NHBC

Environment Agency

Chartered Institute of Environmental Health

Guidance for the Safe Development of Housing on Land Affected by Contamination

R&D Publication 66: 2008 Volume 1

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Foreword

The safe development of housing on Brownfield land is a fundamental element in the delivery of sustainable development. The Barker review commented *"housing is a basic human need – fundamental to economic and social well being"*. Accordingly house building rates need to rise substantially to avoid increased homelessness and social division – but this should not be at the expense of losing our precious green open spaces.

Paramount to the sustainability of such development is the management of environmental risks both during construction and also to ensure the subsequent safe occupation by the new residents. This Guidance has been written to support and supplement the substantial body of existing advice in this field. Our aim has been to ensure that it is consistent with current best practice, it aligns with the Model Procedures and that it provides pragmatic and accessible advice which is equally useful and relevant to developers, regulators and their specialist advisors.

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Publication and acknowledgements

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This report has been developed from R&D66 published in 2000. That document was produced under the Environment Agency R&D Project P5-24 by CES and was jointly funded by the Environment Agency and the National House-Building Council (NHBC). This current report up-dates R&D66 (2000) by reference to numerous publications but most importantly to the Environment Agency Model procedures (CLR11).

The preparation of the report which was sponsored by the NHBC was carried out by a consortium drawn from Buro Happold and Enviros overseen by a steering group consisting of George Fordyce (NHBC), Trevor Howard (Environment Agency) and Bill Baker (Chartered Institute of Environmental Health). The main authors were Hugh Mallett (Buro Happold) and Louise Beale (Enviros) who gratefully acknowledge the advice and assistance provided by the Steering Group and also by their respective colleagues, most notably Maddy Bardsley, Heidi Hutchings and Tim Rolfe (Enviros) and Simon Pilkington and Louise Taffel Andureau (Buro Happold).

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Executive summary

This Guidance has been prepared on behalf of the NHBC (National House-Building Council), the Environment Agency and the Chartered Institute of Environmental Health (CIEH). It updates earlier guidance (R&D66 – published in 2000) on the redevelopment of land affected by contamination. The guidance, whilst written to be relevant to housing development on such sites, is also generally applicable to other forms of development, to existing developments and to undeveloped land, where such sites are on land affected by contamination.

In the period since publication of R&D66 in 2000, a substantial body of technical guidance has been produced by the Environment Agency and others, including most importantly the Environment Agency Model Procedures (CLR11). These Model Procedures now form a framework within which the assessment of all sites of land affected by contamination should be carried out. This Guidance has therefore been prepared to accord with the Model Procedures, but has been written and published in a manner designed to enable the practical application of good practice within this framework by all of the relevant parties.

The Government's repeated commitment to the redevelopment of land affected by contamination (for both housing and other developments) emphasises the continued need for the adoption of the good practice procedures described here. Such good practice satisfies the requirements of guidance relevant to development regulated through the planning regime. In addition, development which complies with this good practice guidance will "as a minimum" ensure that the land is not capable of "determination" as Contaminated Land under Part 2A of the Environmental Protection Act.

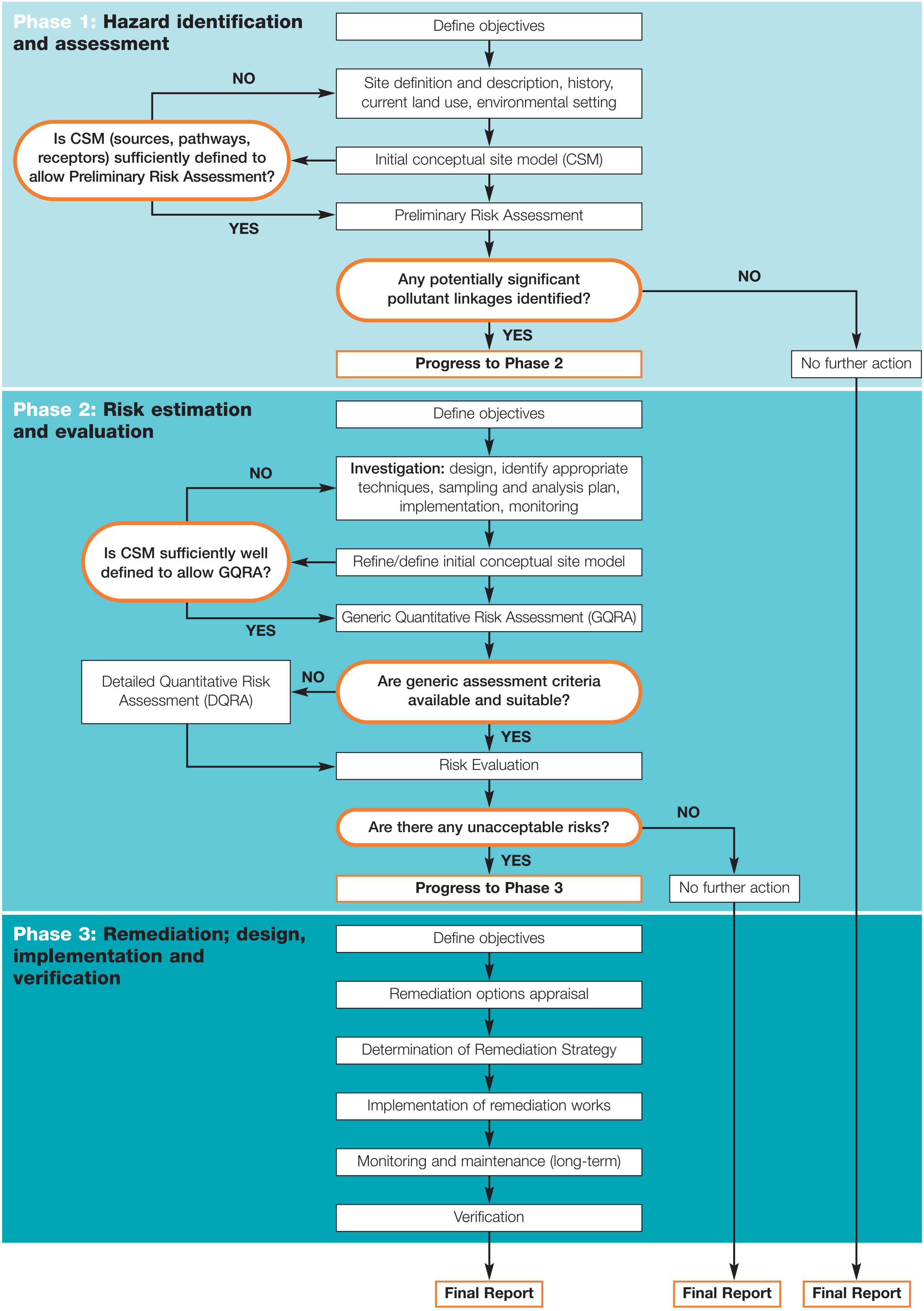
This Guidance describes in some detail the structured series of activities involved in the phased process of the management of land affected by contamination [Chart A].

- **Phase 1** describes the process and activities involved in hazard identification and assessment;
- **Phase 2** describes the process and activities involved in risk estimation and evaluation; and
- **Phase 3** describes the process and activities involved in remediation; design, implementation and verification.

The text in the Guidance is supported by a series of Appendices and technical Annexes which are presented in Volume 2.

KEY WORDS
Land affected by contamination; contaminated land; Planning Policy Statement 23; Part 2A Environmental Protection Act; housing development; site investigation, risk assessment; risk management; remediation, verification.

Chart A The phased process of the management of land affected by contamination



Introduction

General

This report has been prepared on behalf of the National House-Building Council (NHBC), who funded the work, the Environment Agency and the Chartered Institute of Environmental Health (CIEH). It updates the first edition of R&D66 published in 2000 (Environment Agency/NHBC 2000a), by reference to a substantial body of new regulation, guidance and advice. In particular, this update has been carried out to ensure consistency with the Model Procedures [CLR11] (Defra and Environment Agency 2004a). The guidance is particularly focussed on the development of housing on land affected by contamination. However, the advice is generally applicable to other forms of development and to existing developments.

Content and structure

The contents and structure of this report have been guided by R&D66 (Environment Agency/NHBC 2000a) and by Model Procedures (Defra and Environment Agency 2004a). This introduction sets out the basis of the technical guidance which follows. The principles of the identification and assessment of land contamination are briefly described. These technical/policy issues are then set into the context of housing policy. The main technical guidance of the report is presented in the three chapters of Volume 1, whose titles reflect the three phases of the process of managing land contamination. This text is supported by a series of Appendices and technical Annexes in Volume 2. A Glossary of technical terms and acronyms is presented at Appendix 1 and a listing of organisations involved in matters related to and affected by contamination at Appendix 2.

The policy, legislative and regulatory framework within which this guidance operates is complex. It is briefly described below (pages 11 to 16), with some text describing how the regime operates in Northern Ireland, Wales and Scotland given in Appendix 3.

The structured procedure for managing the potential risks associated with the development of housing on land affected by contamination is illustrated in a flow chart (Chart A). The text in the report follows this logical sequence. Phase 1 describes the tasks necessary to develop an initial conceptual site model. Phase 2 sets out the processes and techniques necessary to confirm or deny the validity of the potential pollutant linkages in this model. Various methods or tools are then described which aid in the assessment of the level of risk particular to each site. Phase 3 describes the process of the appraisal and selection of remediation techniques, its implementation and verification. Each of those Phases of work is detailed by its own flow chart (Charts 1, 2 and 3). This process is also illustrated by a 'case study' in Volume 2.

Table 0.1 Terminology of the phases in the management of land contamination

Terminology used in R&D66: 2008	Terminology used in Model Procedures (CLR11)
Phase 1: Hazard identification and assessment [Chart 1]	Risk Assessment (Preliminary) [Figure 2A]
Phase 2: Risk estimation and evaluation [Chart 2]	Risk Assessment (GQRA and DQRA) [Figures 2B and 2C]
Phase 3: Remediation; design, implementation and verification [Chart 3]	Options Appraisal and Implementation [Figures 3A, 3B, 3C and 4A, 4B, 4C]

Readership

This report is relevant to all of the various parties involved in the development of land affected by contamination. Particular attention is given to those involved in housing development, but the advice is also relevant to parties concerned with existing development on land affected by contamination and/or concerned with other types of development.

The parties who will find this report helpful are:

- housebuilders;
- developers;
- local authority and Environment Agency regulators;
- consultants who advise all of the above; and
- other professionals who advise landowners, developers etc. (such as chartered surveyors, insurers, funders etc.).

Objectives

The objectives of this guidance are:

1. To provide concise, accessible advice which is useful, practical and readily capable of implementation by all parties;
2. To describe both the process and examples of good practice in the risk based approach to the assessment of land affected by contamination (but also pitfalls to avoid);
3. To facilitate safe development by the production of consistent procedures, the improvement of data acquisition, interpretation and presentation;
4. To outline the roles and responsibilities of the various parties (e.g. the local authority regulator, the Environment Agency etc.); and
5. To encourage early liaison and a co-operative partnership approach between developers, advisors and regulators.

Consistent application of the principles set out in this report will assist in:

- The provision of confidence to all stakeholders with an interest in the development of housing on land affected by contamination;
- Ensuring that the decision making process is robust, open, transparent, provides traceability and properly reflects site specific variability; and
- The reduction of financial risk and residual liabilities.

