procedure for the Development of appropriate soil sampling strategies for contaminated land** R&D Technical Report P5-066/TR.

- Environment Agency **Guidance on Monitoring of Landfill Leachate, Groundwater and Surface Water** (in preparation)

- Environment Agency **National Sampling Procedures Manual – Quality Management System for Environmental Sampling** (internal Environment Agency guidance);

- Environment Agency (in preparation) **Guidance on Monitoring the Operational and Post-remediation Performance of Remedial Techniques**. R&D Project P5-044.

- British Standard ISO/5667- 18 (draft): **Guidance on sampling groundwaters from potentially contaminated sites** (ISO/DIS 5667-18).

Further reference material is listed in:

Text Supplement 5.6 "Further Reading" in Volume II

5.3 Strategies

Prior to developing a sampling strategy a conceptual model of pollutant linkages associated with the site needs to be produced. The sampling strategy should then enable these linkages to be investigated. In developing the sampling strategy, it may be appropriate to zone the site into areas where pollutant linkages are and are not anticipated. Sampling is likely to be biased more towards those locations where they are anticipated, compared to those where they are not. However, it should be noted that it is more difficult to demonstrate that a site is not contaminated than it is to demonstrate that it is contaminated. The sampling strategy should consider the nature, location and environmental behaviour of the likely contaminants of concern. For detailed information on developing sampling strategies, see the Environment

Agency document “Secondary Model Procedure for the Development of Appropriate Soil Sampling Strategies Contaminated Land” , 2001.

A checklist of major issues to be considered when developing a sampling strategy is provided in:

Text Supplement 5.1 “Checklist of Major Issues to be Considered in Preparation for and When Sampling” in Volume II

5.4 Methods

There are many different sampling methods, each with advantages and limitations for different situations. For detailed published guidance – see:

Text Supplement 5.6 “Further Reading” in Volume II

5.5 Classifying and referencing

Consideration should be given to an appropriate system of classification and referencing for investigation locations and samples long before the first phase of site investigation is undertaken. For reasons outlined below, it may be necessary to decide on appropriate systems at desk study/site reconnaissance stages. Such decisions should not be made on the first day on site when the supervising scientist/engineer stands at the first borehole location with the first sample pot in hand. Invariably in this situation, the sample pot will be labelled “BH1/sample 1”, which may be entirely inappropriate for the overall project objectives, the intended phasing of the investigation and the data management system planned.

While there are no definitively right and wrong ways to classify and reference investigation locations and samples, there are a number of issues that should be considered. The principal ones are listed below.

5.5.1 Need to distinguish between different investigation location types

Commonly, boreholes are labelled “BH” and trial pits “TP” and this simple distinction often works well in distinguishing between location types on site drawings, on logs, when using analytical data etc. As shown in Chapter 4, there is an increasingly wide range of investigation methods available (including many different types of boreholes for example), and consequently great potential for creativity with acronyms. The essential point is that, if a range of investigation methods may be used during different investigation phases, consideration should be given to an appropriate referencing system for distinguishing between these.

It may also prove helpful to distinguish between those boreholes where there are permanent groundwater/gas monitoring installations and those that have been sampled and then backfilled. In most cases, the addition of a letter denoting “monitoring point” (e.g. “BHM”) may work well but take care with data sorting to make sure that alpha-numeric references are accommodated. In all cases, choices should be made after also taking into account the requirements of the data management system that the data will feed into (outlined briefly below and explained more fully in Chapter 3).

Watchpoint

Sometimes an asterisk * is incorporated into borehole references to indicate that a borehole has a groundwater monitoring installation e.g. BH101*. It may not be appropriate to use an asterisk if data are to be fed into a GIS or other data management system.

5.5.2 Phasing of investigations

Chapter 2 gives guidance on how to plan and phase site investigations. Where an investigation is phased, it is usually desirable to distinguish between investigation locations, field and laboratory data etc. from the different phases. The separate phases of trial pits, boreholes etc. can be grouped into "series" e.g. "100 series" for the exploratory phase, "200 series", "300 series" and so on thereafter. For example, boreholes from the second phase may be labelled:

- **BH201, BH202, BHM203** etc. This reveals that these boreholes are from the second phase of investigation. It also reveals (following on from the previous section) that the last borehole, which incorporate the letter "M" in its reference, has a groundwater monitoring installation while the first two do not.

It can be useful to develop this approach even where a project is inherited after an investigation using a simple BH1, BH2, BH3 system has been carried out by others, as long as appropriate notes are made in the investigation report and on the site drawings etc.

5.5.3 Site zones

Some sites will have been zoned during their operational history – particularly large sites such as power stations, steelworks, shipyards, airfields etc. This zoning would usually relate to the operational aspects of the site. For example, within a coal-fired power station site there might be an "Area A" where the process plant and turbine house were located, an "Area B" where the coal stockpiles were and an "Area C" used for disposal/storage of pulverised fuel ash.

These zone references may persist throughout decommissioning, demolition, investigation and construction stages of a site's redevelopment and be used by all involved parties (site owner, property management company, developer, architect etc as well as site investigation related parties). In this case, it can be useful to incorporate the zone reference into the site investigation location reference. For example:

- **ABH201, ABH202, CBH203, CBHM204**, etc which reveals that both of the first boreholes, incorporating the letter "A" are in Zone A while the last two, incorporating the letter "C" are in Zone C. Following on from above, the references also reveal that all boreholes are from the second phase of investigation and that only the last one has a groundwater monitoring installation.

Watchpoint

Do not use hyphenation or other punctuation (e.g. A-BH201 or A/BH201) if data are to be fed into a GIS or other data management system.

In some cases, once a zoned industrial site has closed down and been put forward for development, reference to the former site zones ceases. It may be that the site is treated as one general area, or it could be re-zoned in accordance with future development plans. In the latter case, it may be appropriate for those planning ground investigations to incorporate the new zone references in borehole and trial pit references etc. in a similar way to that described above.

Whether to include such additional information on site zones into a referencing system is rarely critical to the overall success of the site investigation but may assist the data management and interpretation exercises. For example, laboratories should more easily be able to group data together that are from one part of a site and, using the example of the three zones of the power station from above, it should assist in attributing data to the areas of PFA disposal/coal stockpiling etc. However, it should also be recognised that it may be entirely inappropriate in some instances as it may inhibit the development of an overall conceptual model of a site as e.g. where mobile contaminants have formed a plume traversing zone boundaries.

5.5.4 Compatibility of data format with data management and digital information systems

When considering the above issues, the data management system which will be used subsequently should also be considered, including any digital information systems that will be used once field work has finished to ensure compatibility. These issues are covered in more detail in Chapter 3.

5.6 Storage, handling, transporting and chain of custody

The type of samples and labelling requirements for samples taken from each method of investigation are presented in:

Text Supplement 5.2 "Labelling Samples – Information Needed" in Volume II;

Text Supplement 5.3 "Type and Amount of Samples" in Volume II.

Details of sample requirements for various types of field techniques are presented in:

Text Supplement 5.4 "Field Techniques Used in Soil Sampling" in Volume II

It is very important that field samples are uniquely identifiable (as described later) and that there is an appropriate chain of custody from the person taking the sample, to the laboratory. A typical chain of custody form is given in:

Text Supplement 5.5 "Sample Chain of Custody Form" in Volume II

The size and type of sampling bottle or container and any fixative requirements will depend on the analysis required, and may differ between laboratories. Advice from the laboratory should be sought on sampling vessels and fixatives and good communication between the laboratory and the person taking the sample is imperative.

5.7 Legal defensibility

Many of the aspects of ensuring that work carried out is legally defensible relate to following established good practice and to ensuring that all work carried out is properly documented. Nevertheless, where it is known that the findings of site investigation are likely to be used in court, special attention to detail is warranted. With respect to legal defensibility, Environment Agency staff should consult the appropriate internal manuals, and persons outside the Environment Agency should seek appropriate legal advice.

6. ON-SITE MEASUREMENTS

6.1 Introduction

On-site measurements encompass both the use of portable instruments for measuring parameters such as gas concentrations or certain water quality parameters such as pH and which are used to generate quantitative site data on environmental conditions. On site measurements also include the use of instruments to undertake physical measurements such as depths of strata, distances etc.

6.2 Key References

The key references for on site measurements include:

- Environment Agency **Guidance on Monitoring of Landfill Leachate, Groundwater and Surface Water** (in preparation);

- CIRIA (1993). **The Measurement of Methane and Other gases from the Ground.** Report 131.

Further reference material is listed in:

Text Supplement 6.5 "Further Reading" in Volume II.

6.3 Portable detectors and other measurement devices

The following aspects should be incorporated in the use of any portable detectors that are used to make on-site measurements:

- all instruments and other measurement devices used should be regularly serviced and calibrated both prior to and following each time they are used;

- units of measurement should always be recorded whilst on site in addition to the measurement result, rather than after the event. This is particularly important when instruments with multiple units and scales are used.

A range of instruments have been developed specifically for ground contamination and landfill site investigations. The most commonly used portable instruments are summarised in:

Text Supplement 6.1 "Portable Instruments Commonly Used for Site Investigations" in Volume II

6.3.1 Recording measurements on portable detectors

The following key aspects should be considered in respect to the recording of measurements made on site using portable instruments:

- for most instruments, the manufacturers recommend that calibration checks should be carried out before the instrument is used, in addition to the regular calibrations carried out by the manufacturers. The result of the calibration check should be recorded and any long term trends should be investigated and resolved. If the instrument is out of calibration beyond the manufacturer's recommendation, it should be re-calibrated prior to use;

- weather conditions should be recorded since some instruments may be affected by high humidity, extremely high or low temperatures, rain, atmospheric pressure or wind. These records may help interpreting unusual data;

- the type and serial number of the instrument used for the measurements should be recorded. Wherever possible, the same instrument should be used for repeat measurements at the same locations to promote consistency in the way the results were obtained (a standard operating technique is also required to minimise any operator bias). Furthermore, if later during data processing and evaluation, the data are found to be unusual, the instrument can be checked for faults retrospectively.

6.4 Field sampling devices for groundwater and gas

(See also Chapter 5).

Sampling devices used in the field can greatly affect the quality of groundwater and gas samples. The correct use of appropriate sampling devices is critical to the success of site investigations, since an analysis can only be as accurate and representative as the samples provided.

The choice of sampling device depends on:

- type of medium;
- type of parameters to be analysed;
- volumes to be sampled;
- type and size (e.g. diameter) of the monitoring point;
- specific requirements for the quality of the sample.

Field sampling devices should be constructed of materials that will not significantly alter the concentration and chemical specification of the determinands by, for example, adsorption of determinands or release of substances from the sample containers and transmission lines. Non-reactive materials such as PTFE or glass should be used where appropriate. Steel may release zinc and iron and PVC may adsorb organic constituents and release phthalic acid esters which are used as plasticisers. However, the choice of material will depend on the reactivity of the sample and the parameters to be analysed. Sampling devices should also be kept clean to minimise the opportunity for cross contamination to occur between measurements (see Chapter 7 for further details).

6.4.1 Groundwater sampling devices

Groundwater sampling installations commonly used for contaminated site investigations are summarised in:

Text Supplement 6.2 "Groundwater Field Sampling Installations Commonly Used for Site Investigations" in Volume II;

The process of sampling itself may alter the composition of the sample if inappropriate techniques are applied. Leachates and leachate-contaminated groundwater, for instance, may undergo significant chemical changes on exposure to air. As a result, organics may be aerobically converted and metals may be precipitated if the sample is exposed to air during collection. Pumping may also affect volatile concentrations.

The applications and limitations of commonly used sampling pumps are listed in:

Text Supplement 6.3 "Groundwater Sample Extraction Methods Commonly Used for Site Investigations" in Volume II

Any surplus water which is generated during the sampling process should be disposed of in a proper manner and in full accordance with the appropriate legal requirements.

6.4.2 Gas sampling devices

For gas sampling, all sampling installations from the point of gas entry must be air-tight. Appropriate valves and air-tight connectors should be used to avoid dilution of the sample with ambient air. The internal volume of the gas sampling lines should be kept to a minimum to reduce the volume of gas required for flushing and thus reduce the possibility of dilution of the sample with ambient air. Samples should be analysed as soon as possible, since no container can be considered completely leak-proof. For flammable gases such as methane both measurement and sampling devices should be intrinsically safe. Typical gas monitoring installations and sampling containers are listed in:

Text Supplement 6.4 "Soil Gas Sampling Equipment Commonly Used for Site Investigations" in Volume II

Further guidance on groundwater sampling and landfill leachate, groundwater and gas monitoring is provided in the reference material listed in:

Text Supplement 6.5 "Further Reading" in Volume II

7. CROSS-CONTAMINATION

7.1 Introduction

This chapter deals with two situations where there is the potential for cross-contamination to occur - sample quality and the potential for cross-contamination of the ground to be caused by site investigation work.