Background

Pollutant linkages

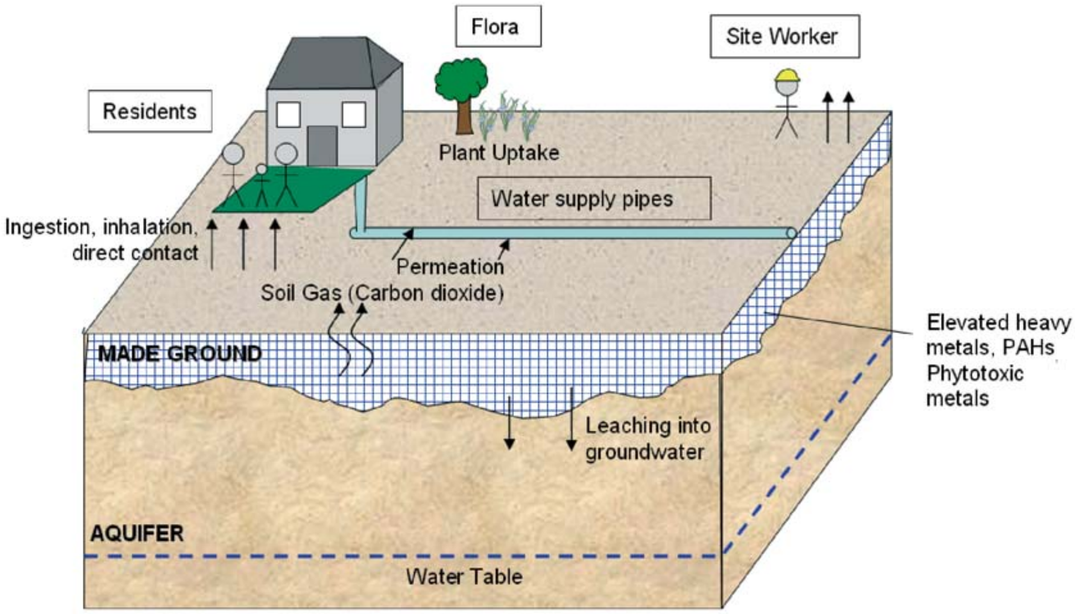
Government policy in relation to land affected by historic contamination is founded on a 'suitable for use' approach (Defra 2006a). This approach informs consideration of sites on land affected by contamination under each of the three main drivers for assessment and remediation, namely:

1. Voluntary action;
2. Development under the planning regime; and
3. Regulatory action to mitigate unacceptable risks, for example, under Part 2A of the Environmental Protection Act 1990.

In order for a risk to be realised related to land affected by contamination, a 'pollutant linkage' must exist. A pollutant linkage requires the presence of:

- a source of contamination;
- a receptor capable of being harmed; and
- a pathway capable of exposing a receptor to the contaminant.

A ‘source’ of contamination can be defined as a harmful or toxic substance present in the ground (as a solid, liquid or gas/vapour). A ‘receptor’ can be a person, an environmental subject (groundwater, surface water, flora or fauna) or a building/structure. The exposure pathway can be direct (e.g. skin contact with contaminated soils) or indirect (e.g. movement of a contaminant source through air, as contaminated dust, or via water) eventually to impact the receptor. An example of possible pollutant linkages in a simplified “Conceptual Model” of a site is illustrated below. By consideration of the sources, pathways and receptors in each pollutant linkage, an assessment can be made of the significance and degree of risk.



The presence of contamination

Contamination may be present at a site (in the ground and/or in the underlying groundwater) as a result of a historic or current industrial use. Typically such contamination is present because of leaks, spills or disposal of residue, wastes and excess raw materials. Contamination may also be present due to:

- the purposeful application of chemicals (e.g. the spraying of herbicide/pesticide);
- migration from adjacent land; or
- naturally occurring processes (e.g. elevated concentrations of particular heavy metals associated with specific geological strata).

The extent of contamination in the UK has not been well defined but it has been estimated that there could be up to 200,000 hectares of land affected by contamination in the UK (DETR/ Urban Task Force 1999a) and the Environment Agency estimated that the number of ‘problem sites’ (i.e. those that may need regulatory intervention) could range from 5,000 to 20,000 (Environment Agency 2002a).

In the context of housing development, government policy encourages the beneficial reuse of brownfield sites having set a target of 60% of new homes being built on such sites. Data from the NHBC (personal communication) showed that between April 2006 and April 2007 just over 11,400 sites were registered with the NHBC that year (down from 12,500 in 2005) and that in total about 40% of all plots were on land that was affected by contamination. These figures could be slightly misleading as a very high proportion (70%) of sites are small (<10 plots) and of these small sites only 30% were on land affected by contamination. For the larger sites (i.e. those with over 50 plots) over 80% were constructed on land affected by contamination.

Housing policy

The Government has acknowledged that there are substantial challenges to be faced in the UK with regard to home provision, namely:

- there is a significant gap between the supply of and demand for new homes;
- from 1970 to 2000 the level of new house building fell by 50% (to rates of around 175,000 per annum in 2000) whilst the number of households increased by 30%;
- the latest forecasts indicate that the number of households in England will grow by some 223,000 per annum of which 70% are single person households; and
- the Government has set ambitious targets to reduce the number of people in temporary accommodation, Bed & Breakfast accommodation, and sleeping rough.

In order to understand the issues better, the Government commissioned a review of housing supply (Barker 2003a and 2004a). This review of housing supply clearly identified that the housing market had not responded sufficiently to meet the demand for new homes. At the time of the report, Government plans for new homes totalled 150,000 per annum. The Government response to the Barker report (ODPM 2005a) signalled a commitment to build more homes for future generations, in particular to increase the rate of new housing build to 200,000 per annum. More recent policy statements have indicated the target will be raised with 2 million new homes to be built by 2016 and 3 million by 2020 (Y Cooper – Ministerial Statement, Hansard 23 July 2007).

In addition to this statistical information, the Barker report also identified some important social aspects related to this lack of provision. In some key phrases, the report noted:

> *"Housing is a basic human need which is fundamental to our economic and social well being."* and *"For many, housing is becoming less affordable."*

The report recognised this fundamental aspect of housing by noting that *"homes are more than shelter"* for people, because having a home will place people as a part of a community. It will provide access to the wide variety of services that are the basis of our social fabric (healthcare, schools, social services etc.). Homes are also the most significant element of a person's/family's financial stability.

One of the conclusions of the review (Barker 2003a) with respect to the rates of housebuilding was *"continuation at current rates is not realistic unless homelessness and social division are accepted"*. Barker made a number of recommendations with respect to housing policy, including that more land should be allocated for development. It was recognised that such a policy would have environmental impacts. However, it was also recognised that these impacts could be reduced by ensuring that land is used efficiently, that *"the most valuable undeveloped land is preserved"* and that *"land which society values least is used"*. The Government's response to these reports has recognised and accepted the basis of these recommendations. Recent policy statements have again signalled the importance the Government places upon the issue of housing: *"putting affordable housing within the reach not just of the few but of the many is vital both to meeting individual aspirations and a better future for our country"* (G. Brown July 2007).

The Government's special advisor on brownfield land, English Partnerships, recognises that much remains to be done in the sustainable reuse of brownfield sites, but was encouraged that in 2005, 74% of new housing was built on such land. In its guide to practitioners (English Partnerships 2006a) the importance of the complex inter-relationships necessary to realise these policy aspirations is stressed. *"Unlocking brownfield land successfully is about vision, leadership, professional skills and using the latest technologies. Creating sustainable environments should be at the forefront in brownfield projects, with land being reused to provide housing, employment and recreation - - -". " - - - Land reuse though is not an end in itself; it is also about local people being engaged in the development process and helping to shape the future use of the areas in which they live, work and spend their leisure time."*

In its response to English Partnerships work in developing a National Brownfield Strategy, the Government acknowledged that the re-use of brownfield land lies at the heart of a wide range of its policies for the revival of our towns and cities and achieving more sustainable patterns of development (CLG 2008a).

The implications for land affected by contamination are clear. The beneficial reuse of brownfield sites for housing can meet these policy aspirations. However, what is also paramount is that any such development must be carried out in a way which is safe for the residents of such sites, safe for their neighbours and without risks being realised to the environment.

Policy, regulation and guidance

European Directives

Soil Framework Directive [Proposed]
The proposal to establish a framework for the protection of soil was first published in September 2006 (EU 2006a). The document recognises that many countries already have in place some provision for soil protection. However because there is no EU legislation on soil protection, the proposal aims to establish a common strategy for the protection and sustainable use of soil. The proposed strategy is to; integrate issues regarding soil into other policies; preserve soil function; prevent threats to soil and to mitigate impacts. The draft Directive was not approved by EU member States in 2007 and at the time of writing this report, the European Commission was considering the future of the Soil Framework Directive.

Water Framework Directive [Directive 92/43/EEC]
The Water Framework Directive (EU 2000a) established a framework for the protection of inland surface waters, coastal waters and groundwater that, amongst other matters; prevents further deterioration, protects and enhances the status of aquatic ecosystems and ensures the progressive reduction of and prevention of future groundwater pollution. The Directive was transposed into UK law in 2003 and is being implemented to an agreed timetable.

Waste Framework Directive [Directive 2006/12/EEC]
The Waste Framework Directive (EU 2006b) provides a definition of waste that informs the Environment Agency's regulatory position (Ref Environment Agency 2006d). [See also Annex 7 of this report]. The Directive also lists different types of waste in the European Waste Catalogue (EWC). The excavation, treatment and re-use of contaminated soils (and groundwaters) on brownfield sites may involve materials which fall within this definition of 'waste' and therefore fall into the waste regulatory regime and require description under the EWC.

Landfill Directive [1999/31/EEC – supplemented by Council Decision 2003/33/EC]
The objective of the Landfill Directive (EU 1999a) was to prevent or reduce as much as possible the environmental impacts of landfills and landfilling operations. Wastes consigned to landfill must now comply with the criteria and procedures defined by the EU. Implementation of this Directive has had a significant impact upon the development of land affected by contamination, as costs for disposal to landfill have increased substantially and the number of landfills capable of accepting these wastes has reduced.

National policy

The Government's 'suitable for use' policy with respect to land affected by historic contamination:

- ensures land is suitable for its current use;
- ensures land is made suitable for planned future use(s); and
- limits the scope of remediation to that necessary to mitigate unacceptable risks.

The adoption of this policy will also ensure appropriate reconciliation of the various environmental, social and economic needs with respect to land affected by contamination.

English Partnerships guidance is aimed at assisting the decision making process at each phase of brownfield redevelopment (English Partnerships 2006a). It acknowledges that the redevelopment of brownfield land tends to be more complex and may expose developers to more risk than on greenfield sites.

Strategic planning

Spatial Strategies

Spatial Strategies [Regional Spatial Strategies in England (various authors and dates), the Wales Spatial Plan (Welsh Assembly Government 2004a), National Planning Framework for Scotland (Scottish Executive 2004a); N. Ireland – Shaping our future 2025 (Department for Regional Development Northern Ireland 2001a)] aim to make the planning system play a more strategic and proactive role in sustainable development. Land affected by contamination is a material planning consideration in these strategies and soils are identified as one of the environmental considerations for sustainable development to be considered in such strategies. The Environment Agency is recommending that all such plans and strategies draw appropriate attention to the potential for contamination and that all developments incorporate proper risk assessment, remediation and long-term management. In some key messages the Environment Agency stresses the importance of the Water Framework Directive, a holistic ('area based') approach to remediation which encourages sustainable remediation, enables appropriate development and which is appropriately validated.

Brownfield Action Plans

The Sustainable Communities Plan (SCP), published by the ODPM in February 2003 (ODPM 2005b), refers to the proposed National Brownfield Strategy (English Partnerships 2003a) with the specific aim of bringing a significant proportion of previously used land back into beneficial use. Accordingly, the Government called upon the RDAs to produce Brownfield Land Action Plans. Such Plans will be produced in co-operation with local authorities and other relevant agencies and statutory bodies and will fit closely with the Regional Economic Strategies and Regional Housing Strategies.

Legislation, regulation and guidance

There are two primary legislative/regulatory drivers which require the assessment of land affected by contamination prior to the re-development of a site:

1. The Town and Country Planning Act (1990) (OPSI 1990a) and related Planning Guidance;
2. Building Regulations (2000) (OPSI 2000a).

The particular Regulations and Guidance associated with these primary instruments vary between England, Wales, Scotland and Northern Ireland (see Appendix 3). Other regulatory regimes relevant to the development of land affected by contamination (e.g. regarding environmental assessment, controlled waters and waste) are also briefly described below. In addition to these Regulations and Guidance which apply solely with respect to development, Part 2A [Part 3 in Northern Ireland] of The Environmental Protection Act 1990 (as inserted by Section 57 of the Environment Act 1995) and associated Statutory Guidance (Defra 2006a) which apply principally with respect to historic contamination, are also significant in the development context.

The planning regime

In circumstances where sites are subject to redevelopment, the developer assumes responsibility for the costs of any remediation necessary to ensure safe development. Proposals for development are subject to scrutiny via the planning system. Developers must demonstrate to the satisfaction of the local authority that they have addressed all matters of material planning consideration (including contamination). In circumstances where land affected by contamination is to be redeveloped, advice provided under the planning regime is relevant [PPS 23 in England (ODPM 2004a) and PAN33 in Scotland (Scottish Executive 2000a) – see Appendix 3]. These documents provide advice on the implications of contamination for the planning system and advise local authorities about the determination of planning applications when the site is, or may be, contaminated. These guidance documents include clear statements that consideration of land quality and potential impacts arising from development are a "material planning consideration". A key provision of planning guidance is to ensure that the land is made suitable for its proposed new use. For example, PPS 23 states that local planning authorities must be satisfied that *"the potential for contamination and any risks arising are properly assessed"* [i.e. that the conceptual site model is sufficiently well designed] *"and that the development incorporates any necessary remediation and subsequent management measures to deal with unacceptable risks"*.

On sites where the land is known or suspected to be affected by contamination, developers must provide sufficient information with the planning application to demonstrate the existence (or otherwise) of contamination, its nature, extent, and the risks it may pose as well as evidence that such risks can be mitigated to an acceptably low level. It is recognised that following the phased approach (described in both Model Procedures and R&D66: 2008) does not necessarily mean that a detailed site investigation is required with every planning application. However, applicants are advised that **as a minimum** a desk study (including a walkover survey) should be carried out. This Desk Study will be sufficient only if it is capable of developing a conceptual site model identifying the sources of contamination and the pathways linking them to receptors. In addition, the Desk Study report must identify the means by which the pollutant linkages can be broken.

The expectation should be that on land affected by contamination, developers will have to carry out a phased programme of assessment which will include intrusive investigations. In order to ensure mutual understanding regarding the likelihood and possible extent of contamination and any implications for the proposed development, developers should, wherever practical, carry out pre-application discussions with all interested parties of the local authority (in particular, planning, environmental health, contaminated land officers and Building Control).

If the desk study confirms the potential presence of contamination, then further studies and investigations by the developer must be carried out to assess risks and identify the need for and scope of any remediation. Any remediation must remove unacceptable risk and make the site suitable for its new use. As a minimum, any such remediated and redeveloped sites should not be capable of being determined as contaminated land under Part 2A of the Environmental Protection Act 1990. PPS 23 also encourages developers and local authority regulators to utilise the opportunities presented by the development of land affected by contamination to enhance the environment.

Building Regulations
The Building Regulations (OPSI 2000a) aim to make sure that people living in and around buildings can do so without adverse effects upon their health and safety. The Regulations also set minimum requirements for the functioning of the building (e.g. environmental performance, accessibility etc.). The Guidance for meeting the requirements of the Regulations is set out in a series of related publications. Approved Document C (ODPM 2004b) deals with land affected by contamination and it requires that:

- reasonable provisions are made to secure the health and safety of persons in and about the building;
- people and the buildings themselves are safeguarded against contaminants on or in the site which will be occupied by the building and land associated with it; and
- people and the buildings themselves are safeguarded against contaminants on or in groundwater beneath the site which will be occupied by the building and land associated with it.

The Building Regulations require builders/developers to obtain building control approval of new developments. This is achieved by means of an independent check carried out by a building control provider (see below) whose responsibility it is to determine that the Regulations have been complied with.

The Environmental Protection Act and Statutory Guidance
Part 2A of the Environmental Protection Act 1990 and the Statutory Guidance (Defra 2006a, WAG 2006a and Scottish Executive 2006a) describe the contaminated land regime and is primarily aimed at dealing with the legacy of contamination. The main objective of this regime is the provision of a system to identify and remediate sites where, for the current use, contamination is giving rise to unacceptable risks to people or the environment. The government also anticipated that this regime would encourage voluntary remediation by land owners/occupiers. Under this regime, responsibility for dealing with the costs of remediation accord with the polluter pays principle. If the 'polluter' cannot be found, this liability passes to the current landowner (or other parties identified via a series of tests set out in the Statutory Guidance).

Other regulatory regimes

There are a number of other regulatory regimes which do, or can, affect the development of land affected by contamination. A detailed description of all of these legal and regulatory regimes is outside the scope of this document. However, a summary of the main issues related to each is set out in tabular form below, with some additional detail also presented in Appendix 3 where applicable.

Table 0.2 Summary of other relevant regulatory regimes

Issue	Regulation title	Comment
Environmental impact assessment	Town and Country Planning (Environmental Impact Assessment) England and Wales) Regulations 1999 Environmental Impact Assessment (Scotland) Regulations 1999 The Planning Environmental Impact Assessment (Northern Ireland) Regulations 1999	Requires developers of certain categories of project to carry out evaluation of the likely effects their proposals for development may have on the environment. An EIA will also identify the mitigation measures that will be implemented to reduce or remediate adverse impacts.
Flood risk assessment	Planning Policy Guidance Note 25: development and flood risk. PPG 25 (2001) Scottish Planning Policy (SPP 7). Planning and flooding (2004) N Ireland. Planning Policy Statement 15 (PPS 15) Planning and flood risk June 2006	Describes the approach that must be adopted by planners/developers to the assessment of flood risk for new developments. This may be relevant to development on land affected by land contamination where for example remediation solutions may become impaired by flooding.
Controlled waters [Groundwater and surface water bodies]	Water Resources Act 1991	Empowers the Environment Agency to issue a 'Works Notice' requiring remediation of controlled waters where there is pollution or likelihood of pollution.
	Groundwater Regulations 1998	Requires authorisation for the disposal of List I or List II substances under Part 2 of the EPA 1990. Describes procedures for prohibiting or regulating activities on land that pose a threat to groundwater from List I/II substances.
Waste management	Waste Management Licensing Regulations 1994	Describes the regulatory responsibilities of the Environment Agency to issue and maintain registers of waste management licences, exemption certificates, enforcement and licence surrender.
	Environmental Permitting Regulations	The Environmental Permitting regime in force from April 2008 streamlines and combines Waste Management Licensing and Pollution Prevention and Control to create a single approach to permit application, maintenance, surrender and enforcement. www.defra.gov.uk/environment/epp

Financial Regulations

A number of financial incentives have been introduced by the Government in order to incentivise the development of land affected by contamination and other brownfield sites. Contaminated Land Tax Credit Land Remediation Relief (Schedule 22 Finance Act 2001 (OPSI 2001a)) was introduced to provide 150 per cent accelerated tax credit to cover the costs of cleaning up land affected by contamination. This relief is subject to conditions which essentially relate to costs being incurred because of the presence of contamination which would not have been incurred for a comparable greenfield site. This was extended to cover Japanese Knotweed in 2008.

Wastes disposed of at landfill sites are subject to landfill tax. In 2007/8, the rate of landfill tax was £24/tonne and is to increase at £3 per annum until 2010. Contaminated spoil arising from the reclamation of land affected by contamination may be exempt from landfill tax subject to certain conditions, provided the reclamation; involves the reduction or removal of harmful contaminants from the site and facilitates development (or the provision of amenity/agricultural uses). This exemption will be phased out from 2012.

Early consultation with HM Revenue and Customs about either form of tax relief is recommended to ensure eligibility and to allow for processing of applications www.hmrc.gov.uk. The Treasury have recently proposed changes to these Financial Regulations www.hm-treasury.gov.uk. It appears likely that the tax credit scheme will be replaced by ‘Derelict Land Relief’, the details of which are yet to be finalised, but may be broadly similar to the original scheme. However, it also appears likely that the exemption from landfill tax for development schemes on land affected by contamination is likely to be withdrawn, although details for transitional measures (if any) have not been determined.

Roles and responsibilities

The roles and responsibilities of the various parties involved in the development of land affected by contamination **and the consultants who may advise them** are summarised below.

Table 0.3 Summary of roles and responsibilities

Party	Roles and responsibilities
Owner/ developer	Responsible for implementing site investigations using appropriately qualified persons, sufficient to undertake an appropriate assessment of potential risks. Responsible for demonstrating that potentially unacceptable risks can be successfully mitigated by remediation. Responsible for implementation of remediation works and verification. Particular responsibilities under CDM Regulations.
Local Planning Authority Local	Responsible for determining the appropriateness and acceptability of the developer's site investigation, risk assessment and proposal for remediation. Responsible for control of development, taking into account all material consideration including contamination. Responsible for ensuring that planning conditions are complied with.
Environmental Health [Contaminated Land Officers]	Responsible for carrying out duties of inspection and determination under Part 2A of the Environmental Protection Act 1990. Responsible for the provision of advice to Planning Department colleagues on technical matters related to land affected by contamination to include monitoring of compliance with planning conditions/Section 106 agreements. Responsible for determination of appropriateness and acceptability of the developer's site investigation, risk assessment and proposals for remediation.
Environment Agency	Responsible as the enforcing authority under Part 2A for 'Special Sites'. Responsible for control under the PPC Regulation to prevent future contamination. Responsible for the protection of controlled waters (under the Water Resources Act 1991 and Water Industry Act 1991). During development, responsible as a consultee (currently only on certain planning applications) to advise on pollution of controlled waters and waste management.
Health & Safety Executive	Responsible for the enforcement of health and safety at work (and provide particular advice when working on land affected by contamination. Particular provisions under CDM.
Local Authority Building Control	Responsible for implementation/enforcement of Building Regulations (ODPM 2004b). Consult with Environmental Health where contamination suspected.
National House-Building Council	An 'approved inspector' and able to grant approval under Building Regulations in England and Wales. Provider of the NHBC Warranty which covers both structural defects and land contamination for a period of 10 years. [Warranties similar to the NHBC Warranty are also provided by other insurance providers.]

The technical framework

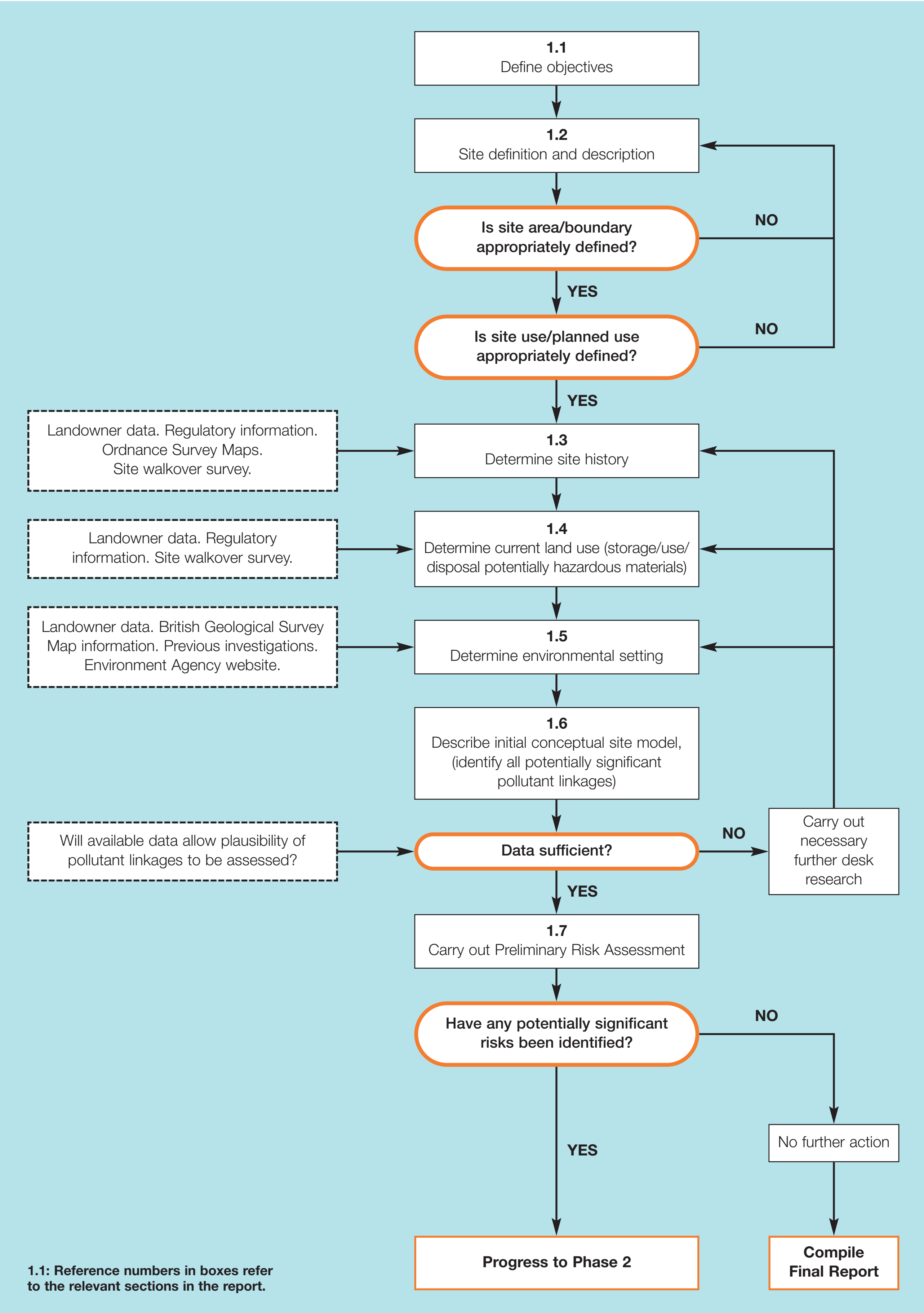
In the UK, the 'suitable for use' approach ensures that the management of land affected by contamination is risk based. This risk based approach applies to consideration of such land under both Part 2A of the Environmental Protection Act 1990 and under planning, and is described in the Model Procedures (Defra/Environment Agency 2004a). This document provides a technical framework on which decisions about land affected by contamination are based. This framework assists all stakeholders involved in making management decisions about such land: landowners, developers, regulators and their professional advisors. [The framework in Model Procedures has also informed the structure and content of this document, R&D66: 2008].
It is recommended that all elements of the investigations, assessment and remediation of land affected by contamination are properly referenced to and compliant with, relevant guidance (such as Model Procedures), British Standards (such as BS10175 (BSI 2001a) and BS5930 (BSI 1999a)) and other industry good practice documents referred to throughout this document.