7.2 Key references

Guidance on issues of cross-contamination and decontamination can be found in the following documents:

- Environment Agency **Decommissioning Redundant Boreholes and Wells** (leaflet produced by the National Groundwater and Contaminated Land Centre)
- CIRIA (1995). **Remedial Treatment for Contaminated Land**. Volume III: Site Investigation and Assessment;
- USEPA (1991) **Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells** EPA1600 14-89 1034 (available on the Internet: http://www.epa.gov/swerust1/cat/wwelldct.pdf *last accessed August 2000*).

Further reference material is listed in:

Text Supplement 7.5 "Further Reading" in Volume II

7.3 Planning an investigation to minimise cross-contamination

The potential for cross-contamination to occur during a site investigation can be greatly minimised if good decisions about investigation design, drilling/excavation techniques and working methods are made during the planning stage. These can then be built on during preparation for and implementation of the site investigation. It is important that *all* investigation workers are informed of the site specific issues and why particular investigation techniques and working methods have been chosen. However, no amount of care taken in sampling, decontamination, drilling etc. during the site investigation itself can compensate for an overall poor investigation design where the wrong investigation and working methods have been chosen. Aside from the impact on the quality of the investigation data and subsequent risk evaluation if cross-contamination occurs, there are potentially serious environmental implications, principally in terms of possible impacts on water quality.

The key ways in which cross-contamination can occur during a site investigation and possible mitigation measures are listed in:

Text Supplement 7.1 "Some Ways in Which Cross-contamination Can Occur During a Site Investigation" in Volume II

Many of the issues need to be considered at the planning stage so that the appropriate persons have time to implement the necessary actions. Some actions will have significant budget implications, others merely require the application of a degree of common sense on site.

7.4 Planning an investigation in sensitive circumstances

Investigation of contaminated sites frequently involves site investigation into, over or close to controlled waters (groundwater, surface water and coastal waters) and it is important that the investigation does not result in cross-contamination of these. It is usually possible to design and implement site investigation works in such a way that the potential for cross-contamination is greatly minimised or even eliminated.

If drilling is to be undertaken through/into more than one aquifer/groundwater body, the local area office of the Environment Agency should be contacted as early as possible for approval of drilling methods etc. This notification is essential to make sure that there is no detriment to water resources or cross contamination of strata. For further guidance, see the Environment Agency's Groundwater Protection Policy document.

In cases where there is artesian flow from any exploratory or monitoring borehole, the structure should be sealed and capped in an appropriate manner. Leaving such a borehole overflowing is illegal.

Abandoned boreholes may become damaged/lost over time and act as preferential pathways for contaminant movement. Boreholes that are no longer required should be made safe, structurally stable and backfilled or sealed. Information on the decommissioning of redundant boreholes is given in the Environment Agency leaflet " Decommissioning Redundant Boreholes and Wells".

7.4.1 Investigations on sites underlain by aquifers

The most frequently encountered situation in relation to this issue is the need to sample from and install groundwater/gas monitoring installations where an aquifer underlies a contaminated site. The actual situation presented could be one of many including:

- the aquifer lies directly beneath contaminated ground;
- the aquifer lies at some depth beneath contaminated ground but there is no low permeability layer between the two;
- a low permeability horizon separates contaminated ground and an underlying aquifer.

The above examples are very simplified and, in reality, the geology, stratigraphy, hydrogeology, anthropogenic activities, contaminant parameters etc. combine to mean that each site context is unique and will require a unique site investigation design. However, a number of protocols will always apply:

- where a low permeability horizon separates contaminated ground and an underlying aquifer, trial pits should be excavated extremely carefully to avoid penetrating through the intervening "barrier". If the low permeability horizon is reached, the trial pit should be terminated immediately. An illustration of proper backfilling is given in:

Text Supplement 7.2 "Examples of Well and Badly Constructed Trial Pits" in Volume II

- trial pits should never be used to penetrate through a low permeability horizon into an aquifer;

- where a low permeability horizon separates contaminated ground and an underlying aquifer, investigation techniques that have no way of protecting the aquifer during drilling (e.g. window sampling, hand auger) should not be used to depths greater than the upper surface of the low permeability horizon;

- where there is no low permeability horizon separating contaminated ground from the aquifer and contaminant migration into the aquifer has occurred, an investigation method should still be chosen that will minimise the potential for contamination of the aquifer;

- if there is a need to penetrate through a low permeability horizon into an aquifer, a drilling method should be chosen that will minimise the risk of causing cross-contamination between strata (i.e. a method that will not affect water quality). Information on different drilling techniques and guidance in choice of method is given in:

Text Supplement 4.1 "Investigation Method Summary Sheets" in Volume II

Text Supplement 4.3 "Choosing an Intrusive Investigation Method" in Volume II

Text Supplement 4.4 "How to Use the Table in 4.3 and a Worked Example" in Volume II

- boreholes that are to penetrate through a low permeability horizon into an aquifer need to be designed and constructed very carefully. Details of the sequence of events when penetrating through an aquiclude into an aquifer are given in:

Text Supplement 7.3 "Description of How to Drill a Borehole through an Aquiclude into an Aquifer " in Volume II

Text Supplement 7.4 "Illustration of How to Drill a Borehole through an Aquiclude into an Aquifer" in Volume II

7.4.2 Investigating a landfill

The Environment Agency should be consulted before an investigation into a landfill is undertaken. For landfills that have active waste management licences, the conditions of the licence will need to be reviewed to make sure that any investigation work is not in breach of the licence. Particular care should be taken during the investigation of a containment landfill to make sure that the liner is not damaged or punctured by the investigation process. A landfill cap that has been penetrated during a landfill investigation will need to be carefully re-instated.

7.4.3 Investigating near a stream/river/coastal waters

The potential for cross-contamination of surface waters when drilling/excavating nearby can be minimised by use of common sense and good housekeeping during the site investigation.

Good management of water and soil arisings from trial pits/boreholes is critical. The use of sand bags may be necessary to prevent run-off of contaminated groundwater into adjacent watercourses. Similarly, purge water will need to be contained and this is most simply done by purging direct into a bucket and transferring this to a bowser or other container or directly to a suitable drainage point (a trade effluent consent may be required).

The condition of any plant and vehicles used close to surface waters should be closely monitored and if any leakages of oil etc. are noted, the plant/vehicle should be repaired or replaced.

If working right at the water's edge, all plant and equipment should be secured carefully to prevent anything falling into the water (precautions that should be taken to ensure the safety of investigations in relation to river walls, wall ties etc. are dealt with in Chapter 10).

The Environment Agency's authorisation may be needed to work on a river bank. The local Environment Agency office should be contacted as early as possible and as a minimum two weeks prior to start of site works.

7.5 Avoiding cross-contamination when drilling/trial pitting

All trial pitting, rig and down hole equipment should be cleaned before, during and after use. At the outset of an investigation, it is important to establish that suitable services (power, water, drains, interceptor etc) are available for use in a conveniently located and sized working area.

A drill rig or excavator should arrive on site in a clean condition, without any leaking oil etc. If not in a satisfactory condition then equipment should be pressure washed/steam cleaned and any oil leaks stopped before setting up on a borehole or trial pit location. If in a totally unsuitable condition the equipment should be sent off-site immediately for replacement.

All equipment that is to be used in the ground for drilling (casing, augers, drill rods, samplers etc.) or trial pitting (breaker unit and bucket) should be washed between borehole/trial pit locations. In most circumstances, a simple high-pressure water washer is adequate. However if viscous substances such as tars are present or a higher level of protocol is required, then a steam cleaner will be needed. Both types of washers can be used with detergents but the detergent should be biodegradable with a low phosphate content and should not leave a residue after the equipment has dried. All equipment washed with detergent should be rinsed thoroughly.

All waste water from pressure/steam cleaning should be contained so that it does not spread contamination on site. Discharge to foul sewer may be possible subject to the approval of the relevant Water Company.

A discussion of issues to be considered when carrying out boreholes and trial is provided in section 7.4.1. The choice of materials used for borehole construction should be made carefully and the quality of all materials should be checked on site.

All trial pits should be excavated and backfilled carefully to avoid cross-contamination between different horizons. This is illustrated clearly in:

Text Supplement 7.2 "Examples of Well and Badly Constructed Trial Pits" in Volume II

The left-hand side of the diagram shows different types of materials being separated during excavation and backfilled in such a way that the original ground profile is reformed as much as possible. The right-hand side shows a badly backfilled trial pit where the original material ends up completely mixed up in the hole with contaminated material lying at a much lower level than originally was the case.

7.6 Avoiding cross-contamination during sampling

See also Chapter 5 "Sampling" and Chapter 6 "On-site Measurements".

When sampling, it is important to consider exactly what equipment will be needed at the project outset. Sampling may be carried out during the investigation itself and during subsequent monitoring exercises. For some sites, the monitoring rounds may be frequent and long-term. It is important that accurate notes on the protocol and equipment used are kept throughout the monitoring programme.

The equipment usually used for sampling soil is often a simple trowel or spatula (which should be stainless steel). In many cases, samples are "grab samples" taken with glove covered hands and gloves are changed between samples. For re-usable trowels/spatulas, the level of cleaning can range widely depending on the level of protocol adopted. In most cases a simple wash between each sample is adequate though, if a legally defensible sampling protocol is to be used (see Chapter 5) then other procedures will be needed (which will need to be documented). Where a very high degree of confidence in the cleanliness of equipment is required, this can be achieved by using three buckets, three scrubbing brushes, a number of trowels and a quantity of paper towels. A biodegradable detergent in solution is added to the first bucket, clean tap-water is added to the second and to the last is added de-ionised water. Between samples a trowel or spatula is scrubbed in each bucket in turn before drying.

Equipment used for purging or sampling groundwater should be treated in the same way as the sampling tools. The best way to avoid the process of decontamination is to have dedicated purging/sampling equipment allocated to each borehole. This can be expensive initially but should be more economical on long-term projects.

Re-usable systems for groundwater sampling include bailers (HDPE, PTFE ("Teflon"), stainless steel) and inertia pumps (HDPE and stainless steel) which are easily cleaned between locations, although hosing should normally be disposed of after use (unless the hose itself is dedicated to a well). There are also battery powered pumps available for pumping shallow groundwater heads, which are increasingly used. Where there are greater heads or large volumes of groundwater to be removed, then heavier duty pumps will be needed. It is appropriate to choose a pump with a stainless steel impeller. Such pumps are usually used for purging purposes only and not for groundwater sampling unless there is confidence that a representative groundwater is emerging from the outlet and the parameters to be analysed are not affected by passing through the pump's metal parts. After purging, the chosen sampling equipment should be installed and used for the sampling itself. The pump should be rinsed through with clean water, possibly steam cleaned on the outside or the delivery hose replaced (if contaminated). Additional detail on the selection of groundwater pumps is given in Chapter 6 of Volumes I and II.

7.7 Post-investigation

It is important that, irrespective of whether formal re-instatement works are carried out, a site should be left in a safe condition. This will include ensuring that no contaminated material is left exposed at the ground surface that (aside from presenting a health and safety risk) could form “run-off” after heavy rain.

Borehole covers should be securely locked, particularly on sites accessible to the general public and especially children. There have been many incidences where items and substances have been deliberately forced into boreholes and entered the groundwater below.

The supervising scientist/engineer should take time to check that every investigation location has been properly finished off before leaving site on the last day.

8. ANALYTICAL STRATEGIES

8.1 Introduction

This chapter provides guidance on preparing, implementing and developing an analytical strategy, together with key aspects of laboratory QA (quality assurance) and laboratory QC (quality control).

8.2 Key references

- Environment Agency (in preparation) **Guidance on Monitoring the Operational and Post-remediation Performance of Remedial Techniques**. R&D Project record P5-044.

- Department of the Environment, Transport and the Regions **Model Procedures for the Management of Contaminated Land** (2000 in preparation). CLR 11 prepared by Stanger Science and Environment in association with Monitor Environmental Consultants Limited;

- CIRIA (1995). **Remedial Treatment for Contaminated Land**. Volume III: Site Investigation and Assessment.