To support this risk based approach, Government Departments, the Environment Agency and others (e.g. CIRIA, CL:AIRE, CIEH, BRE and AGS) have produced a considerable body of technical guidance, information and advice. This documentation is referred to throughout the technical advice in this report (Chapters 1 to 3) and is also listed in the references and bibliography at the end of this Volume 1.

One element of this body of guidance is concerned with 'guideline values'. These values are concentrations of particular chemical determinands in soils which can be used as generic assessment criteria in the assessment of risk to people. A series of reports presenting these Soil Guideline Values (SGVs) were published by the Environment Agency in 2002/2003 (see Bibliography). Concerns were expressed by a number of bodies about the use/practicality of some of these SGVs in response to which the Government set up an SGV Task Force. As a result of the work of this Task Force, proposals for a way forward were published for public consultation (Defra 2006b). At the time of preparing this report, the results of Defra's consideration of the consultation responses has not been published. However, the technical guidance presented in Chapters 1 to 3 has been drafted so as not be reliant on any particular threshold values.

In its response to English Partnerships National Brownfield Strategy, the Government signalled its intention to set up a National Brownfield Forum (CLG 2008a). The stated aim of this Forum is to *"bring together Whitehall Departments, the Environment Agency, the Health Protection Agency and industry stakeholders with the aim of promoting a more cohesive and inclusive approach to policy development and to encourage the exchange of best practice and knowledge"*.

Phase 1: Hazard identification and assessment



Phase 1
Hazard identification and assessment

1.1 Objectives

1.1.1 General

The overall aim of the Phase 1 work (often referred to as a "Desk Study") is to identify and assess the potential hazards that could be present on a particular site. It is important to remember that there will always be some site specific factors which, in combination are particular to that site. Every site must therefore be considered unique and thus considered on its own merits. The process of hazard identification and assessment begins with the description of the context of the site and the definition of the risk assessment objectives. It progresses by means of a series of tasks to conclude with a Preliminary Risk Assessment as illustrated in Chart 1 [and by the Case Study, Chart 1A in Volume 2].

The process of hazard identification and assessment thus comprises:

- Definition of objectives [Section 1.1.2];
- Description of the site, in terms of location, extent, boundaries and current appearance [Section 1.2];
- Determination of the history of the site land use [Section 1.3];
- Identification of the current land use, including use/storage of hazardous materials etc. [Section 1.4];
- Description of environmental setting and establishment of site sensitivity [Section 1.5];
- Description of the initial conceptual site model [Section 1.6].

The results of these tasks will allow a Preliminary Risk Assessment to be undertaken [see Section 1.7] which in turn will inform the identification of potentially significant pollutant linkages and determine the need for and scope of any further investigations (desk based or intrusive) in Phase 2.

Remember:
The sequence/timing of these tasks can be critical. For example, the site location and extent must be clearly established and defined before any of the subsequent tasks can be carried out.

1.1.2 Definition of objectives

Both the objectives and the scope of the assessment will vary according to who commissions the work, their reasons for such a commission as well as site specific factors, such as any regulatory involvement/action; the particular development proposals; funding; timescale etc.

The setting of appropriate, well defined and relevant objectives is crucial to all stages of the redevelopment of land affected by contamination. Lack of precision and/or clarity in setting objectives will inevitably increase uncertainties. This can lead to inappropriate conclusions being drawn and recommendations for further work which later turn out to be inadequate (i.e. the scope of work was underestimated) or unnecessary (i.e. an appropriately scoped Phase 1 would have negated the need for, or reduced the scope of, such further work). Objectives for Phase 1, the hazard identification stage therefore should include the following:

- to construct an initial conceptual site model;
- to enable a preliminary risk assessment;
- to inform the need for and scope of further work (desk based or intrusive investigations);
- to assess the potential for formal determination as Contaminated Land.

1.2 Site definition and description

Typically the information defining "the site" and providing an initial description will be provided by the land owner (or agent). This initial information will be supplemented by data gathered from other tasks as the desk study progresses. At the outset of any desk study it is crucial to understand the exact area occupied by the study site. Ideally a plan will be provided clearly showing the site's boundaries however this is not always the case. Should only an address or grid reference be provided for a site confirmation of the site's boundaries must be sought by requesting the client/site owner/agent etc. either to provide a plan showing the boundaries or annotate a plan provided by the report producer. Site ownership boundaries particularly on industrial sites can often not reflect boundaries as shown on contemporary maps and can form unusual shapes which are not intuitive. It is therefore inadvisable for the site boundary to be defined by anyone but the client or site owner. Incorrectly identified site areas can lead to significant errors in the assessment of risks and can result in abortive work (both costly and embarrassing to all parties!).

Typically a small scale plan showing the site boundaries will be accompanied by a large scale map showing the site location in a regional context. Ideally a national grid reference will also be provided. If the grid reference is not provided by the commissioning party, this must be identified, agreed and included in the desk study report.

Remember:
A site name (or even post code) is not a unique identifier. Your desk study may be on a site of the correct name, but it may relate to the wrong part of the country. A six figure National Grid Reference (NGR) uniquely identifies the a site and must be used to locate the land in question and must be stated in the report.

Having defined the site area, an accurate description of what currently occupies the area (i.e. buildings, hard standing, tanks) is required. This description should be kept concise but the location of sources of potential contamination such as tanks should be clearly defined. Where multiple similar features are present a suitable labelling system should be adopted and adhered to throughout the report (including figures). Descriptions of the condition of potential contaminating features such as tanks should also be made. The site description should include the following information:

- the lie of the land (topography)
- access to the site (i.e. names of roads, entrances etc.)
- the presence of any surface water features
- the proportion and make up of hard standing areas compared to areas of soft landscaping
- the layout of the site
- current site activities
- the nature of surrounding land uses
- information on any areas of identified contamination including those on surrounding sites should be listed.

1.3 History

1.3.1 Sources of historic information

Understanding the history of a site or parcel of land is crucial to understanding the potential for contaminants to be present on a site. It can also provide a useful indicator as to the likely location of those contaminants. The identification of the historic land uses of a site is usually determined utilising a number of sources of information. The most common sources are tabulated below (in alphabetical order) and described in more detail in the following text. A listing of useful sources is also given in CLR3 (Department of the Environment 1994a).

Although now rather dated (and thus not referring to some of the more recent data sources now available) the listing in CLR3 is an important reference to several sources of information not captured by the current commercial providers (see below).

Table 1.1 Sources of historical information (in alphabetical order)

Information source	Details	Contact details
Anecdotal evidence	Long-term employees and local residents can often shed light on the recent history.	
Bodleian Library, Oxford	Supplies A4 extracts of maps in 10 working days.	01865 277 013 www.bodley.ox.ac.uk
British Library, London	Map extracts of UK and parts of Europe available. Order maps prior to visiting.	0207 412 7700 www.bl.uk
Environment Agency	Provide data on licensable activities (e.g. waste management licences and pollution control permits).	www.environment-agency.gov.uk
Commercial third party environmental search providers	Provide historic maps and updated regulatory data electronically and in hard copy. [Does not currently cover N Ireland]	
Internet search engines	Can turn up data from a range of sources – best to use multiple search engines as they can produce very different results.	
Local Authorities	Hold records of past planning decisions, often intimate and detailed knowledge/records of land use. Hold information about historic landfills (provided via Environment Agency).	Planning, Environmental Health/ Protection and Building Control Departments
Local studies libraries	Can hold historic photos of the site. May have local historic accounts.	
National Library of Scotland Edinburgh	Maps extracts of most of the UK can be ordered on the day.	0131 466 3813
National Library of Wales Aberystwyth	Map extracts of the UK can be ordered on the day.	01970 632 800
Belfast Central Library	Map extracts of the N Ireland can be ordered/ viewed on the day.	028 9050 9100

Of these sources a quick and convenient method for obtaining the basic historic (and other) information is by purchasing maps from the commercial suppliers. This can be done via the internet within a short period of time. It is good practice for these products to form part of the Phase 1 report.

Remember:
Products from commercial suppliers, whilst a convenient and rapid source of data, on their own do not constitute a Phase 1 report. The assessment text that sometimes accompanies these otherwise factual reports is often highly caveated and caution should be used if reliance is to be placed on such text.

1.3.2 Historic maps

Background
The first comprehensive UK wide map series was produced by Ordnance Survey from the mid 1800s. The first maps were surveyed by County at a scale of 1:2,500 (1:25 inch) and are called the County Series. Later versions of the County Series were also available at a scale of 1:6 inch (1:10,560), which were superseded by 1:10,000 scale maps post decimalisation. Larger scale 1: 25,000 maps are also available from Ordnance Survey from the mid 1800s though due to their scale they are of limited use. If required, earlier maps can be available for some areas though generally these are not commercially available but can be sourced via the libraries listed.

Mapped evidence of site history
Historic plans can provide the following information:

- the history of industrial and other uses of a site and the surrounding area;
- the type of industrial activity undertaken i.e. early Ordnance Survey maps often identify industrial uses such as acid works, gas works, or lead works whereas later (or large scale) maps often only label these features as ‘Works’ or ‘Factory’ etc.;
- the layout of the site, including locations of buildings and tanks etc. at the date of the map; and
- evidence of excavations and infilling (e.g. mounds of material and earthworks).

When reviewing historic maps, as well as the obvious labelling identifying historic use of the buildings on the site, there is often other relevant information to be gained from their study. For example:

- distinctive names such as Gasworks Road, Clay Pit Lane etc. shown on maps indicate the former presence/proximity of such potential sources of contamination;
- the disappearance of cut features such as pits and quarries or water features such as canal basins or ponds can indicate land filling;
- re-routed water courses will indicate linear areas of infilling;
- care must be taken when interpreting slope marking symbols (which sometimes are not well defined) as it is very important to interpret spoil heaps or excavation features correctly.

The identification of site history from historic maps must be undertaken diligently. It is wrong to assume that this is a simple task that can be undertaken by untrained staff. The interpretation of mapped information requires care, precision and understanding. Important information regarding the meanings of abbreviations and symbols used on Ordnance Survey maps is given in CLR3 (Department of the Environment 1994a) to which appropriate reference must be made.

Description of site history
For the purposes of clarity and accuracy the reporting of historic reviews should be divided into two sections; on-site history and off-site history. All comments should be in chronological order starting with the oldest information. It is important that factual mapped information is accurately reported. For example, where the use of buildings have not been specifically identified the feature could be described as “a large (20,000m^2 approx) unlabelled building likely to have been of commercial/industrial use”.

Evidence of activities within the site boundary should be recorded and dates when features appear/disappear should be stated. Activities and features of note include all potentially contaminative land uses as well as pits, ponds, quarries, railway cuttings etc. which may have been filled. When describing features within the site boundary the text must avoid ambiguity. This can be achieved by using the term ‘in’ (i.e. “tanks were present in the north of the site”) rather than ‘to’ which could suggest features off-site (i.e. “tanks were present to the north of the site”). It is also important that the reported age of activities/features is accurately given. For example if a petrol station is shown on the 1965 map, but is not recorded on the 1935 map the most appropriate description is “A petrol station was constructed on the site at sometime between 1935 and 1965”. It is misleading to imply that the petrol station dated from 1965 (i.e. “a petrol station was present on-site from 1965”) as this could affect the period, extent and nature of the contamination.

Typically off-site historical descriptions should be concentrated on an area up to 250m around the site boundary. Features at greater distances should only be described if they are particularly large or have the potential to affect the land quality at the site (e.g. landfills) or the wider environmental quality of the site (e.g. power stations, large facilities such as oil refineries etc.). The distance and direction from the site boundary should be given as part of any off-site feature described. Particular care should be taken when defining the distance of a landfill from the site as it is most important to measure from the nearest landfill boundary rather than the central location of the landfill.

In report text describing both on and off-site histories there can be a tendency for features which have no potential to cause contamination (i.e. roads, housing etc.) to be overly detailed. This can make the history excessively long and can detract from the features which are of potential concern. In such cases general comments such as “the area becomes developed with housing by 1980” can be made which adequately demonstrate an awareness of this history without detracting from an appropriate focus on land quality.

It is good practice to include a copy of all available maps in reports. An example of a site history is presented in CLR3 (Department of the Environment 1994a).

Caveats

It is important to remember that historic maps (and plans) do not provide a comprehensive description of a site’s history. They provide details of the site from a date prior to the publication of the map (i.e. a snapshot in time). The period between map editions can be substantial (i.e. several decades). Not all map series are available for every date range in many areas of the UK and therefore there will be gaps in this mapped record for some sites. Potentially contaminative land uses could have come and gone in such periods and may therefore not be a part of this particular record. In addition, there will be potentially contaminative land uses which do not make it on to the map record, for example, small scale storage/use of hazardous materials, illegal/unlicensed waste disposal activities etc.

Different map series do map different features utilising differing symbols which can result in features disappearing from maps which may have remained on-site. Some features are also not mapped for security reasons such as airfields and other military installations. These areas are mostly shown as blank white areas on the map. This absence of any mapped information can be conspicuous and in such cases, there may often be clues in the map record. For example, the first record of an airfield or flying club on a map dating from the 1950s should be taken as an indication that this may have been a war-time airfield, occupied by the Ministry of Defence or the USAF and thus subject to further enquiry.

1.3.3 Historic aerial photos

Historic aerial photographs are available for most UK cities and are available from a number of specialist commercial providers including the Ordnance Survey www.ordnancesurvey.co.uk. There are also a series of aerial photographs taken between 1939 and 1954 by the Luftwaffe, RAF and USAAF which are available from various third party commercial companies and can prove invaluable in identifying features that are poorly mapped or are unclear such as spoil heaps and pits.

1.3.4 The internet

The internet can, on occasion, prove to be an invaluable source of a variety of information on the local area and/or the activities of a site. The use of search engines can enable rapid and easy access to relatively obscure data which otherwise would be very difficult and/or time consuming to source. However, in addition to authoritative/accredited information there is also the potential for erroneous or mischievous data to be retrieved from internet searches.

Remember:
The reliability of all information sources should always be carefully assessed and the source of any such data properly referenced in the report.

Examples of useful web sites include www.controltowers.co.uk which holds historic and current details of war time airfields. This can prove particularly useful as these airfields are ‘blanked out’ on historic maps. A source of near current detail of a site can be obtained from digital satellite imagery of the earth’s surface via an internet search engine. Reference to this photography can be useful in site orientation prior to or during a site walkover survey and also for subsequent reference (although the user should always determine the date of such imagery as it can be several years old).

Internet search engines should also be interrogated for accounts of local history. For example searching for a named factory/location will often reveal useful very detailed accounts of land use providing site specific data on the nature and extent of potential contamination associated with activities on the site.

1.3.5 Local Authorities

Local Authorities retain a great deal of publically available data that could prove useful for assessing the history of a site (usually at a relatively modest cost). It can however take some time for this information to be sourced from the Authority. Information available on potential use includes: details of planning consents, the planning register, information held by the environmental protection team and information of past landfilling activities.

1.3.6 Libraries

As well as the national libraries listed in Table 1.1 above, local studies libraries can provide a service that allows a search of their records for relevant documentation. These can include books, local newspapers, local photographs and historic accounts not available from other locations. Some industrial/former military sites have histories written by former employees which can prove extremely useful however such documents are not commonly available. Additionally, in particular regions or for certain topics, there may be specialist books or publications which provide invaluable data. For example in London, books such as The Lost Rivers of London (Barton 1992a) and The London County Council Bomb damage maps (Saunders & Woolven 2005a) are essential references. Similarly, 'The Mighty Eighth' (www.mightyeighth.org) provides details on the activities of the US Army Air Force based in the UK during World War II. Books and other publications which may be difficult to find are accessible via Inter Library loan.

1.3.7 Other sources

As described above (Section 1.3.1) other sources of information are listed in CLR3 (Department of the Environment 1994a). Detailed accounts of site histories may also be available from the corporate entities who previously occupied the site and in many cases have carried out their activities for many decades. For example, detailed accounts of many of the former gasworks are available from British Gas properties, details of steelworks from Corus, information on coal mining activities from the Coal Authority. The Law Society and Coal Authority have published a Directory (and guidance) of coal mining and brine subsidence claims (Law Society 2006a).

Anecdotal evidence of the past uses of a site can also be obtained (often by a walkover survey – see below) from people who either worked on a site and/or who lived in its vicinity. Although care should be exercised in the use of such information (and its anecdotal nature must always be appropriately reported) such data can be invaluable and may not be available from any other source.

1.4 Current use

Details about the current site use can be determined from a number of sources however a critical element in determining the current use of a site is the undertaking of a site walkover survey.

1.4.1 Site walkover survey

Site walkover surveys should be conducted utilising an aide memoire (site visit questionnaire) which is tailored to the type of site being audited i.e. active single use site, derelict or non-operational site, industrial estate etc. An example of such a questionnaire is given in Annex 1. Such surveys should be carried out only after essential base data has been obtained and assessed (see Section 1.2). A camera should always be taken on a site walkover. Photographs should be taken of; potential contamination sources, areas of visual contamination, of the site area as a whole and of any 'unusual' features (i.e. plants which are suspected to be Japanese

Knotweed, possible vent stacks, unusual grid patterns on the site surface, manholes and possible breather pipes etc.) current activities and standards of housekeeping etc.

There may be health and safety aspects associated with carrying out walkover surveys (e.g. lone working on derelict sites, sites with no power/lighting where internal access is required) and these should always be determined prior to the visit. Many organisations will have their own procedures for working in such circumstances to ensure the welfare of the surveyor, which normally includes as standard practice the availability of a mobile phone on all site walkover surveys.

The objectives of a site walkover survey will vary to reflect the specifics of both the site itself and also the nature of the project. Typically, the objectives will include the following:

- to identify and assess visual and olfactory evidence of contamination e.g. staining of concrete/soils, odours, presence of gas protection measures etc.;
- to identify locations of potential sources of contamination and assess their condition i.e. tank location, presence/condition of secondary containment/bunds, location of fill points, process areas etc.;
- to identify surrounding land uses and any potentially contaminating activities;
- to identify/verify the presence of potential receptors (on- and off-site) which may be affected by the identified sources;
- to obtain information on activities/procedures and standards of housekeeping etc. (e.g. by interview with a site manager or appropriate staff and review of site environmental records); and
- to assess site access and potential investigation locations and constraints.

Remember:
It is highly desirable that the site walkover survey is carried out subsequent to the initial determination of historical use. This enables any features identified by the map review to be examined and assessed on the ground. For example, areas of adjacent off-site quarrying – are those quarries still holes in the ground? Have they been infilled? Have they been developed and if so is there evidence of remediation measures? etc.

1.5 Environmental setting

1.5.1 Identification

The determination of a site's geological, hydrogeological, hydrological and ecological setting (and that of the surrounding area) is a crucial element of the Phase 1 work. These factors need to be determined to establish the vulnerability of the site with respect to the potential for contamination of the surface and sub-surface aqueous environments. Typical data requirements and the sources of such data needed to inform the subsequent sensitivity assessment are summarised in Tables 1.2 to 1.6 below. The availability of information may vary greatly between sites.

Table 1.2 Topography

Key information	Sources
Elevation of site in metres above Ordnance Datum;	Ordnance Survey maps (various scales);
Location relative to nearest built up area or prominent geographical feature;	Aerial photography;
Landscape description such as slope of land; abrupt changes of slope, cuttings and embankments etc. (e.g. slope down to river can give an indication of both surface water run-off direction but also local groundwater flow).	Visual observations from walkover survey.

Table 1.3 Geology

Key information	Sources
Made Ground – nature, thickness and variability.	Previous site investigations. 1:10,000 British Geological Survey (BGS) maps (1:50,000 maps can show significant areas of made ground e.g. landfills).
Drift (including recent unconsolidated deposits such as glacial and river deposits) – strata, description, thickness.	BGS maps (typically also include vertical and horizontal cross sections and may indicate depth to solid geology). BGS regional appendices (accompany 1:50,000 scale maps). Institute of Geological Sciences (predecessor to the BGS) Mineral Assessment Reports (accompany 1:25,000 maps of areas where sand and gravel deposits exist, include strata description, borehole logs, photographs). Last published in 1990, available directly from the BGS (01159 363241) but not currently on general sale. May be stored in public libraries.
Solid strata, description, thickness, relevant structural information (e.g. faulting, folding).	BGS maps (typically also include vertical and horizontal cross sections and may indicate depth to various strata). Borehole logs (BGS).
Mining – is the site within the zone of influence of current or former below ground or opencast mine workings, mine entries, subsidence.	BGS maps. The Coal Authority.
Radon – is the site in an area of radon potential.	Indicative Atlas of Radon in England and Wales [www.bre.co.uk/radon/protect.html]. Radon in dwellings in Scotland 1996. Radon in dwellings in Northern Ireland 1999.

Table 1.4 Hydrogeology

Key information	Sources
In England, Wales and Northern Ireland. Aquifer Classification; Scotland does not have a formal classification system comparable with that of England and Wales although SEPA is now classifying groundwater bodies for the purpose of the WFD. Soil vulnerability.	Environment Agency Groundwater Vulnerability maps (1:100,000) and accompanying regional appendices. In Scotland, Hydrogeological Map of Scotland BGS 1:625 000 and for soil vulnerability 1:625 000 Groundwater Vulnerability Map of Scotland.
Groundwater flow mechanisms; Groundwater flow direction and depth; Surface water/groundwater interaction; Groundwater quality.	BGS Hydrogeological maps (only cover parts of country where significant groundwater exists).
Groundwater abstractions (within a minimum of 1km of the site boundary).	Environment Agency records*. Commercial providers of regulatory search reports. Local Authority (hold records of private generally domestic unlicensed abstractions where known).
Source Protection Zones.	Environment Agency website. Commercial providers of regulatory search reports.
Discharges to ground, pollution incidents to groundwater.	Regulatory search report providers such as Landmark and GroundSure. Environment Agency*.

* requires written request for information, in letter or email form. Information will be chargeable and can take up to 3 months to be provided. Charges and response time vary with volume of information requested.