- Eurochem (1998) **Quality Assurance in Research and Development and Non-routine Analysis** (can be downloaded from the Internet free of charge: http//www.vtt.fi/ket/eurochem/publications.htm *last visited July 2000*)

- Eurochem (1998) **The Fitness for Purpose of Analytical methods** (can be downloaded from the Internet free of charge: http//www.vtt.fi/ket/eurochem/ publications.htm *last visited July 2000*)

Further reference material is listed in:

Text Supplement 8.3"Further Reading" in Volume II

8.3 Preparing an analytical strategy

In developing an analytical strategy, as with a sampling strategy, it is very important to understand the conceptual model of the site, the possible pollutant linkages associated and the purposes of the investigation. The analytical strategy should be influenced by the possible pollutant linkages but should also be flexible enough to allow for additional analyses based on visual or olfactory evidence of contamination encountered during the site investigation.

An understanding of the purpose of the investigation is essential to its success. For example:

- an investigation *to determine the extent of contamination* from the leakage from an underground unleaded petrol tank may only require a limited suite of analytes for soil and groundwater analyses such as PRO (petroleum range organics), benzene and MTBE (methyl-tertiarybutylether);

- by contrast, an investigation carried out *to determine whether a site is suitable for housing development* may require a fuller analytical suite applied to soil and groundwater.

The US EPA has developed a systematic (holistic) procedure for this process which is referred to as the Data Quality Objective (DQO) Process. This process, according to the US EPA Office of Water, is defined as "*a logical, systematic procedure for developing the information needed to support an environmental decision*".

The approach essentially emphasises the principle of thinking carefully about how data is to be used and the quality of data needed. Other aspects of the DQO process may not prove universally useful.

The different physical characteristics of contaminants could, for example, be used to advantage. Using the earlier example of MTBE for instance, the relatively high solubility of MTBE in water could be used as an indication of the extent of the contamination plume. Subsequently, this could trigger the need to analyse water samples within the plume for benzene, which although less soluble, has more severe toxicological properties than MTBE.

In defining an analytical strategy, it is important also to consider any daughter products, especially where these may be more toxic than the parent. An example would be an historic trichloroethene (TCE) spill, where biodegradation produces dichloroethene (DCE) and chloroethene (vinylchloride, VC) with VC being very much toxic than trichloroethene.

Another cost-effective tool is to employ screening methods. These can be used both *in situ* and *ex situ* to determine which samples should be scheduled for a more select laboratory analysis e.g., the use of a laboratory PAH screen analysis initially to determine which samples should be submitted for speciation analysis for the 16 USEPA PAHs. However, it should be noted that this would increase the laboratory turnaround time for completing all analyses, unless the laboratory is specifically instructed to conduct speciation automatically once a specified trigger concentration has been exceeded at the screening stage.

In situ screening methods for laboratory oil typing, for example, might simply employ visual or olfactory triggers, or might employ the use of field instruments or test kits (which may measure the concentration of a contaminant, or provide information on its level of ecotoxicity). Prior to use, test kits should always be calibrated against a well-characterised laboratory method using duplicate samples (see also Chapters 5 and 6).

Often, some 'general' analysis (i.e. a basic range of organic and inorganic determinands) will be required, particularly during early phases of investigation and where "made ground" is all that has been previously reported for shallow ground conditions.

8.4 Implementing and developing an analytical strategy

Unlike the USEPA which has developed standard methods of analyses for a wide range of contaminants in different media, the UK has refrained from such an approach in a bid to encourage laboratories to develop new superior, methodologies.

Therefore, when devising an analytical strategy, the reader is advised to enter into a full discussion with the laboratory, describing what the purpose of the analysis is, and the likely types of contaminants that may be encountered on site (as identified from the conceptual model of the site). For example, low detection limits may be required for comparison against site derived remedial targets. Alternatively if it is important to know if a hydrocarbon spill is recent (i.e. unweathered) or historic (i.e. weathered) a far more detailed analysis of the constituent hydrocarbon compounds will be required rather than a single value that refers to the concentration of a relatively wide range of hydrocarbons.

What parameter is analysed and the actual values determined are influenced significantly by the method of analysis used by the laboratory. Most confusion occurs over hydrocarbon analyses as discussed further in:

Text Supplement 8.1"What Do We Mean by Total Petroleum Hydrocarbons (TPH)?" in Volume II

In addition, a checklist of key points that should be considered in developing an analytical strategy is provided in:

Text Supplement 8.2"Key Questions to be Considered in Developing an Analytical Strategy" in Volume II

8.5 Laboratory QA and QC

Laboratory Quality Assurance (QA) and Quality Control (QC) are very important in order to determine the level of confidence in the contaminant concentration data. The data should be relevant, reliable, accurate and reported on time.

Quality Control is a planned system of activities, designed to provide a quality product or service, whereas, Quality Assurance is a planned system of activities designed to make sure that the quality control programme is effective.

The Environment Agency's policy statement, "Chemical Test Data on Contaminated Soils-Qualification Requirements", ref. EAS/2703/1/6/Version3/FINAL 1 summarises its requirements i.e. only "… data on soils that are fit for purpose are used to inform its regulatory decisions".

As a general point, the quality of the information provided to a laboratory at the time that its services are requested can influence the quality of the data that is provided back. If samples are accompanied by a description of what they are expected to contain and the general order of magnitude of contaminant concentrations, then this will assist the laboratory in its choice of analytical technique, and to cope with the presence of interfering substances.

8.5.1 Quality assurance (QA)

A laboratory QA system should encompass the following issues and procedures:

- Documented Quality System – Quality Manual, procedures, etc.;
- suitable competency of staff;
- suitable equipment and standards;
- certified reference materials – for calibration and quality control;
- training;
- validated methods of analysis;
- reporting procedures;
- records of calibration, training, etc.;
- quality audit and management review;
- proficiency testing schemes;
- complaints procedure.

There are a number of accreditation schemes, including:

- **UKAS (United Kingdom Accreditation Services),** which has superseded the NAMAS (National Measurement and Accreditation Service) accreditation scheme, provides assurance that analytical calibration and testing conforms to the defined standard. This demonstrates the competence of the accredited laboratory for the analytical work defined in the scope of accreditation. This scope can range from one test, to all the analyses performed by the laboratory. UKAS accreditation also ensures that a laboratory has a quality management system which complies with EN 45001 (soon to be superseded by ISO/IES 17025). The laboratory has, to a large degree, the flexibility to define its own performance criteria and some laboratories define more challenging criteria for themselves than others. Use of an UKAS-accredited laboratory cannot guarantee that results will be high quality but it is generally considered to be a valuable risk reduction measure (as are other measures such as laboratory audit and data quality assessment). Most laboratories also use non-accredited tests, which are not assessed by UKAS. The Environment Agency is working towards developing an accreditation scheme for laboratories in conjunction with UKAS;

- **ISO 9000** is an internationally recognised quality system designed for a wide range of businesses to make sure that a facility has the necessary systems and procedures in place, in order to assure contractual requirements are agreed and delivered to the customer;

Essentially, all parts of the laboratory service, procedures, analysis, results, corrective actions, etc. should be documented to allow full traceability. Traceability may be required to a person, a reference material or a piece of equipment to check that the data are correct.

Method validation

Analytical methods may be the definitive/standard methods (e.g. ISO, CEN or BSI), reference methods, a user defined method (e.g. BG proficiency scheme) or a routine in-house method used by the individual laboratory. In all cases the methods employed needs to be validated to make sure that it meets the *fit for purpose* requirement. Once validated for the type of sample concerned, laboratories must be able to demonstrate their continued performance through a combination of analytical quality control (as described overleaf) and interlaboratory proficiency testing schemes.

Validation requires the following to be determined:

- precision[1];
- accuracy[1];
- limits of detection;
- applicability;
- interferences (where possible); and
- traceability to national standards.

These are not always easy to determine, especially for heterogeneous soils. Also, there are few, if any, standard methods for soil analysis that can be used to compare the efficacy of an in-house method. This is where proficiency-testing schemes are invaluable.

The aims of a proficiency testing scheme encompass the ability of a laboratory to:

- compare its present performance against an external standard;
- compare its present performance with its past performance;
- compare its performance against other laboratories in its peer group;
- identify unsatisfactory performers; and

[1] for an explanation of the difference between "precision" and "accuracy", see Chapter 3.

- enable organisers to assess general improvements in turnaround time.

CONTEST, developed by the Laboratory of the Government Chemist (LGC), is one of a number of proficiency testing schemes in the UK that is aimed at ensuring that a laboratory is competent to perform the analysis of a particular analyte or analytes in a particular soil matrix or group of soil matrices. It allows a laboratory to compare its performance against an external standard: to compare against past performance; and, to compare against other laboratories. Test samples are supplied by LGC and the assessed laboratories use their own analytical methods. Proper investigation of the outcome of such schemes should lead to continuous improvement of the analytical techniques of all the laboratories involved.

Analysis of contaminated water samples and leachates also pose analytical challenges. There is also a proficiency testing scheme for water samples, Aquacheck, which is administered by WRc (Water Research Centre).

8.5.2 Quality control (QC)

Quality control is typically measured by a combination of the following analytical checks, which are instigated either internally by the laboratory, or externally by the client. However, the client must decide between which level of quality control is achievable in theory, and which is practicable and desirable in practice (e.g. cost constraints, indicative analyses):

- **blanks** are used to determine the contamination of an analytical process – instrument blanks monitor cross-contamination between samples; reagent blanks are a check on reagent contamination and are analysed with each sample batch, trip blanks monitor any cross-contamination that may have occurred between samples transported in the same batch; and field blanks monitor any contamination that may have occurred in the field, for example from ambient concentrations;

- **standards** are used for calibrating instruments or producing calibration graphs. A sufficient number of standards, representative of the minimum and maximum of the range of contaminant concentrations that are required to be measured, should be used. Independent standards are used periodically to check calibrations and should be from a different source/supplier to those used for calibration;

- **duplicate** samples are analysed regularly to check preparation or instrument repeatability. These are portions of the same sample which are prepared/analysed consecutively using the same method;

- **check samples** are used to monitor the performance of the method. These samples may be independent standards or samples of analyte concentration that has been determined by comparison with a certified reference material. They are analysed at a frequency of at least one in twenty samples, but more usually one in ten. The frequency of the check sample is dependent on many factors, including the cost of standard materials, the frequency of sample analysis by the method and the cost of the analytical procedure etc.;

- **control charts** are used to monitor the check samples visually and to define limits at which point the method is considered to be out of control and producing data which are outside the permissible error. Should a check sample result fall outside the limits set, the technician should automatically repeat the analysis of both the samples and the check standard. Should the standard consistently fail, the cause should be investigated. Control chart limits may be determined, for example, by collating data from a check standard and calculating the standard deviation (sd) of the data set. The limits are then set at 2sd, a level where, statistically, 95% of the standard results fall within the limits. Control charts can give the analyst much information regarding the performance of the analytical process and any changes which may be traced to a particular event, via the quality system documentation;

- **blind samples** are standards or samples of known analyte concentration that are unknowingly entered into the laboratory system and labelled as if from the client. In this way the sample is not known by the technician to be a standard or sample used to check the laboratory results. Therefore, blind samples are an internal check of the quality system and sample analysis;

- **certified reference materials** (CRM) are relatively expensive and hence are not designed to be used on a regular basis. They are generally used for initial calibration and as primary reference materials to characterise secondary reference materials that are used on a more frequent basis;

- **sample spikes,** also known as matrix spikes, ensure perfect matrix matching for the analysis. A portion of the sample is analysed and a second portion is spiked with a known amount of the analyte prior to analysis. The recovery of the standard in the spiked sample is used to assess the error due to the sample matrix. Therefore, the cost of analysis is double for the assurance that any errors due to the matrix are accounted for.

8.5.3 Accuracy and precision

See Chapter 3 for an explanation of the difference between precision and accuracy.

Due to the heterogeneity of many soil matrices, it is very difficult to assess the accuracy and precision of a particular analysis for a particular set of field samples. Therefore, reference should be made to duplicate samples (as described above), which will provide an indication of the precision of a particular analysis for a specified soil matrix. Precision will generally be poorer where analysis is on an “as received” sample compared to the situation where it is possible to dry and grind/homogenise.

The accuracy of a test is invariably determined on a reference standard in a single matrix, not always similar to the field sample; e.g. standard ICP (Inductively Coupled Plasma) solutions (for metal detection) are in acidified water. Proficiency testing give the best estimate of the accuracy a laboratory achieves for any given analysis since they include a mean of the results from all the participating laboratories. This can then be used to assess the accuracy of the results where a certified reference material is not available.