Table 1.5 Hydrology

Key information	Sources
Nearby surface watercourses and local surface water network (proximity to site and flow direction); Proximity to coastal waters.	Ordnance Survey maps
Surface water abstractions; Licensed discharges and pollution incidents to surface water.	Environment Agency records Commercial providers of regulatory search reports
River quality [RQO (river quality objectives) including chemical assessment criteria].	Environment Agency website www.environment-agency.gov.uk
Flood zones.	Environment Agency website www.environment-agency.gov.uk
Coastal waters [presence of marine nature reserves (MNRs), Special Area of Conservation (SACs), Special Protected Area (SPAs)].	Natural England website www.naturalengland.org.uk ('nature on the map' section)

Table 1.6 Ecology

Key information	Sources
Sites with ecological designations within 1km National Nature Reserves (NNR) Local Nature Reserves (LNR) (Local Authority Nature Reserves in Northern Ireland) Sites of Special Scientific Interest (SSSI). Areas of Special Scientific Interest (ASSI) in Northern Ireland) National Parks Areas of Outstanding Natural Beauty (AONB) (National Scenic Areas in Scotland) Special Areas of Conservation (SAC) Heritage Costs Ramsar Sites Special Protection Areas (SPA) Regional Parks (Scotland Only) Likelihood of the presence of protected species on-site	Commercial providers of regulatory search reports Natural England Scottish Natural Heritage Countryside Council for Wales Environment and Heritage Service

1.5.2 Assessment of site sensitivity

The sensitivity (vulnerability) of the site is then assessed on the basis of this data set, which will also enable identification of potential contaminant migration pathways. It is important that the characterisation of site sensitivity is logical, transparent, robust and repeatable. A scheme describing terms of sensitivity for groundwater, surface waters and ecology is presented in Annex 2. The assessment of site sensitivity by personnel with an appropriate, relevant technical background will increase the technical rigour and repeatability of the assessment. For example description of a site where the groundwater sensitivity has been classified as "High" could be as follows:

> *"The site is underlain by a Major Aquifer with groundwater abstraction within 1km. This groundwater is likely to provide baseflow to a sensitive watercourse less than 100m from the site boundary. The site is within the Source Catchment protection zone (Zone II)."*

The sensitivity of particular receptors at/adjacent to the site must then be taken into account during the subsequent risk assessment.

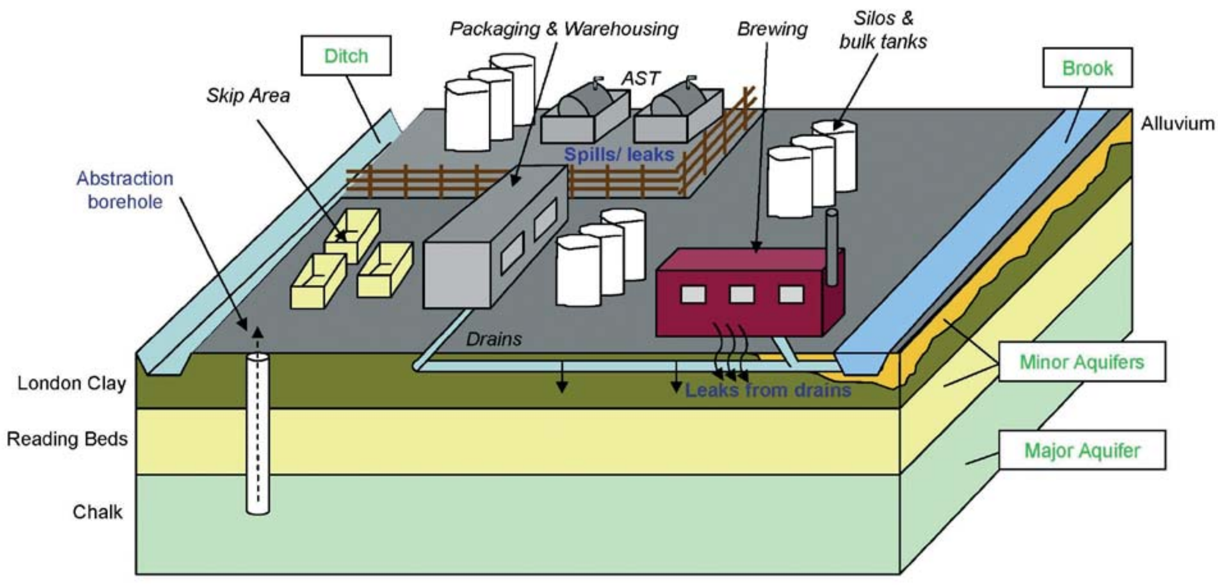
1.6 Initial conceptual site model

The following text from Model Procedures (Defra/Environment Agency 2004a) describes how the Phase 1 information (including data from the site walkover survey) is combined to develop an initial conceptual site model. *"A conceptual model represents the characteristics of the site in diagrammatic or written form that shows the possible relationships between contaminants, pathways and receptors." "The term pollutant linkage is used to describe a particular combination of contaminant-pathway-receptor."*

Getting the conceptual site model right and demonstrating a clear understanding of all potential pollutant linkages at this stage is crucial. It can then be used as a basis for designing a ground investigation, which tests the conceptual site model. If any potential pollutant linkages are missed then the site investigation is unlikely to be sufficient. Areas of uncertainty, e.g. exact location of former land uses or unknown ground conditions, also need to be highlighted. The conceptual site model is a device for improving our understanding of something, in this case the pollutant linkages identified for a site. It summarises the nature of a problem for which a solution is being sought.

The format of the conceptual site model is likely to be based on the complexity of the site. For instance the pollutant linkages associated with a residential house in an undeveloped area located directly on a Non Aquifer with no nearby watercourses may be easily described in words. However, increased numbers of pollutant linkages may be easier explained in a table or 3D cross section, or a combination of both.

Figure 1.2 Example initial conceptual site model



1.6.1 Contaminant sources

Potential contaminants associated with former and current land uses and other local factors need to be established. Naturally occurring contaminants can be associated with particular geologies. Contaminants can also migrate from adjacent land uses. The Department of the Environment's Industry Profiles describe specific industrial processes and the chemicals that are commonly found on industrial land. A summary of this information is given in CLR8 (Environment Agency 2002b) and also in R&D66: 2000 (reproduced here in Volume 2 Annex 3). However, not all contaminants listed with a particular land use will require assessment on all sites. For instance chloride is an essential micronutrient and is not considered an important contaminant in most soils, although it may be toxic to plants and have a detrimental effect on the performance of building materials at elevated concentrations (Environment Agency 2002b). Some sites may have significant concentrations of contaminants not indicated for a particular land use due to their infrequent occurrence, e.g. some toxic chlorinated solvents (used as degreasers). The opinions of a chemist or similar specialist should be sought at this stage to confirm the main contaminants of concern.

1.6.2 Receptors

Information on receptors may be obtained from the site walkover, the environmental setting and any proposed development plans. On any particular site, receptors can include any or all the following:

- human health (e.g. site occupants, adjacent land users, maintenance workers, trespassers);
- water environment (e.g. groundwater, surface water, coastal waters, artificial drainage);
- ecosystems (e.g. flora and fauna); and
- construction/building materials (including services).

Consideration should be given to how each receptor may be affected by the identified contaminants and to the sensitivity of that receptor. For example, separation of 'site residents' may be required into a number of more specific classes, such as; adults, children and elderly people for example. Similarly, groundwater resources would be sub-divided into Major and Minor Aquifers, to reflect their respective sensitivity (see Annex 2). Certain determinands have greater significance for some receptors than others. For example, phytotoxic metals such as copper and zinc can affect flora at much lower concentrations than those of concern to human health. The Industry Profiles and CLR8 identify receptors which are most likely to be at risk from exposure to these contaminants.

1.6.3 Pathways

The pathways by which a sensitive receptor may be exposed to a contaminant source can be identified from the earlier desk study. Geological maps can provide information on the presence of permeable strata through which contaminants present at the ground surface could migrate to groundwater. Exposure to contaminant sources can be either direct or indirect as indicated in Table 1.7 below.

Table 1.7 Examples of potential exposure pathways

Receptor	Direct pathways	Indirect pathways
People (Human Health) and animals (fauna)	Direct contact, dermal absorption, soil ingestion	Inhalation of dust/vapours, ingestion of fruit and vegetables and/or waters; migration of hazardous gases/vapours via permeable strata
Controlled waters	Spillage/loss/run off direct to receiving water	Migration via permeable unsaturated strata, run off via drainage/sewers etc.
Flora (plants)	Direct contact with contaminated soils	Uptake via root system, migration of hazardous gases/vapours via permeable strata
Buildings and structures	Direct contact with contaminated soils	Migration of hazardous gases/vapours via permeable strata

1.6.4 Updating the conceptual site model

The conceptual site model is likely to change to reflect the situation for an existing development and during/after proposed development. It is important that the model is updated with new information as the investigation, risk assessment, selection of remediation measures and implementation of risk management proceeds. For example, a model based on the risk of exposure of occupants of future development to contamination in soil by direct contact would need to be modified if, during ground investigation, waste deposits capable of producing landfill gas were encountered. The risks associated with accumulation of gases in confined spaces would then need to be considered. Further investigations of gas concentrations in the ground may be required, and the data from these may result in further amendments to the conceptual site model to reflect a new pollutant linkage.

The conceptual site model might also be updated if the form of the proposed development is changed. For example on a development incorporating private gardens that could be cultivated by residents for vegetables the conceptual model could include identification of toxic heavy metals to which residents could be exposed by eating contaminated produce. On a site with no private gardens and managed public open space, consumption of vegetables grown in contaminated soil may not be a relevant pollutant linkage.

Remember:
The conceptual site model is the key to the development of a proper understanding of land affected by contamination. Such a model must inform all three phases of work. An inadequate understanding of the conceptual site model will inevitably give rise to errors, delays and inefficiencies in subsequent enabling or development activity.

1.7 Preliminary risk assessment

Contaminated land risk assessment is based on development of a conceptual model for the site. As discussed in Section 1.6 the initial conceptual site model is a representation of the relationships between contaminant sources, pathways and receptors developed on the basis of hazard identification. Risk assessment is the process of collating known information on a hazard or set of hazards in order to estimate actual or potential risks to receptors. The guiding principle behind this approach is an attempt to establish connecting links between a hazardous source, via an exposure pathway to a potential receptor, referred to as a ‘pollutant linkage’. The objective of a Preliminary Risk Assessment is to identify the nature and magnitude of the potential risks. This involves consideration of:

- each potential pollutant linkage (contaminant source – pathway – receptor);
- current status of the site, construction activity, proposed new use etc.;
- short-term (acute) and long-term (chronic) risks;
- uncertainty (does enough data exist to provide confidence in the assessment?).

This approach is in accordance with the Statutory Guidance on Contaminated Land (Defra 2006a, WAG 2006a and Scottish Executive 2006a) and the Model Procedures (Defra/Environment Agency 2004a).

Risk is based on a consideration of both:

- the likelihood of an event (probability) [takes into account both the presence of the hazard and receptor and the integrity of the pathway]; and
- the severity of the potential consequence [takes into account both the potential severity of the hazard and the sensitivity of the receptor].

A pollutant linkage must first be established before tests for probability and consequence are applied. If there is no pollutant linkage then there is no potential risk. For example, when assessing the risks to groundwater from surface contamination at a site where groundwater is present within a Major Aquifer which is overlain by clay of significant thickness (say for example

50m) and there are no development proposals to penetrate the clay, then there is no plausible pollutant linkage. Consequently, the risks to the Major Aquifer need not be subject to formal risk assessment. In such circumstances, reports should clearly state the source and the receptor but state that because there is no linkage there is no risk.

There is a need for a logical, transparent and repeatable system in defining the categories of severity of consequence and likelihood as well as for the risk itself.

Severity (consequence) can be defined as the adverse effects (or harm) arising from a defined hazard, which impairs the quality of human health or the environment in the short or longer term. For example a consequence defined as *"Severe"* could be defined as *"Highly elevated concentrations likely to result in 'significant harm' to human health as defined by the EPA 1990, Part 2A, if exposure occurs"*. The type and form of the contaminant needs to be known in order to understand the effect on humans and therefore severity of potential harm. For instance different forms of cyanide behave differently. Complex cyanide (*"blue billy"*) is relatively "non toxic" whereas free cyanide is "highly toxic" (Environment Agency 2002b).

Probability can be defined as the chance of a particular event occurring in a given period of time. For example, a *"High Likelihood"* could be defined as *"where an event would appear very likely in the short-term and almost inevitable over the long-term, or there is evidence at the receptor of harm or pollution"*.

A scheme defining the various categories of severity and likelihood, based upon CIRIA 552 (CIRIA 2001a) is presented in Annex 4.

1.7.1 Risk classification

Once the consequence and probability have been classified for a pollutant linkage they can be compared to produce a risk category from "very high risk" to "very low risk". It is not possible to identify a risk rating of "no risk" as the acceptability of risk may depend on the viewpoint of the stakeholder concerned. It may be necessary to deal with a risk even if it is "very low" although this action may not be urgent. The following classification of risk has been developed to assist in qualitative assessment of potentially unacceptable risks.

Table 1.8 Categorisation of risk

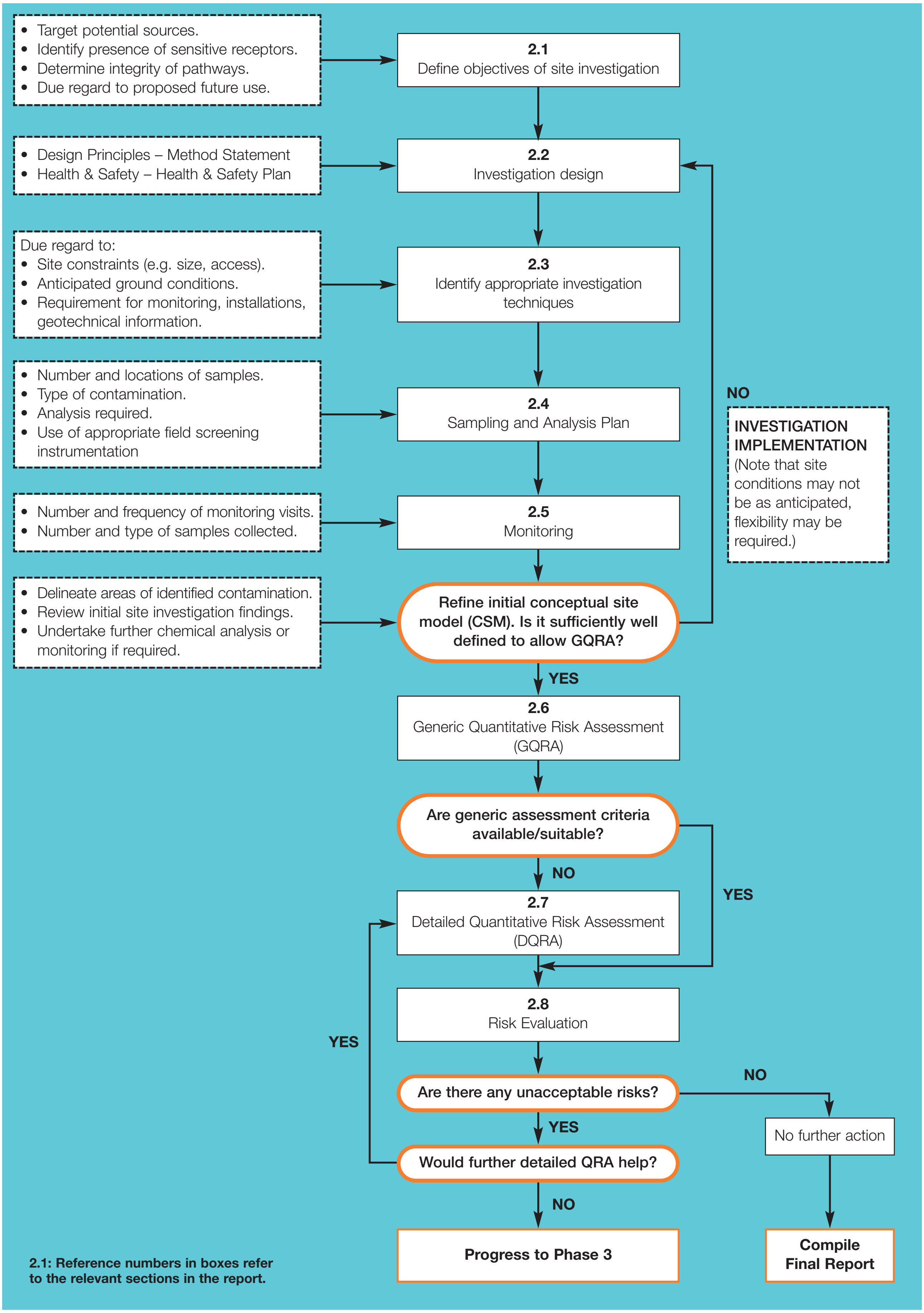
Probability (Likelihood)		Consequence			
		Severe	**Medium**	**Mild**	**Minor**
	High likelihood	Very high risk	High risk	Moderate risk	Low risk
	Likely	High risk	Moderate risk	Moderate/low risk	Low risk
	Low likelihood	Moderate risk	Moderate/low risk	Low risk	Very low risk
	Unlikely	Moderate/low risk	Low risk	Very low risk	Very low risk

It is also important that these terms describing the various levels of risk are appropriately defined. The definitions set out below are also taken from CIRIA 2001a. These are not "statutory" definitions and other terms may be used, provided that appropriate definitions accompany the terms of risk description.

Table 1.9 Description of risk levels

Term	Description
Very high risk	There is a high probability that severe harm could arise to a designated receptor from an identified hazard at the site without appropriate remediation action.
High risk	Harm is likely to arise to a designated receptor from an identified hazard at the site without appropriate remediation action.
Moderate risk	It is possible that without appropriate remediation action harm could arise to a designated receptor. It is relatively unlikely that any such harm would be severe, and if any harm were to occur it is more likely that such harm would be relatively mild.
Low risk	It is possible that harm could arise to a designated receptor from an identified hazard. It is likely that, at worst if any harm was realised any effects would be mild.
Very low risk	The presence of an identified hazard does not give rise to the potential to cause harm to a designated receptor.

Chart 2 **Phase 2:** Risk estimation and evaluation



Phase 2
Risk estimation and evaluation

2.1 Objectives

2.1.1 General

The overall aim of the work in Phase 2 is to estimate and evaluate the potential risks that have been identified in the Phase 1 Desk Study. The process of risk estimation and evaluation therefore begins with the initial conceptual site model and progresses by means of various field, laboratory and office based activities to refine that model and thus determine those risks which are potentially unacceptable as illustrated in Chart 2 [and by the Case Study, Chart 2A in Volume 2].

The process of risk estimation and evaluation thus comprises:

- Definition of objectives [Section 2.1.2];
- Design of the investigation [Section 2.2];
- Employment of appropriate investigation techniques [Section 2.3];
- Sampling and analysis [Section 2.4] and monitoring [Section 2.5];
- Quantitative risk assessment [Section 2.6].

The testing and refinement of the initial conceptual site model will be achieved either by further more detailed desk based study and/or by an appropriately focussed site investigation. The site investigation, must be informed by the data obtained during the Phase 1 desk study and will therefore be designed to test all of the identified potential pollutant linkages.

Aspects of the conceptual site model additional to the presence, extent (lateral and vertical) and concentrations of contamination must also be addressed in Phase 2. For example, as well as the determination of the site geology and hydrogeology, the physical parameters of both the soil and groundwater regimes must be investigated (e.g. density, particle size distribution, porosity, hydraulic conductivity etc.).

Remember:
Wherever possible, site investigations should combine aspects of both contamination and geotechnics (AGS 2000a).

2.1.2 Definition of objectives

Setting appropriate objectives which encompass both the geotechnical and geoenvironmental aspects without compromising the requirements of each discipline is crucial. If the objectives are not well determined, inefficiencies will be inevitable, in the worst case involving omission of vital data or duplication of work. Typically the objectives would include:

- Determination of the ground conditions (soil and rock strata, groundwater);
- Determination of geotechnical, geochemical and radiological conditions (of soils and water);
- Determination of the soil gas regime;
- Determination of unacceptable risks.

The objectives, must also:

- be framed to address the overall aims of the particular project;
- be well defined and appropriate;
- reflect the particulars of the planned use of the land (continuation of current use or its redevelopment);
- take account of any site specific issues or constraints.

For example, an appropriate objective might be; *"To determine the physical and chemical nature of the near surface (<1m) soils"*. Such a well defined objective will enable the site investigation designer to ensure that both the method of investigation and the sampling and analysis plan can be designed to ensure that the objective is achieved.

An example of an inappropriate objective (which superficially may appear similar) is *"To dig ten trial pits"*. It is clear that this objective could be satisfied, but with completely inadequate results as it would not relate to the conceptual site model, the site investigation design or the overall objectives of a particular project.

The objectives, once identified should be described in writing and included in the final report.

2.2 Investigation design

2.2.1 Design principles

As described above a site investigation must be designed to test all elements of the initial conceptual site model (i.e. potential sources, pathways and receptors). The investigation design must also take into account any site specific constraints (many of which will also have been identified in the Phase 1 work). The extent of the site (in three dimensions) must also be reflected in the site investigation methodology. Typically a well designed site investigation will employ a number of the available techniques (described in 2.3 below) in combination, to ensure the various objectives are addressed.

In designing a site investigation, consideration must be given to:

i. the aerial extent of the site and its accessibility;
ii. the depth intervals occupied by the strata of interest;
iii. any specific locations of potential contaminant sources;
iv. any parameters that will vary with time;
v. the presence of controlled waters (groundwater or surface water bodies) which could form contaminant migration pathways or could be receptors to any contamination;
vi. the soil gas regime;
vii. any potential contaminant sources with 'unusual' properties (e.g. dense phase non aqueous liquids which will sink through an aquifer to the top of an aquiclude and then migrate following gravity rather than groundwater flow direction);
viii. any potential contaminant sources which should also be investigated by on-site measurement (e.g. volatile compounds or radionuclides etc.);
ix. particular sampling techniques/storage vessels necessary to recover and maintain the integrity of particular contaminants;
x. the site investigation health and safety plan (which must reflect the potential hazards identified in the Phase 1 desk study);
xi. the need for on-site environmental monitoring (e.g. of site personnel, dust etc.);
xii. time, budget and any other particular site constraints.

Almost inevitably there will be conflict between the possible design responses to such issues. Often a balance is achieved by designing the investigation (including the chemical analysis) in phases (CIRIA 1995a, British Standards 1999a and British Standards 2001a, Environment Agency 2001a).

The usual sequence is:

i. An exploratory site investigation designed to prove the basis of the ground model; to confirm the existence (or absence) of potential hazards suspected from the Phase 1 study and to provide a level of data across the whole of the site area;
ii. A detailed (or main) investigation designed; to better define the ground model; to describe in more detail the nature and extent of identified contamination (in three dimensions); to confirm areas where contaminants are absent/below relevant thresholds); to examine areas of unusual variation; to focus on particular contaminant types etc.;

iii. A supplementary investigation designed to fully define particular facets of the conceptual model (often linked to the design of remediation treatment etc.).

Not all site investigations will require all of the three phases described above. It may be the case that an exploratory level site investigation provides sufficient data to enable an appropriately rigorous risk assessment and assessment of the need for and scope of remediation treatment. Often, on sites where limited (if any) potential pollutant linkages have been identified in the Phase 1 work, a site investigation carried out primarily for geotechnical purposes, may also include a limited exploratory level of investigation of contamination for confirmatory purposes.

2.2.2 Health and safety

Health and safety is the responsibility of everyone involved to ensure that site investigations are managed and conducted safely. There is a substantial body of legislation to be considered and adhered to in site investigation to minimise risks to the health and safety of the site workers, visitors, neighbours etc. All intrusive site investigations are governed by the Construction (Design and Management) Regulations (CDM) 2007 (HSC 2007a and associated Approved Code of Practice (HSC 2007b)) which came into force in 2007. The key aim of these Regulations is to integrate health and safety into the management of the project and to encourage everyone to work together to:

- Improve project planning and management resulting in improved competence, cooperation, communication, coordination and control;
- Ensure efforts related to Health and Safety are targeted where they can do the most good and reduce bureaucracy; and
- Identify hazards early, so they can be eliminated or reduced at the planning and design stage and that residual risk can be mitigated.