Although matrix effects can make soils analysis difficult, analysis of leachates and contaminated water samples can also be challenging due to interference effects and the possibility of multi-phases being present in the sample. However, water reference samples are more likely to be similar in matrix to the field sample than the corresponding soil reference and field samples. Where very low contaminant concentrations in water are of interest, laboratory air quality will need to be controlled to avoid accuracy being affected by the laboratory background (commonly a problem for dichloromethane).

8.5.4 Detection limits

There are different types of detection limits such as the method quantification limit (MQL), or the practical quantification limit (PQL). The MQL is the lowest concentration of an analyte that can be measured by the method. The PQL is the lowest level that can be reliably achieved during routine operating conditions, i.e. after routine sample preparation. For example, the MQL for iron may be 1 ppm, but on a soil sample the PQL would be 20 ppm since 5g of soil has been digested and diluted to $100cm^3$ (a 20x dilution). It is often the case that a lower PQL can be reached if more sample is provided or if special steps are taken.

As a general rule, the detection limit for any analyte should be lower than the "environmental standard" that the results are to be compared against.

8.6 Choice of data format

Choice of data format must be made in the context of a data model that should be designed early on in the project. The key issues are discussed in greater length in Chapter 3.

Watchpoint

Be wary when comparing analytical data from different laboratories that you have not commissioned yourself (e.g. if using historic data for a site) as different analytical methods may have been used. For example, consider "over what pH range has a laboratory defined "complex" or "unavailable" cyanide, and are they the same thing?" This is very important for organics where for example, the use of two different solvents to quantify the hydrocarbon content will yield often widely varying results – see:

Text Supplement 8.1"What Do We Mean by Total Petroleum Hydrocarbons (TPH)?" in Volume II

9. TOPOGRAPHIC SURVEYS

9.1 Introduction

The topographic survey provides the base plan from which desk studies, ground investigations and remedial works can be designed. The above ground survey can be supplemented with a survey of the underground services and can also be assimilated with historical plans and records.

9.2 Key references

Key references are:

- **Surveys of Land, Buildings and Utility Services at Scales of 1:500 and Larger** - Client Specification Guidelines 2nd Edition 1996. RICS Business Services Limited (RICS Books);

- **Ordnance Survey maps at various scales;**
- BGS/EA 2000 **Some Guidance on the Use of Digital Environmental Data** BGS Technical Report WE/99/14, EA NGWCLC Report NC/06/32.

9.3 Choosing an appropriate type of topographic survey

Topographic surveys can be produced using a wide range of techniques and equipment including ground-based optical and electrical measurements, aerial and terrestrial photography and scanning systems, and satellite Global Positioning Systems (GPS).

Topographic surveys can be commissioned at various stages in a site's development to provide, for example:

- positions of planned boreholes and trial pits in preparation for site investigation;

- the actual locations of the "as constructed" boreholes and trial pits once the site investigation is finished;

- setting-out site boundaries or sub-divisions;

- setting-out new structures;

- monitoring existing structures or features for movement or deformation.

The final survey product can be presented in a variety of formats, from paper drawings to 3-dimensional computer models which can be incorporated into CAD or Geographic Information Systems (GIS) in order to be used in assessing, planning and managing projects.

Depending on the requirements of the investigation, different types/levels of topographic survey can be utilised. Essentially, however, there are two initial options i.e. either to

(i) purchase Ordnance Survey (OS) digital data and then to add further limited information (usually height information), or (ii) specify a detailed topographic survey. The advantages and disadvantages of these options are set out below.

9.3.1 OS digital data

Advantages

- It is a published dataset;
- it provides a relatively low cost product with comparatively quick availability.

Disadvantages

- Comparatively low accuracy, ±0.75m at 1:2500 scale (plan dimensions);
- largest original scale mapping limited to 1:1250 scale;
- limited height information on plans;
- limited detail shown on plans;
- information may be out of date;
- difficult to relate subsequent works on site to original plans.

9.3.2 Detailed topographic survey

Advantages

- Greater accuracy of mapping;
- survey can show much greater detail and height information, which can be tailored to individual project requirements;
- provides an up to date plan of the site;
- can provide an accurate and permanent control network, enabling all stages of the project, from investigation onwards, to be related to the same positional system.

Disadvantages

- Comparatively high cost;
- some may not be related to the national OS grid system.

9.4 Commissioning a topographic survey

Many consultants and contractors own basic survey equipment, including GPS, and some of their staff have the necessary experience of surveying techniques to be able to operate it and carry out simple surveys. This may be entirely suitable in situations where a high degree of precision and accuracy is not needed. However, in most cases, it will be necessary for a professional surveying company to be commissioned to undertake topographic survey work.

A project manager commissioning a topographic survey will need to specify the project requirements clearly to the contracted surveyor. A list of items and information that may be needed is provided in:

Text Supplement 9.1"Example of Topographic Survey Items/Information Needed" in

Volume II

The Royal Institution of Chartered Surveyors publishes a number of 'Client Specification Guidelines' that are commonly used either verbatim or in an abridged format as the basis for topographic survey specifications.

9.5 Co-ordinate data

Good planimetric control is the foundation of a reliable survey. Primary survey stations should be permanently marked and of stable construction, allowing them to be used throughout the lifetime of the project. The most common types of permanent ground markers are shown in:

Text Supplement 9.2"Permanent Ground Marker Types" in Volume II

Generally, Type One ('road nail and washer') and Type Four ('ground spike') represent the optimum in terms of ease of installation.

The survey grid can be related to four different grid types, i.e. an arbitrary grid, the OS National Grid, a local grid based on the National Grid and an existing grid for the site. These are described briefly below:

9.5.1 Arbitrary grid

Used solely for the current project and having no relationship to previous surveys or other sites. The co-ordinate system is easily established and easy to use. It refers to a 'flat earth' system in which distances taken from the drawings will equate directly to distances measured on the ground.

9.5.2 National grid

This is the grid system used by the OS. Using National Grid co-ordinates allows direct comparison between the site survey and available current or historical OS mapping. It also allows separate sites to be surveyed on the same grid and thus accurately related to each other.

Watchpoints

Any survey drawn on the National Grid will be affected by a scale factor of up to approximately 50mm/100m. The potential for confusion engendered by differences between National Grid and 'actual' distances means that National Grid co-ordinate systems must be treated with caution.

The Ordnance Survey no longer maintains its network of Triangulation Stations and it may well be that published co-ordinate values are over 30 years old. For most practical purposes these values will be adequate, but to refer surveys to the most recent co-ordinate values, it will be necessary to connect to the current network of OS GPS control stations.

Depending on the local availability of OS control stations, deriving National Grid co-ordinates for the survey stations on site may be a time-consuming process.

9.5.3 Local grid based on national grid.

Survey station positions are computed on the National Grid, then a Projection Factor (combined Scale and Mean Sea Level reductions) and origin shift is applied to 'reduce' the survey to a 'flat earth' projection .

This system combines the advantages of a survey related to the National Grid with the ease of working with 'actual' distances on the ground.

9.5.4 An existing grid

This is used for previous mapping on the site, and may have been based on any of the above.

9.6 Level datum

Surveys should, wherever possibly, be related to Ordnance Datum, using OS benchmarks and level information should be included on site logs, reports and drawings. On larger sites, levelling adjusted to fit several benchmarks may contain forced errors and it is generally better to specify one benchmark as the datum and to check that value against one or more adjacent benchmarks.

Watchpoints

In the late 19th and early 20th century Ordnance Datum was related to sea level in Liverpool rather than Newlyn and this may produce discrepancies when comparing OS mapping of differing ages.

Benchmarks in areas of extensive mining or quarrying activity may well have been subject to subsidence or other movement and may require additional checking.

To refer surveys to the most recent Ordnance Datum values, it will be necessary to connect to the current network of OS GPS control stations. This is because the OS no longer maintains its network of Triangulation Stations and it may well be that published co-ordinate values are over 30 years old.

On occasions, it may not be practical or viable to relate a survey to Ordnance Datum and an arbitrary datum may be used. In this case the datum should be a permanent and identifiable feature or point on or adjacent to the site, and all documentation related to the survey should make it clear that an arbitrary datum has been used. Once the site topography is changed (e.g. during redevelopment), the value of some previous investigation data will be reduced if an arbitrary datum has been used and thus OS benchmarks should be used wherever possible.

9.7 Global positioning systems (GPS)

GPS should be regarded as an increasingly effective tool in producing topographic surveys. Given favourable operating conditions – which in general terms means a clear view of the sky - GPS can have advantages over conventional surveying techniques. GPS can provide fast and accurate survey data without the need for intervisibility between survey stations, enabling survey work to continue in poor weather and remote locations.

There are three basic techniques used for surveying with GPS as listed below:

- **static** - giving positions to an accuracy of ±5mm horizontal and ±10mm vertical;
- **kinematic** - giving positions to an accuracy of ±10mm horizontal and ±15mm vertical;
- **real time kinematic** - giving 'instant' positioning to an accuracy of ±20mm horizontal and ±25mm vertical.

By using a combination of these techniques, GPS can be used in the following ways:

- to relate survey control to National Grid and Ordnance Datum;
- to carry out a detailed topographic survey of a site;
- to set out boundaries or structures on site;
- to monitor structures on or adjacent to the site for movement or deformation;
- to position, monitor or track plant on site, e.g. during top-soil stripping or road grading operations.

9.8 Underground services

Details of underground services can be assimilated with other topographic survey data. This information may be obtained in two different ways, i.e. via a survey of underground services, or from utilities record drawings.

9.8.1 Underground services survey

This can be achieved using electro-location, possibly supplemented with visual inspection, closed circuit television and excavation. The advantages and disadvantages of such a survey are as follows:

Advantages

- Provides accurate positioning and identification of cables and pipes;
- services positioned on the same co-ordinate system as the topographic survey;
- provides an up to date record of the site;
- may also be able to provide information on the condition of the services.

Disadvantages

- Comparatively higher cost;
- may require some initial works and excavation on site.

9.8.2 Utilities record drawings

Record drawings either scanned or digitised and superimposed on the topographic survey. The advantages and disadvantages are listed below.

Advantages

- Drawings are usually easy to obtain from utilities;
- lower cost than a full underground survey;
- information can be obtained without accessing the site.

Disadvantages

- The original drawings were compiled for use by others;
- the drawings are usually based on OS plans, hence a comparatively low accuracy (±0.75m at 1:2500 scale) is provided;
- there may be discrepancies in relating information to the site survey;
- information may be out of date and incomplete (e.g. private/Ministry of Defence services may not be accessible);

- information can take considerable time (several weeks) to obtain from the service providers.

9.9 Historical information

If available, historical data can also be added to the topographic survey. This can be extremely useful in ground investigation design and later interpretation.

This historical information will usually be in the form of OS maps that each show a "snap-shot" of the site in time. These plans can be scanned or digitised and then related to the topographic survey using either the OS grid or, with great care, by matching up detail common to both drawings.

The value of assimilating topographic survey data with historic maps is illustrated in:

Text Supplement 9.3"An Illustration of the Value of Assimilating Topographic Survey Data with Historic Maps" in Volume II

This demonstrates how an overlay of topographic survey data with a historic map can aid site investigation (in the example, site areas that required focussed investigation such as areas of infilling along a lagoon edge were identified).

Watchpoint

When overlaying any site drawing or map on another, check carefully that the original scale has not been distorted via photo-enlargement/reduction.

9.10 Level data

To ensure consistency in monitoring boreholes and wells on a site, it is important that level data for each are referenced to the same point over time. It is also important that the levels are related to a permanent site datum, allowing a reference point to be checked or re-established in the event of a well or borehole being damaged. Two typical monitoring well configurations and suggested alternative points to which the level data should be referenced are shown in:

Text Supplement 9.4 "Suggested Points of Measurement on a Borehole for the Level" in Volume II

9.11 Data format

The data management system that will be used subsequently should be considered before topographic survey is carried out. Many systems need a fixed format for grid references and so it is essential that data is collected in a way that is compatible. Some systems may be unable to cope with an alpha-numeric referencing system (e.g. OS National Grid References) and therefore a method of conversion will be needed.

Watchpoint

Many data management systems need twelve figure grid references and, if data are not collected to this accuracy, a common practice is to add two zeros to the end of the grid reference. It is essential that this addition is recorded so that the true accuracy of the grid reference is known i.e. so that it is not assumed that drawings/cross-sections etc derived from the survey data are more accurate than they actually are.

Data management issues are covered in more detail in Chapter 3. See also the British Geological Survey/Environment Agency document "Some Guidance on the Use of Digital Environmental Data", BGS Technical Report WE/99/14, EA NGWCLC Report NC/06/32.

10. SITE OBSTRUCTIONS AND GEOTECHNICAL CONSIDERATIONS

10.1 Key references

- British Standards Institution **Code of Practice for Site Investigations**. BS5930: 1999.

- **Guidelines for Combined Geoenvironmental and Geotechnical Investigation**. 2000. Association of Geotechnical Specialists

Further reference material is listed in:

Text Supplement 10.2 "Further Reading" in Volume II

10.2 Site obstructions

Most potentially contaminated sites, particularly former industrial or otherwise previously developed sites, will have obstructions above and below ground that could affect the design and execution of an investigation. Some of these obstructions will not be visible from ground level, especially those sites where demolition works have been carried out. It is therefore essential that a thorough desk study, including a site reconnaissance survey, have been carried out before the investigation is designed or commences (see Chapter 2). It may be valuable to include geophysical (non-intrusive) techniques in the site investigation design (see Chapter 4).

The types of obstructions that should be considered include:

- existing foundations (ground slabs, bases, piles and basements);

- buried tanks (concrete or metal);

- services (below ground and overhead);

- waterways (river walls, culverts and flood defences);

- tunnels (services, subways and transport);

- highways;

- unexploded ordnance;

- old mine workings;

- adjacent properties.

Each of these is discussed below.

10.2.1 Existing foundations

When arranging the position of exploratory holes the location of any existing obstructions below ground, arising from previous construction works, should be taken into account. Such obstructions can include reinforced or mass concrete bases; piles in steel, concrete or wood; ground slabs; ground beams; retaining walls and basements.

Details of structures and their foundations, existing or demolished, may be provided on record or construction drawings held by the site owner or the local authority building offices. The existence of historical structures can often be identified from historical and ordnance survey maps. Actually locating these on site can be a difficult exercise, especially where surface evidence of buildings has been removed or obscured e.g. by new features such as fences, walls and hedges. It can often be helpful to secure the assistance of someone who previously worked on the site in establishing the location of former features.

10.2.2 Buried tanks

Buried tanks, apart from being an obvious obstruction to any exploratory hole, could still retain residue from their recent contents, in liquid, solid or vapour form(s). The residue may be explosive and/or toxic to humans and as such be a health risk to any person working near, if the tank were breached during excavation. Tank residues are also a potential source of contamination if the tank is not properly emptied before it is moved or removed, or if the tanks base is inadvertently breached during investigation.

Careful examination of records and drawings should be carried out where it is known, or suspected, that chemicals have been stored; to determine location and content of any storage facility that may still exist.

10.2.3 Services

In any excavation the uncovering of buried services and field drains must be considered. Onsite services are usually the responsibility of the site owner, who may hold location record drawings. Services entering the site from the highway or surrounding area will be the responsibility of others, the ‘service providers’. Services to be considered include:

- electricity cables;
- gas mains;
- water mains;
- sewers;
- all telecommunication cables;
- oil pipelines;
- Ministry of Defence services (if relevant to the study area).

Whilst obtaining details of any services it would be useful to find out if the service providers have any special requirements relating to work being carried out above or adjacent to their property.

10.2.4 Waterways

Sites that are adjacent to rivers, flood defences, canals, reservoirs and docks will require attention to be given to safeguarding the waterway and associated structures from the proposed investigation. Many waterways have river walls and/or bunds that protect the river course and prevent flooding of the surrounding land and property. Flood defence systems can involve a range of engineering measures/structures e.g. a driven sheet pile wall tied back to anchor blocks.

In general, two organisations are responsible for the majority of the waterways and associated structures, British Waterways and the Environment Agency. There are a further small number of private organisations that own or are responsible for individual waterways. All of these organisations will have special requirements regarding work that is to be carried out on or adjacent to their property. This could have an effect on the design of the investigation and the programme.

The Environment Agency is able to impose restrictions on work within specified distances of rivers *via* its powers under the Land Drainage Act 1976 and utilising Land Drainage Bylaws enacted by former water authorities' under the Water Resources Act 1991. The distance within which restrictions are imposed is determined by the classification of the river. Non-tidal watercourses generally have restrictions imposed within 8 m of their banks whereas tidal watercourses have greater restrictions, extending to around 16 m.

Any work that is to be carried out near watercourses requires the prior approval and consent of the Environment Agency, which should be contacted as soon as possible before site work is to be carried out. Details of the exploratory hole locations, method statements for the work and a works programme will need to be provided.

10.2.5 Tunnels

Under some sites, especially in densely populated areas, there will be the possibility of shallow or deep tunnels. The tunnels could be for roads; railways; underground railways systems; the Post Office; the Ministry of Defence, subways etc. Ordnance Survey maps will show the approximate locations of most tunnels but more detailed information will need to be obtained from the owners. In the case of the Ministry of Defence this may be quite difficult. In the extreme, it may be necessary for a line and level survey of the tunnel to be carried out to locate precisely the structure before the owner will give permission for any boreholes to be excavated in the proximity of the tunnel. The owners of the tunnels can have quite stringent special requirements for work being carried out adjacent or above their property. For example, London Underground do not allow boring within three metres of their tunnels.

10.2.6 Highways

Investigations and subsequent re-instatement carried out in the highway will require some forward planning. Permission from the local or County Council Highways Department will be needed under the New Roads and Street Works Act 1991. From date of application/notification to the authority, this can take between two and six weeks to obtain. In the case of motorways, direct approval from the Police (Traffic Control) will be required.

Timing of work on roads may be limited to weekends and at night, to reduce the effect on road users. Also, warning notices may be required in advance of the work commencing and hazard signs suitably positioned to provide warning to vehicle drivers and pedestrians.

It is common for services to be routed alongside or beneath roads. Therefore, for any investigation associated with the public highway a services search will be required. At times, it can be difficult to find space within or alongside a highway to excavate a trial pit due to the number of services (together with their easements) that are present.

When the project involves an investigation in land adjacent to the highway, details of any construction works carried out related to the highway need to be collected. Possible works could include:

- retaining walls (sheet pile, concrete pile, gabions), including anchor systems;
- reinforced soil for slope stability or slope steepening (soil nails, geotextiles, cement columns);
- slope drains and toe drains/trenches.

10.2.7 Unexploded ordnance

For sites located in large cities a further consideration should be unexploded ordnance. Although rarely encountered these days there are still occasional bombs exposed on construction sites. There are few reliable records available but those that do exist are based on recorded sightings and local knowledge. Information may be obtained from local authorities, the Ministry of Defence or small organisations set up specifically to collate this type of information. Information on these organisations can be found on the internet, using ‘unexploded ordnance’ as the search words.

10.2.8 Old mine workings

If, at the desk study stage, mine workings or natural cavities have been identified as being present on the investigation site, they will need to be taken into consideration in designing the investigation. Contaminated ground investigations tend to be shallow, to a depth of 10 m or less, and will generally avoid the more modern deeper mine workings, which are usually well recorded. The shallower workings tend to be older, usually abandoned and poorly recorded but could impinge on an investigation.

The extent of the workings may need to be identified. This can be carried out by intrusive drilling on a grid system or by using geophysical methods. The type of intrusive investigation will need to be discussed with a specialist ground investigation contractor to make sure that the equipment used is suitable for the anticipated ground conditions of mine workings. When cavities are encountered borehole cameras can be used to examine the conditions and plan further investigation locations if considered necessary. Geophysical investigations would be suitable to identify shallow workings but are often difficult to interpret and will require the input of a specialist.

When using intrusive investigation techniques for mine workings consideration should be given to the possibility of encountering explosive gases in cavities and, if more than one level of workings is anticipated, the transfer of gases between the workings.

10.2.9 Adjacent properties

The effect of excavations on adjacent structures, especially those not belonging to the client needs to be considered. If possible, exploratory holes should be kept well away from existing structures. If this is not possible then it will be necessary to carry out the work in such a way as not to affect the integrity of the adjoining structure.

Where the structure is the property of an adjoining owner The Party Wall etc. Act 1996 also needs to be considered. This act prescribes how excavations can be carried out adjacent to an adjoining owner's property. It also requires that at least one month before work commences notice must be given to the adjoining owner, providing details of the proposed work and that their agreement to the work is obtained. The approval of the adjoining owner must be obtained, it is not sufficient just to serve the notice. Indeed, if the adjoining owner's permission is not given within 14 days, it is assumed that he/she objects and that there is a dispute. As part of the approval, if obtained, it may be necessary to carry out a condition survey on the structure before the work starts.

Further details and a diagrammatic presentation of the part of the Act relating to excavation near adjacent properties are given in:

Text Supplement 10.1"Diagrammatic Presentation of Section 6 of the Party Wall etc. Act 1996 Adjacent Excavation and Construction" in Volume II

10.3 Geotechnical considerations

10.3.1 Benefits of integrating contamination and geotechnical investigations

Contamination ground investigations are often related to the purchase or sale of land. Whilst the primary purpose of the investigation would be to obtain sufficient information to allow a conceptual model to be tested, it could be beneficial to include some limited geotechnical investigation.

Where new buildings, highways, foundations, earthworks, etc are to be constructed, geotechnical information will be needed. Provided that the technical requirements of each type of investigation are consistent/compatible, contamination and geotechnical investigations can be integrated to avoid unnecessary duplication of cost and loss of time.

Additionally geotechnical information on the physical nature of contaminated soils will often be critical for carrying out risk assessments and design of remediation programmes.

10.3.2 Practical implications of integrating contamination and geotechnical investigations

Combining geotechnical and contamination investigations can have practical implications, e.g.:

- conflict in sampling requirements for geotechnical and contamination testing. Appropriate sampling schedules will need to be prepared to suit both requirements. If the level of contamination is shallow the majority of contamination samples required can be taken from trial pits;

- soil samples may need to be sent to different laboratories for geotechnical and contamination testing;

- the geotechnical testing laboratory may not routinely handle contaminated samples and must be informed that some, if not all, of the soil samples may be contaminated (with as much information on what is expected as is possible);

- boreholes for environmental purpose are often shallow (e.g. often no greater than 10 m). For geotechnical purpose they are often deeper. To extend the length of a borehole would obviously have cost implications, although the increase in cost may prove small compared to carrying out two separate ground contamination and geotechnical investigations;

- requirements for descriptions of materials are often different for ground contamination and geotechnical investigations. However, this difference can be easily overcome by training environmental staff to log trial pits and boreholes to suit geotechnical requirements as set out in BS 5930:1999 and by training geotechnical staff to make proper notes on odours, staining, waste descriptions etc;

- it is important that, when combining a ground contamination and geotechnical investigation, the technical requirements of neither are compromised by the movement of investigation locations to suit the other discipline.

10.3.3 Geotechnical testing

Some geotechnical testing on site or in the laboratory will be required to assist in modelling the possible contaminant – pathway – receptor relationship and for decisions on remediation options. Typical geotechnical tests would be:

- **particle size distribution** expresses quantitatively the proportions by weight of various sizes of particles present within a soil or prepared sample;

- **bulk density** of a material per unit volume;

- **index tests** are a series of tests that measure the moisture content of a cohesive soil, both in the natural state and under certain defined conditions, which may classify and assess their engineering properties. The tests may include some or all of the following: natural moisture content, liquid limit, plastic limit, shrinkage limit, swelling capability, linear shrinkage and puddle characteristics;

- **permeability** is a standard measurement of the ease at which water may flow through the soil or rock;

- **drained shear strength** is the maximum resistance of a soil to shear stress on a potential rupture surface within the soil mass, which will allow seepage from the soil/material during loading, thereby allowing any excess porewater pressures freely to dissipate to zero;

- **undrained shear strength** is the maximum resistance of a soil to shear stress on a potential rupture surface within the soil mass, which may be achieved under conditions that do not allow seepage of water during the loading of the sample tested. The volumetric strains of the sample are taken to be zero, with changes in the total stress generating excess porewater pressures that may dissipate towards the steady state porewater pressure, at the point of maximum shear stress;

- **compaction** of a soil or crushed rock/aggregate is the process of packing soil particles more closely together, usually by mechanical means, thus increasing the dry density of the soil/material).

In addition to the above, some simple *in situ* testing (SPT (Standard Penetration Test), permeability and shear vane) could be carried out at very little expense to the investigation.

If geotechnical testing is to be carried out, there are likely to be different requirements for sample vessels/quantities etc., compared with testing for contaminants.

11. HEALTH AND SAFETY

11.1 Key references

Detailed guidance on health and safety issues and procedures relating to the investigation of contaminated sites is given a series of publications including the following, which should be considered as key reference documents for this topic:

- Environment Agency **Code of Practice Manual** (available to Environment Agency staff only);
- Environment Agency **H&S Risk Management Manual** (available to Environment Agency staff only);
- Environment Agency **Management Procedures Manual** (available to Environment Agency staff only);
- Environment Agency **Occupational Health Manual** (available to Environment Agency staff only);
- CIRIA Report 132 **A guide for safe working on contaminated sites**. CIRIA 1996;
- HSE **Protection of Personnel and the General Public during Development of Contaminated Land**. HS(G)66. HMSO, 1991;
- HSE. **A Guide to Managing Health and Safety in Construction**;
- HSE. **Managing Construction for Health and Safety, Approved Code of Practice**;
- Site Investigation Steering Group (1993) **Guidelines for the safe investigation by drilling of landfills and contaminated land;**
- HSE **Five steps to Risk Assessment**. HSE (IND(G)163L).

Further reference material is listed in:

Text Supplement 11.9“Further Reading” in Volume II

11.2 Planning for health and safety

The legislative framework relating to planning for health and safety on contaminated sites is provided principally by the:

- Management of Health and Safety at Work Regulations 1999 (MHSW);
- Control of Substances Hazardous to Health (COSHH) Regulations 1999;

- Construction (Design and Management) Regulations 1994; and the
- Personal Protective Equipment at Work Regulations 1993 (PPER).

Other more general health and safety regulations which may also apply include the:

- Construction (Health Safety and Welfare) Regulations 1996: and the
- Lifting Operations and Lifting Equipment Regulations 1998.

11.2.1 Management of Health and Safety at Work Regulations 1992 (MHSW)

An assessment of risks to health and safety should be undertaken as required by the MHSW Regulations. In practice it is appropriate to consider the wider health and safety risks that should be addressed under the MHSW Regulations, e.g. physical risks associated with working with mechanical plant and in close proximity to deep excavations, in parallel with the COSHH assessment of hazardous substances.

On many contaminated sites the acute risks associated with physical hazards are likely to be greater than the direct health and safety risks associated with the presence of contaminants.

11.2.2 Control of Substances Hazardous to Health (COSHH) Regulations

The Control of Substances Hazardous to Health (COSHH) Regulations 1999 require that, where employees may be exposed to substances hazardous to health, employers must undertake a suitable and sufficient assessment of the risks involved and the measures required to prevent or control exposures. Consequently there is an explicit legal requirement for employers to ensure that a COSHH assessment is undertaken prior to start of any work, including site reconnaissance visits and investigations, on contaminated or potentially contaminated sites.

The assessment must be reviewed if it is no longer valid. For example if new information on the scale and/or nature of the hazards becomes available or if the method of working needs to be revised for other reasons (e.g. if an alternative investigation method is selected after the start of the investigation).

Regulation 7 of the COSHH Regulations states that:

(1) Every employer shall ensure that the exposure of his employees to substances hazardous to health is either prevented or, where this is not reasonably practicable, adequately controlled.

(2) So far as is reasonably practicable, the prevention or adequate control of exposure of employees to a substance hazardous to health, except a carcinogen or biological agent, shall be secured by measures other than the provision of personal protective equipment.

In the context of the investigation of contaminated sites, the principal means by which exposure can be prevented or controlled is through the selection of an investigation technique that minimises the exposure to contaminants. For example, on a site where high concentrations of volatile organic compounds (VOCs) are suspected to be present in the ground, the use of a borehole technique is likely to present a lower risk to site investigation personnel and to others (e.g. the general public etc.) than the excavation of trial pits. In this situation boreholes should allow much smaller quantities of VOCs to be released and in a much more controlled fashion than if trial pits were excavated.

The use of personal protective equipment (PPE) should be restricted only to address those hazards which cannot be dealt with by other means i.e. it should be seen as a last resort. Inevitably there will be circumstances where the need to use basic PPE such as wearing protective gloves when collecting samples is unavoidable regardless of the use of investigation technique. However the use of PPE should not be relied upon as the primary method for controlling exposure to hazardous substances.

A checklist for COSHH assessments is presented in:

Text Supplement 11.1"COSHH Checklist" in Volume II

11.2.3 Construction (Design and Management) Regulations 1994 (CDM)

CDM applies to most building, civil engineering and engineering construction works. CDM also applies to the design stage of construction work. The definition of construction work, in terms of CDM, includes site exploration or site investigation of a physical nature. If CDM does apply to a particular site investigation the tasks given in the following checklist will need to be carried out:

Text Supplement 11.2"CDM Checklist" in Volume II

Flowcharts that help establish if the CDM Regulations apply to an investigation and provide guidance on the need for the investigation to be notified to the HSE are provided in:

Text Supplement 11.3 "Requirement Flow Chart for Application of CDM Regulations" in Volume II; and

Text Supplement 11.4 "Requirement Flow Chart for Notification to HSE" in Volume II.

Guidance on how to comply with the CDM Regulations throughout the various stages of the investigation is contained in the HSE document 'A Guide to Managing Health and Safety in Construction'. Further guidance is given in the following references:

- Managing Construction for Health and Safety, Approved Code of Practice, HSE Books;
- CDM Regulations – Work Sector Guidance for Designers, CIRIA Report 166;
- CDM Regulations – Practical Guidance for Clients and Client's Agents, CIRIA Report 172;

- CDM Regulations – Practical guidance for Planning Supervisors, CIRIA Report 173.

11.2.4 Personal Protective Equipment at Work Regulations 1993 (PPER)

The Personal Protective Equipment at Work Regulations (PPER) came into operation on 1 January 1993. The requirements replace much of the older more specific legislation and provide one complete set of regulations covering all forms of Personal Protective Equipment (PPE). However, the specific requirements of current legislation dealing with PPE take precedence over the more general requirements of the PPER, (e.g. the Control of Lead at Work Regulations 1998; the Ionising Radiation Regulations 1999 etc.).

Further guidance on the implementation of the PPE Regulations is provided in the HSE Guidance Note, Personal Protective Equipment at Work Regulations 1992 (L25).

11.2.5 British Drilling Association (BDA) guidelines

The BDA Guidelines (see above for reference details) provide a colour coding system for sites (red, yellow and green), which is commonly referred to by site investigation contractors involved in the investigation of landfills and contaminated sites. Within the guidance document lists of PPE, site equipment and emergency equipment are given for each of the three categories.

The definitions of the three categories are provided in:

Text Supplement 11.5"BDA Site Colour Coded Site Characterisation System" in Volume II

Watchpoint

Whilst the BDA site colour coding system is still in use by drilling contractors, the categories contain a number of duplications and inconsistencies. Consequently there is a tendency for many contaminated sites to fall into the red category which, in accordance with the guidance, requires the extensive use of PPE.

The fact that this guidance relies almost entirely on the use of PPE rather than seeking to find other means to prevent the exposure of personnel to hazardous substances, means that the system is directly contrary to COSHH.

In all instances a site-specific assessment should be undertaken by the contractor rather than placing reliance on the use of the BDA guidance to specify PPE requirements.

11.2.6 Planning and site visit safety checklists

A checklist that can be used for safety planning of site investigations and surveys is provided in:

Text Supplement 11.6"Investigations and Surveys Safety Checklist" in Volume II

A Site Visit Safety Checklist is provided in:

Text Supplement 11.7"Site Visit Safety Checklist" in Volume II

Reference should also be made to section 2.7.2 relating to site reconnaissance visits and to Text Supplements 2.5 and 2.6.

11.3 Implementation on site

11.3.1 Safety method statements

Investigation contractors should be required to provide a Safety Method Statement (SMS) prior to the start of any work on site. In essence the SMS should define what is to be done, who is responsible and the manner by which it will be achieved. Issues that should be considered in developing or evaluating an SMS are set out in the following checklist:

Text Supplement 11.8"Safety Method Statement Checklist" in Volume II

11.3.2 Use of PPE

Although the use of PPE should be viewed as a last resort to control the exposure of personnel to hazardous substances, almost inevitably some level of PPE will be required for the majority of investigations of contaminated sites. Staff should be trained in the correct use of PPE and the reasons why PPE is required in order to ensure that it is used properly and effectively.

It is critical that the correct type of PPE is selected for each project both in terms of the ability of the PPE to provide a satisfactory level of protection, and also in terms of the general 'wearability' of the equipment. Many forms of PPE are relatively uncomfortable to wear, and can restrict the movement, sight and communication ability of the individual. Consequently there may be an increased physical risk particularly for staff involved in activities such as trial pitting where heavy machinery and deep excavations are involved.

Certain types of PPE can induce heat stress particularly in warm weather and this needs to be considered when determining working patterns. Due to the additional physical stress that the use of PPE can induce, particularly respirators, it is also important to ensure that staff have an appropriate level of fitness to be able to use the equipment safely.

Facilities need to be available for both the proper storage and inspection/maintenance of PPE.

Common mistakes that are made in respect to the use of PPE on contaminated sites are highlighted below in Text Box 11.1.

11.3.3 Atmospheric monitoring

Monitoring of air quality may be required during some site investigations to ensure the safety of the personnel undertaking the investigation, other people on the site and possible site neighbours. As part of the COSHH assessment and the Safety Method Statement the monitoring requirements should be determined and a suitable programme should be designed and implemented.

Text Box 11.1

Common mistakes in the use of PPE

- Selection of inappropriate clothing;
- Tucking overalls into boots and sleeves into gloves;
- Not sealing junctions e.g. between sleeve and glove;
- Leaving respirator cartridges unsealed and so exposed to air overnight;
- Selecting wrong type of canister/cartridge;
- Exceeding canister/cartridge lifespan;
- Contaminated air being fed into fixed line breathing apparatus.

Source: CIRIA Report 132

11.3.4 Responding to unforeseen conditions

Given the nature of work on contaminated sites, it is inevitable that at some stage on the majority of projects, unforeseen ground conditions will be encountered. The safety management systems should be able to both recognise changes in anticipated conditions rapidly and be sufficiently adaptable that revisions can be put in place as required to ensure that safe working conditions are maintained.

The key actions that should be taken in these circumstances are:

- cease work;
- make the site as safe as possible (e.g. by reburying the worst of any excavated contamination and covering with uncontaminated material);
- leave the area immediately; and
- ensure that the incident is reported to whoever is responsible for site safety.

11.3.5 Leaving a site safe after work has finished

On completion of a site investigation the supervisor responsible for the work should ensure that the site is left in safe condition. This should include checking that:

- all exploratory excavations have been properly backfilled;

- all contaminated materials disturbed during the investigation have been either covered with clean material or removed from the site;

- all waste materials generated have been removed from the site and properly disposed of (temporary secure storage of waste may be required pending the receipt of analytical data);

- Any security measures disturbed during the investigation (e.g. fences, gates etc.) have been reinstated.

11.3.6 Contractual arrangements

When selecting site investigation contractors (including consultancy firms), proof should be provided of a good health and safety record together with evidence of a comprehensive health and safety management system Contractors that cannot provide evidence of such a record should not be invited to tender for work and should be removed from ‘approved’ lists.

Investigation contractors should be provided with as much pertinent information (both factual and interpretative) relating to health and safety as possible by the employer to assist them in the preparation of proposals and costings for investigations of contaminated sites. Preferably the information provided should be targeted to the relevant risks and so more easily assimilated by the contractor during the preparation of tenders and proposals.

12. ENVIRONMENTAL PROTECTION

12.1 Introduction

This chapter deals with the main areas of environmental impact that can occur during, or after, completion of the investigation of a contaminated site. In this context three main issues are addressed:

- potential for pollution of controlled waters;
- potential ecological impacts; and
- potential archaeological impacts.

Guidance on other related issues such as the potential health and safety implications for users of adjacent sites, neighbours etc. is given in Chapter 11. Guidance relating to below-ground and adjacent structures is given in Chapter 10.

12.2 Key references

Key reference documents relevant to environmental protection during site investigation are:

- Environment Agency (1998) **Policy and Protection of Groundwater (including series of groundwater vulnerability maps of England and Wales).** HMSO London.
- Scottish Environment Protection Agency and Environment Agency Guidance Note PPG1 **General Guide to the Prevention of Water Pollution**
- Scottish Environment Protection Agency and Environment Agency Guidance Note PPG5 **Works In, Near or Liable to Affect Watercourses**
- Scottish Environment Protection Agency and Environment Agency Guidance Note PPG6 **Working at Construction and Demolition Sites**
- Department of the Environment (1990) **Planning Policy Guidance 16: Archaeology and planning** London.
- Department of the Environment **Planning Policy Guidance 15: Planning and the historic environment** London.
- Coventry S. and Woolveridge C. (1999) **Environmental Good Practice on Site**. CIRIA London.

Further reference material is listed in:

Text Supplement 12.4 "Further Reading" in Volume II

12.3 Controlled waters

12.3.1 Potential receptors

Very often contaminated sites occur within hydrogeologically or hydrologically sensitive areas. Therefore, site investigations should be conducted thoroughly and carefully. At the onset of the site investigation, usually during the desk study, hydrogeological and hydrological sensitive sites should be identified. The following questions should be asked:

- is the site located within a groundwater Source Protection Zone or above a vulnerable aquifer?
- is there a laterally continuous aquiclude or low permeability layer protecting groundwater from any downwards migration of contaminants and if so, how thick is it?
- are surface water bodies, such as springs, streams/rivers, ponds/lakes, wetlands, and coastal water nearby? Are they down gradient of the site?
- are there any surface water drains/gullies on the site linking to streams, ponds etc?
- are active water-supply wells nearby, and especially, are they down gradient of the site?
- are any of the surface or coastal waters near to the site within wildlife protected areas?

12.3.2 Planning the investigation

During the desk study phase, key information relating to the likely sensitivity of controlled waters and hence the need to adopt a specific approach to the investigation can be accessed from a number of sources including:

- Environment Agency;
- British Geological Survey (BGS);
- Institute of Hydrology
- local authorities; and
- academia.

The main information requirements are listed below:

- **hydrogeological information for the site and environs**. This includes the presence of aquifers, the depth to groundwater, groundwater flow directions and stratigraphy. This information can usually be found by consulting EA and BGS documents, reports and maps;

- **status of the groundwater vulnerability in the area of the site**. Groundwater vulnerability maps (1:10,000 maps of England and Wales published by the Environment Agency);

- **water quality**. Environment Agency and British Geological Survey data;

- **locations of nearby surface water courses, such as springs, streams/rivers, ponds/lakes, wetlands, and coastal waters, and their approximate distances to the site**. Ordnance Survey maps are useful for locating nearby surface waters. Their status and uses should be identified in terms of Rivers Ecosystem Classification, fisheries status, water supply and other designations (e.g. Sites of Special Scientific Interest (SSSI's));

- **locations of supply wells within a relevant zone around the site**. This information can be found from the Environment Agency (licensed sources) and local authorities (exempt private potable supplies e.g. District Councils and Metropolitan Boroughs, Source Protection Zones produced for approximately 2000 sources (all private water supply)).

12.3.3 Implementing the investigation

If a site is located within a hydrogeologically or hydrologically sensitive area, then special attention and care should be exercised during a site investigation, particularly an intrusive investigation. Specific issues that should be considered include (see also Chapters 4 and 7):

- avoiding cross-contamination of an aquifer by drilling through an upper contaminated groundwater zone into the underlying clean, water-supply aquifer (see Chapter 7 for additional details);

- proper handling and storage of fuel etc. needed during the site investigation (oils, fuels and chemicals should be stored within a bunded area to prevent spillage – small volumes may be retained on pallets in an upright position);

- fuel stores and plant should be made secure at the end of the working day;

- containing and safely disposing of all surface runoff of drilling fluids or purged water from well development and aquifer testing (discharges from the site to sewer may require a consent from the Water Company);

- preventing the free flow of drilling fluids and purged water on the ground surface, particularly if the site is located near to and upgradient of surface or coastal water (discharges onto the ground/to groundwater may require a consent from the Environment Agency).

12.4 Ecology

12.4.1 Legal background

Many contaminated sites, by virtue of a history of limited alternative land use, have wildlife interest and some may be of particular ecological value. Unmanaged grassland or dense scrub offer nesting habitat for birds. Raised landforms and artificial substrates may offer ideal conditions for reptiles or burrowing mammals such as rabbit and badger. The mixture of habitats, e.g. sunny open ground with grassland and scrub that is typical of many such sites provides ideal conditions for a variety of insect species. Pools, ponds and marshes will have their own wildlife communities including frogs, newts and specialised insects such as damselflies and dragonflies. Derelict buildings, old trees or cave systems may contain bats.

The legal approach to wildlife protection in the U.K. provides for both the protection of identified sites, and for certain named species. The most relevant items of legislation are:

- 1981 Wildlife and Countryside Act (as amended) (W&C Act); and
- 1992 Badgers Act.

The W&C Act provides the mechanisms whereby the U.K. enacts the obligations placed by the European Community Directives on the protection of wild birds and habitats.

Protection of sites

In addition to the legal protection afforded, under the W&C Act, to nationally important sites such as SSSI's, second-tier sites of recognised local importance for wildlife are usually designated in local or regional plans. These are protected through the local planning system by a presumption against adverse developments. Similarly, designated trees, or stands of trees, and old hedgerows are protected by local authorities under Tree Preservation Orders (TPO's) and the 1997 Hedgerows Regulations. Trees in general are protected by licensing conditions administered by the Forestry Commission.

All works near or on an SSSI, which could include site investigations, must be approved by prior consultation with the Statutory Authority, English Nature (EN), or, in Wales, the Countryside Council for Wales (CCW) and in Scotland, Scottish Natural Heritage (SNH). These organisations may require seasonal working or other special mitigation measures to avoid or minimise any adverse impacts. Local authorities need to be consulted over works on other scheduled sites. Where trees need to be felled, depending on their age and number, a licence may be required from the Forestry Commission.

Both non-statutory wildlife organisations, e.g. the Royal Society for the Protection of Birds or the Wildlife Trusts, and central Government recognise that site protection measures cannot alone protect wildlife. A number of initiatives seek to address this including local Biodiversity Action Plans stemming from the 1992 Earth Summit on Biodiversity in Rio de Janeiro. These plans are formulated principally by the Wildlife Trusts in partnership with local authorities and the statutory agencies. These initiatives are normally focussed on known areas or species of conservation importance. In addition, a best practice approach is utilised in relation to wildlife issues, to minimise any adverse impacts on habitats and species, which, though not legally protected, may nevertheless be nationally or locally uncommon.

There are other species listed for protection under Schedule 5 of the W&C Act, e.g. a number of butterfly species, but these have not been separately listed as site investigation works are less likely to disturb these species. Nevertheless, special provisions may need to be made where it is known that significant populations may be affected. There are a number of other species also listed on Schedule 5 where the habitat is not specifically protected. However, it is generally regarded as best practice to afford these animals similar care during works that may cause death or damage to the populations from habitat loss, and arrange for appropriate mitigation works to allow the population to survive. The most relevant animals are all species of reptile and all amphibia, i.e. all lizards, snakes, frogs, newts and toads.

Protection of fauna

For some species of fauna, the legislation protects both the animal and its "resting place" and it is an offence to knowingly disturb these animals or their immediate habitats. The species in this category most likely to be encountered during site investigation work on contaminated sites and also some other rarer species which could conceivably be found at some sites in certain parts of the country are listed in:

Text Supplement 12.1 "Fauna Species that are Protected Together with their Resting Place" in Volume II

Protection of flora

The 1981 Wildlife and Countryside Act makes it unlawful for any unauthorised person to uproot any plant. Authorised persons include the landowner, legal occupier or any contractor undertaking work for which planning permission has been obtained. There are a number of very rare plants listed in Schedule 8 of the Act for which there is absolute protection. These include, for example, lizard orchid, monkey orchid and fen violet. Where proposed works could affect such the statutory authority (EN, CCW or SNH) must be consulted prior to any disturbance.

Occasionally, interesting plants (e.g. orchids) can colonise disturbed ground, or the site may have enclosed small remnant areas of original vegetation, both of which may be of local conservation interest. The local Wildlife Trust can advise in such cases, as there may be scope for transplanting species of particular interest.

Watchpoint

Some foreign plants introduced to Britain in the 19th Century have become aggressively dominant, creating serious problems in some areas. The most important of these are:

- Japanese Knotweed;
- Himalayan Balsam; and
- Giant Hogweed (nb – aside from other problems, this plant poses a serious health hazard).

These plants are found on many derelict sites and have spread mainly as a result of human activities that aid their dispersal e.g. excavation and moving of soils that contain plant parts within a site and transferral of excavated materials off-site.

The 1981 Wildlife and Countryside Act makes it an offence to allow the transmission and growth in the wild of Japanese Knotweed and Giant Hogweed. Himalayan Balsam is not currently included in this legislation.

If these plants are present on a site, great care will need to be taken during site investigations to make sure that they are not moved around/off-site. If disposing of soils that may contain Japanese Knotweed or Giant Hogweed, the receiving landfill operator will need to be consulted (soils containing pieces of Japanese Knotweed may need to be buried several metres deep for example).

for further information and illustrative photographs, see the Environment Agency leaflet "Guidance for the Control of Invasive Plants Near Watercourses" and Environment Agency R&D Note 233 "Control of Invasive Riparian and Aquatic Weeds".

12.4.2 Ecological evaluation

Compliance with the legislation and the best-practice approach will need attention to the following:

- a basic knowledge of the natural characteristics of the site in question, i.e. what ecological features are present;
- consultation with the appropriate authorities (note there is a legal obligation to consult EN (CCW or SNH) over protected sites or species);
- a precautionary approach that could involve, for example, seasonal working to avoid key sensitive phases of the animal's life cycle, e.g. the breeding season or hibernation.

Where there is no site dossier containing information on the wildlife of the site, information should be gathered from the appropriate sources and, where necessary, from site inspection and survey. The approach is given in:

Text Supplement 12.2 "Ecological Evaluation Checklist" in Volume II

The risks of site investigation works affecting protected species that are not considered in the checklist is likely to be very low, particularly in sites where there is no notification to the local planning authority of any ecological interest. However, where there are any doubts, consultation with the statutory authority is always advised.

Where intended works may result in the unavoidable disturbance of any of the above listed animals, or their resting places (i.e. breeding sites, roosting areas, hibernation sites), the appropriate statutory authority (EN, CCW or SNH) must first be consulted as required by the legislation. They may require an appropriate mitigation plan to be drawn up to avoid or minimise any impacts (see below).

The statutory authorities listed are also responsible for issuing the required licences to registered ecological specialists to undertake the necessary mitigation works affecting protected species. It is not usual for licences to be issued during the respective Close Seasons for the species in question and timing of the works may be the only acceptable mitigation technique. Note that the Close Seasons quoted in:

Text Supplement 12.1 "Fauna Species that are Protected Together with their Resting Place" in Volume II

are approximate and will vary according to weather and location in the country. Specialist local advice should always be sought on this issue.

12.4.3 Mitigation measures

When working in ecologically sensitive sites, the main potential impacts will be avoided by a planned approach to the works as advised above. Of paramount importance, for both legal compliance, and to minimise impacts on wildlife, is the need for consultation with the statutory authority when working in protected sites (SSSI) or where protected species may be affected. The majority of potential adverse effects may be avoided by working in the correct season, thereby avoiding, for example, disturbance to breeding birds, or hibernating animals. Suggestions of the types of mitigation measures that may be utilised during site investigations are listed in:

Text Supplement 12.3 "Possible Mitigation Measures" in Volume II

12.5 Archaeology and heritage

12.5.1 Background

Archaeology is " *the study of the material remains and environmental effects of human behaviour*" (Council for British Archaeology, 1998) and as such involves a much broader range of issues and interests than is commonly realised. Archaeology does not involve just the buried remains of past human activities. Upstanding historic buildings can be important for their specific archaeological interest as can the earthwork remains of former agricultural activity and the machinery of former factories. These are each subjects of study in their own right. Thus there is buildings archaeology, landscape archaeology and industrial archaeology. Other examples are urban archaeology, environmental archaeology, marine archaeology, etc.

All the many facets of archaeology are part of an even broader topic which has come to be known as 'heritage', which includes the sociological aspects of our past and the way in which all aspects of the past affect and are affected by present day activities.

Sites of past development i.e. brownfield sites, which may or may not be contaminated, may often contain archaeological remains. They may date from the more distant past (such as the buried foundations of a Roman building demolished say 1800 years ago) or be more recent and perhaps a relic of the activities which gave rise to the contamination. Examples of the latter could be the standing or buried remains of a former blast furnace, gasworks, coal mine or canal.

One other point it is currently the preferred option is for the preservation of remains *'in situ'*. Archaeologists do not go looking for the opportunity to undertake excavation. Rather excavation of remains is a last resort and is generally undertaken as a means of mitigating unavoidable disturbance. Thus developers are often asked to explore engineering solutions in which disturbance to the archaeology is avoided or minimised. This principle should also be applied to site investigations.

12.5.2 Legal status

Nationally important archaeological sites (of all periods) may have statutory protection as Scheduled Ancient Monuments. Historic buildings in England and Wales may have statutory protection as Listed Buildings, which range from Grade III (the least important) to Grade I (nationally important). In Scotland, such buildings are classified using a scheme that progresses from Category C (local importance) to Category A (national or international importance). The historic centres of a few English towns, such as York and Canterbury, are given statutory protection as Areas of Archaeological Importance, and a small number of areas within Britain are designated as World Heritage Sites under a UNESCO convention. In addition and most importantly, archaeology and historic buildings are 'material considerations' in the planning process (Planning Policy Guidance Notes PPG 15 and 16 in England; Welsh Office Circular 60/96 in Wales; National Planning Policy Guidance Note 5 NPPG5 in Scotland).

These statutory arrangements do not cover all aspects of archaeological work. Archaeological sites and historic buildings that are not Scheduled or Listed are not protected and, in theory at least, it would be possible to excavate trial pits or put down boreholes without considering archaeological/heritage issues. In practice such a course of action is highly undesirable. Eventually many investigations of contaminated sites will lead to proposals that require planning consent and, as with all regulatory matters, it is always prudent to involve the regulators at the earliest possible opportunity. The first point of contact should be the planning authority, and all planning authorities employ Archaeological Advisors at County, District or City level as appropriate.

12.5.3 Approach to investigation

Introduction

The level of archaeological work associated with site investigations will, to some extent, depend on the scale of the investigations and their likely impact. A few trial pits on site at which there is no known archaeological remains may only require a discussion with the LPA's archaeological advisor and possible attendance of a professional archaeologist (a Watching Brief) during the excavation of the pits. At the other end of the scale, on sites with known archaeological remains, desk-based investigations may be required, prior to the decisions about the locations of test pits and the test pits may even need to be hand excavated by/together with archaeologists. Set out below is general good practice in the approach to archaeological investigations when considering any works that may have an impact on archaeological remains.

Staged approach

A staged approach should be adopted for the archaeological investigation of sites involving the following principal stages:

- **Stage 1 - archaeological appraisal;**
- **Stage 2 - archaeological desk-based assessment;**
- **Stage 3 - field evaluation.**

A variety of guidance is available on these stages of investigation, including that from the Institute of Field Archaeologists (IFA) and from English Heritage and its equivalents in Wales (Cadw) and Scotland (Historic Scotland). Details of references are provided in:

Text Supplement 12.4 "Further Reading" in Volume II

The close similarity between these stages and the staged approach to geotechnical and investigations of contaminated sites means that it may be cost-effective for combined (i.e. multi-discipline) investigations to be carried out.

Archaeological investigation is intended to characterise the nature and importance of a site's archaeology in sufficient detail for decisions to be made about the mitigation of any impact that subsequent contamination or geotechnical investigations, remediation or development works would have upon it. Therefore there are often three further stages in the overall management of archaeological issues:

- **Stage 4 - mitigation design;**
- **Stage 5 - mitigation implementation and verification;**
- **Stage 6 – reporting the results.**

It is important to recognise that the primary objective of archaeologists and heritage managers is to reduce the impact of development and other projects on the surviving remains (the archaeological or heritage resource). Preservation of remains *in situ* is an important objective, archaeological excavation in the advance of development works being seen as a less satisfactory solution. Fortunately, planning guidance (PPG's 15 and 16) provide a means by which the potentially conflicting needs of development and archaeology can be reconciled. Fundamental to this process is the need to characterise the archaeological/ heritage resource carefully so that rational decisions can be made about the extent to which it can be damaged and the amount of mitigation works required. Archaeological excavation in advance of construction is one possible mitigation strategy.

Commissioning an investigation

Archaeology and heritage management services can be obtained from a range of commercial, charitable and academic organisations which provide consultancy or contracting services, or a combination of the two. It is important that a professional archaeologist or heritage specialist is included *from the start* in the team planning work on sites where archaeological remains or historic buildings are suspected or known to be present.

12.5.4 Implementing an investigation in environmentally sensitive conditions

Archaeological appraisal

This stage should provide a rapid appraisal of readily available information. It can be carried out confidentially, and need not always entail a visit to the site by the archaeological/heritage specialist. The principal sources of information will be the Sites and Monuments Record (SMR), which is maintained by the planning authority, and the statutory records of Scheduled Ancient Monuments and Listed Buildings, which are maintained by English Heritage, Cadw and Historic Scotland. It is helpful at this stage to discuss the site with the planning authority's archaeologist.

The output of this stage should be a brief report that presents the factual information gathered, interprets it and makes recommendations for the subsequent detailed desk-based assessment. The report should also consider the implications of the findings for the project as a whole, and whether there are particular aspects that might have the potential to cause serious technical difficulties, regulatory problems, or delays.

Archaeological desk-based assessment

This stage provides a detailed assessment of available information. A wide range of sources should be consulted, including:

- archaeological and heritage data-bases (e.g. the SMR);
- historical documents (e.g. industrial records);
- cartographic and pictorial documents (e.g. early maps, engineering drawings, prints);
- aerial photographs;
- geotechnical and environmental information;
- secondary and statutory sources (e.g. regional or period studies, planning constraints maps).

These and other sources are described by Shilston *et al* (1999) and in the IFA's Standard and Guidance (1993). Full references are given in:

Text Supplement 12.4 "Further Reading" in Volume II

The detailed desk-based assessment should include a site reconnaissance visit by an archaeologist or heritage specialist, together with further consultation with the planning authority's archaeologist. Consultations should also be held with English Heritage (or their Welsh and Scottish equivalents) if the project could affect a Scheduled Ancient Monument, Listed Building or other nationally designated site or area.

The output of the detailed desk-based assessment should be a detailed report that presents the factual information gathered, interprets it and makes detailed recommendations. Guidance on the contents of the report is given in Appendix 5 of the IFA's Standard and Guidance (1993).

It could be that the assessment concludes that no further work is necessary, in which case it would be prudent to obtain written confirmation of this finding from the planning authority's archaeologist.

Where the assessment concludes that the project will involve archaeological or heritage issues, the report should consider the implications of the findings for the project as a whole, and whether there are particular aspects that might have the potential to cause serious technical difficulties, regulatory problems, or delays. The report should include detailed recommendations for the subsequent stage of work, which would generally be field evaluation.

Field evaluation

This is the field investigation of the archaeological remains, and employs a range of techniques, including:

- aerial photography;
- geophysical surveys (see also Chapter 4);
- buildings surveys;
- topographic surveys (see also Chapter 9);
- field walking (the systematic collection of finds from the surface of ploughed fields);
- trial trenching (see also Chapter 4);
- Auger boring and probe holes (see also Chapter 4);.

Guidance on techniques is given in the IFA Standard and Guidance (1994, revised 1999), that also sets out the requirements for the evaluation report.

As well as describing what was done and what was found, it is most important that the report evaluates the extent and importance of the remains, and makes recommendations for the measures that could be taken to mitigate the impact of the project. Archaeological mitigation is a rapidly developing specialist field. Guidance and examples can be found in the Highways Agency's Advice Note 75/95 on 'Trunk roads and archaeological mitigation' (1995).

13. OPERATIONAL SITES – ADDITIONAL CONSIDERATIONS

13.1 Unusual site types

There are a number of types of site that, because of their operational activities, have stringent and/or specific working requirements covering a range of activities including site investigations undertaken by external parties. The types of sites that could be expected to have specific working requirements include railway stations, MOD sites, nuclear power stations, operational gas and petrochemical plants, prisons, etc. In general such requirements are intended to mitigate specialist safety and/or security risks associated with the operational activities of the site.

The requirements can be quite varied and may be time consuming to comply with. Therefore, it is advisable to establish what the requirements are, how they are relevant to the investigation and to commence collection of the required information and preparation of procedures/documents as soon as possible.

The principal site types that will call for special requirements and a schedule of the typical requirements that may be required are shown in Table 13.1. The table is not exhaustive and not all the requirements highlighted will be needed on every occasion, but it provides an indication of what might be expected.

13.2 Protocols for all sites at operational times

On a working site there are a number of issues that may need to be considered if work is to be carried out during normal working hours. The areas of concern relate to safety and operational issues. A checklist of issues is provided in:

Text Supplement 13.1"Checklist for Working on Operational Sites" in Volume II

This checklist, whilst not exhaustive, demonstrates the type of situations that need to be considered when planning investigations on operational sites.

Risk and COSHH assessments should be carried out at the design stage of the investigation and, where possible, risks should be designed out of the investigation. Appropriate safety procedures and method statements should be prepared to mitigate the remaining risks and staff should be trained in appropriate safe working practices (see Chapter 11).

13.3 Typical additional special requirements

Some sites have unique operational characteristics e.g. related to personal/national security, physical hazards etc. Investigations at such sites will involve special arrangements to be made such as:

- **security passes -** for security reasons some organisations may wish to carry out a background check on all members of the site investigation team before they are allowed on their property;

- **access permits** – on some sites, visiting personnel may be required to have and display at all times an access permit for a site or a particular area of the site. A security pass may, on occasions, double as an access permit;

- **work permit**s - the site owner may run a Permit to Work or Permit to Dig system. Permits may be required on a shift/daily/weekly/monthly basis, for the whole site or for each investigation location;

- **training** - specialist training may be required for some sites before staff are allowed to work on site, for example on railway property in trackside areas, investigation staff will be required to attend courses on safe working practices and track awareness;

- **trained lookouts** - specially trained staff may be required to accompany working parties on the site in areas that are considered to be particularly hazardous. For example, London Underground require all work parties to be accompanied by a protection master, who checks that the electrical power to the tracks has been turned off before access is permitted and be aware of any rail traffic movements;

- **hoardings –** these may be required as protection to the public or other workers that pass close to the work site and to protect the clients or third parties equipment from accidental damage during the investigation;

- **warning signs/traffic management** - signs may be required to be located around the works to warn others that work is proceeding. For example, when investigation work is being carried out on a motorway there is often the need for lane closures. Warning signs would need to be placed at prescribed distances before the proposed work site and cones placed to redirect the traffic so that it passes at least minimum distance to the side of the works;

- **specialist equipment** - for some sites, particularly oil and gas terminals and chemical plants, standard drilling equipment may not be acceptable due to the possibility for potentially explosive gases to be in the atmosphere. Intrinsically safe equipment will be required;

- **PPE (personal protective equipment)** - for further information on PPE that may be required on some sites, see Chapter 10;

- **site access** - limitations may be placed on site access locations, timing of access to avoid congested peak times and acceptable movement routes around the site;

- **working hours –** these may be restricted to suit operational requirements of the site, such as in busy railway stations when work during peak travel hours may be restricted to reduce noise level to allow passengers to hear information announcements;

- **method statements** - work method statements may be required by the client or site owners to assure them that work is being carried out in a safe and responsible manner, taking due consideration to their requirements and to protect their users and assets;

- **medicals** - there may be a need for staff to have a medical examination prior to commencing work on the site. The examination may be as simple as a colour blindness and hearing test for work in areas where coloured warning lights or noise indicators are used to advise staff of danger. On other sites a full medical may be required if a perceived health risk exists and periodic health checks may be required.

The issue of security passes, access permits etc. usually requires considerable elapsed time and could delay commencement of the investigation significantly if it has not been allowed for in the programme. Likewise, if specialist training of staff is required to work in certain environments the training may need to fit in with an existing schedule being run by the site owners and this may also be a cause of delay to the work programme, as well as having a cost implication.

Set out below in Table 13.1 are the principal site types and associated special requirements.

Table 13.1 - Special requirements needed for certain site types

Site Type	Special requirements												
	Security pass	**Access permits**	**Work permits**	**Training**	**Trained lookouts**	**Hoardings**	**Warning signs**	**Specialist equipment**	**PPE**	**Site access & traffic routes**	**Working hours**	**Method statements**	**Medicals**
Railway stations and track		✔	✔	✔	✔	✔				✔	✔	✔	
Airports	✔	✔	✔	✔		✔				✔	✔	✔	✔
Ports	✔	✔	✔							✔	✔	✔	
Motorways		✔	✔	✔			✔			✔	✔	✔	
MOD sites	✔	✔	✔	✔		✔		✔	✔	✔	✔	✔	
Government establishments	✔	✔	✔	✔		✔		✔	✔	✔	✔	✔	✔
Nuclear power stations	✔	✔	✔	✔		✔		✔	✔	✔	✔	✔	✔
Prisons	✔	✔	✔							✔	✔	✔	
Oil and gas terminals	✔	✔	✔	✔		✔		✔	✔	✔	✔	✔	✔
Chemical plants	✔	✔	✔	✔		✔		✔	✔	✔	✔	✔	✔

N.B. This table is not intended to be a definitive guide to investigations requirements at these site types. Actual requirements should be checked on a site-specific basis.