For all site investigations a risk assessment should be carried out. This risk assessment will form the basis of the Health and Safety Plan. This document should include details of the residual risks, how they are to be mitigated e.g. safe working procedure, individuals' responsibilities and contact details for emergency services, utility companies and key personnel. The Health and Safety Plan is a living document and should be kept on-site and updated as necessary. Tool box talks should be held to ensure that all people working on the site are competent, and aware of safe working procedures and residual risks. Where more than one party is working on a site each group must cooperate and coordinate their work to reduce health and safety risks and ensure safe working procedures are adopted.

A common hazard associated with site investigations is the presence of underground services. Sufficient time must be allowed to obtain sub-surface service plans (water, gas, electric etc.) from the appropriate utility companies. Safe systems of working must be adopted for working in areas where such services exist (HSE 2001a). A similar approach must be adopted when working in the vicinity of overhead services (HSE 1997a).

Remember:
Health and safety is everybody's responsibility.

2.2.3 The Sampling and Analysis Plan

The Sampling and Analysis Plan is an essential tool in the site investigation design [see CLR4 (Department of the Environment1994b), CIRIA (1995a), BS 5930 (BSI 1999a), Environment Agency (2001a), BS10175 (BSI 2001a) and AGS (2000a)].

Such a plan should describe the locations of all sampling points (in three dimensions) and provide appropriate justification (i.e. **why** something is being done). It will include broad definition of any instrumentation to be installed in boreholes etc. (e.g. groundwater or soil gas monitoring wells). It will describe any particular requirements for sampling (e.g. volume of sample, type of vessel, use of preservative etc.). Such a plan may also describe the monitoring regime (e.g. for groundwater level and chemistry, or for soil gas) although this may also be in a separate document. Further information on the design of groundwater monitoring is given by the Environment Agency (2006a) and for soil gas monitoring by CIRIA (2007a).

The design of a Sampling and Analysis Plan typically combines two elements:

i. Targeted sampling [sampling is focussed on known or suspected sources of contamination];
ii. Non targeted sampling [sampling is carried out systematically on a grid defined in terms of pattern and spacing. Detail about such systematic sampling strategies is given in CLR4 (Dept of Environment 1994b)].

The decision on whether to adopt one or other of these elements or to utilise them both in combination must be based upon the conceptual site model. That is; an understanding of the ground conditions, the contaminant sources, the potential migration pathways, the averaging area(s), how the data is to be interpreted, the requirements of the risk assessment as well as the development plan itself. It will of course also reflect aspects such as the time available, site constraints (e.g. presence of buildings/structures etc.) as well as cost. Notwithstanding the importance of these aspects, the critical influence must be that of the conceptual site model.

The conceptual site model must also inform the density of sampling. There is no "standard" sampling density for any particular phase of site investigation. Typically, the exploratory level site investigation will utilise a lower density (i.e. a larger spacing say 50m to 100m centres) than the detailed investigation (where spacing of 20m to 25m has been referred to (British Standard Institute 2001a). However the British Standard also emphasises the importance of site specific factors and the conceptual site model. For example, such a pre-defined spacing may be inappropriate for a site of very large of very small aerial extent. A larger spacing may be appropriate for a site where the ground conditions are more uniform/predictable. A tighter grid may be required where ground conditions are suspected to be highly variable or where localised areas of contamination are suspected. Judgement must be used to determine an appropriate sampling and analysis plan. Such judgement will need to take into account all of the factors described above, most particularly the specifics of the conceptual site model.

2.2.4 Uncertainty

No matter how many samples are taken and how much chemical analysis or monitoring is undertaken there will always be elements of uncertainty with respect to the ground conditions and the chemistry of the various strata, the groundwater and surface waters as well as the soil gas regime. This uncertainty reflects not only the partial nature of the sampling, the heterogeneous nature of many soils being investigated, but also temporal variations. This uncertainty needs to be considered in all subsequent stages (i.e. risk assessment, remediation design and implementation) and by all relevant parties. It is useful to quantify the levels of uncertainty that are associated with any particular site investigation design. The report CLR4 (Department of Environment 1994b) described a simple procedure for estimating the confidence level of identifying a "hotspot" of contamination for particular sampling grids. It is a salutary lesson that on a 1 hectare site even with 150 sampling points on a herringbone pattern there is still a 5% chance that the investigation will not detect a localised area of contamination occupying 100m^2. [More detailed information on the uncertainty associated with soil sampling and its quantification has been the subject of considerable research (Taylor and Ramsey 2004a and 2005a). This level of uncertainty is then compounded by consideration of the actual volume of soil sampled and analysed (typically a very small proportion [tiny fractions of a percent] of the whole soil mass) as well as uncertainties in the laboratory analysis (see Section 2.4 below).]

Remember:
A well designed site investigation aims to reduce uncertainty to a reasonable minimum whilst recognising that it exists and then taking it into account during the subsequent decisions on risk assessment, remediation design, verification etc.

2.3 Investigation techniques

2.3.1 Selection

Detailed guidance on-site investigation techniques is given in the two relevant British Standards. BS5930 (BSI 1999a) presents a code of practice for site investigations. BS 10175 (BSI 2001a) describes the code of practice for the investigation of potentially contaminated sites. Other sources of information about site investigation techniques are presented in documentation published by the Environment Agency (2000b), CIRIA (1995a) and the AGS (2000a). As described above, the techniques selected will be determined by consideration of the objectives of the site investigation together with the conceptual site model and any site specific constraints.

The choice of techniques(s) adopted will therefore reflect amongst other issues:

- Access;
- The presence of buildings, structures and hardstanding;
- The nature of activities on the site (i.e. operational or vacant etc.);
- The strata anticipated, depth to water table etc.;
- The sampling and monitoring regimes anticipated; and
- The time period and budget available.

Site investigation may involve both intrusive and non intrusive methods. Non intrusive methods can be useful because they are not disruptive and can cover relatively large areas rapidly. However, they do not measure chemical parameters directly and the data derived from them should be confirmed by appropriate intrusive investigations, sampling and analysis. Nonetheless, they can prove very useful in the general description/definition of ground conditions and in the focussing of intrusive techniques.

2.3.2 Non intrusive techniques

The principle non intrusive site investigation techniques are discussed in some detail in a report by CIRIA (2002a) and summarised in Table 2.1 below. The Environment Agency also provides guidance regarding the use of non intrusive techniques (Environment Agency 2000c and Environment Agency 2000d).

Table 2.1 **Summary of non intrusive techniques**

Technique and description	Pros	Cons
Aerial infrared photography: detects differences in reflected energy	Can cover large areas in a small amount of time by using remote controlled model aircraft Can highlight distressed vegetation resulting from contaminated ground or landfill gases	Results can be caused by natural effects such as waterlogging and drought Height of the aircraft can be difficult to judge and can influence the results Flying restrictions may apply
Ground penetrating radar: radar antennae transmits electromagnetic energy in pulse form; the pulses are reflected by the subsurface and then picked up by a receiving antennae	Rapid acquisition of data High resolution of near surface targets Can detect hydrocarbons Helps identify depth to bedrock Detection of non-metallic, metallic non-ferrous and ferrous objects	Poor signal penetration in conductive ground Cannot image beneath groundwater Presence of high conductivity areas such as clay layers can attenuate the electromagnetic energy Only suitable for relatively even ground
Electro magnetometers: based on the effects of ground conductivity on the transmission of electromagnetic energy generated by either natural or man-made sources	Can detect electrically conductive inorganic pollutants and ferrous objects (metal drums, underground storage tanks) Used to identify near-surface water-borne pollution	Presence of high conductivity areas such as clay layers can attenuate the electromagnetic energy Can be affected by ‘noise’ such as cables and pipes
Electrical resistivity: measurement of apparent resistivity along a linear array of electrodes, to produce an image-contoured 2D cross-section	Can detect electrically conductive inorganic pollutants such as leachate Can be used to differentiate between saturated and unsaturated soils Used to define the location and delineation of the subsurface, for example the base of a landfill site or pathways such as faults Facilitates the acquisition of repeat ‘time-lapse’ datasets, enabling the monitoring of pollutant migration and the progress of remediation	Contact resistance problems can be encountered in high resistivity ground Very difficult to use on hard standing Coarsening of resolution with increasing depth
Seismic exploration: based on the generation of seismic waves on the ground surface and the measurement of the time taken by the waves to travel from the source, through the rock mass to a series of geophones	Used to define the location and delineation of the subsurface, for example the base of a landfill site or the depth to groundwater Seismic refraction can help identify settlement	Slow production of data Presence of significant ambient noise (e.g. busy road) may inhibit the use of seismic refraction Seismic reflection not well suited for near-surface site investigations

2.3.3 Intrusive investigation techniques

There is a very wide range of intrusive investigations techniques, each of which will have particular properties which will need to be taken into account during selection of the preferred method(s). Typically more than one technique will be used in combination. The various advantages and disadvantages of the commonly used intrusive techniques are summarised in Table 2.2 below.

Table 2.2 Summary of site investigation techniques

Technique	Pros	Cons
Trial pits	Relatively quick easy and low cost to explore ground to 4m depth (or so) Provides good opportunity for visual examination, logging and sampling	Potentially disruptive of site operations/ conditions Reinstatement – can be difficult and costly (e.g. reinstatement of hardstanding) Potential for damage to below ground structures Constrained to above water table working Potential for cross contamination Installation of monitoring instrumentation not recommended
Window samplers	Provides rapid widespread coverage Samples suitable for geotechnical and chemical classification Allows installation of small diameter monitoring instrumentation Limited spoil for disposal. Easy reinstatement	Poor recovery and slow progress in coarse granular materials Relatively small volume samples not always representative Potential for loss of VOCs Installations have limited annular filter pack/ response zone
Shell and auger boreholes	Capable of boring through most soils. Permits undisturbed sampling and *in situ* testing for geotechnical purposes. Larger volume arisings facilitate visual examination, logging and sampling Permits larger diameter installation (50mm pipework inside 150mm filter)	Cobbles etc. inhibit progress and sampling. Not capable of drilling though rock Access can be problematic Drilling can disturb the natural groundwater/ soil gas regimes. Potential for losses of fine grained material and VOCs Potential to create migration pathways
Rotary boreholes	Capable of drilling though solid strata Permits installation (50mm pipework inside 150mm filter)	Core recovery in soft/loose soils poor or requires special techniques. Shell and auger often required to start holes Flush medium can be problematic (e.g. water flush impacts groundwater/air flush can impact soil gas regime/encourage migration of gases/vapours)

2.4 Sampling and analysis planning

Sampling (of soils, waters and gases/vapours) must be taken in accordance with the sampling and analysis plan (Section 2.2.3 above). This should then ensure that all the subsequent samples are representative and of sufficient volume and quality to allow the planned chemical and geotechnical analysis. When designing the sampling and analysis plan, consideration must be given to the type of analysis to be carried out and the use to which the data is to be put. This may influence, for instance, whether disturbed or undisturbed samples are required, or whether spot samples or composite samples are required.

Remember:
When taking samples in the field it is important always to refer back to the Sampling and Analysis Plan to ensure a proper understanding of where, why and what the samples are being taken for.

2.4.1 Sampling of soils

The decision of what soil material should be sampled will be determined by the sampling and analysis plan including consideration of the likely source and likely behaviour of the substances being sampled, as well as site observations regarding the geology and any evidence of contamination.

Representative samples of soils should be taken in accordance with the well defined protocol designed to; minimise cross contamination and loss of volatile compounds etc. and placed in containers appropriate for the subsequent suite of analyses. Samples must be properly labelled (AGS 2000a) immediately in permanent ink and packed in a cold cool box in a manner sufficient to survive transport. The potential for cross contamination can be avoided by the use of appropriate equipment, cleansing materials etc. The recording of the location of where the samples were taken from and their description is critical to the subsequent assessment. Samples should be kept cool and dark and despatched to the laboratory as soon as practicable. If hazardous substances (such as asbestos) are known or suspected to be present or previous investigations have indicated that levels of particular contaminants are very elevated, such information should be passed on to the laboratory to facilitate appropriate handling and sample preparation.

2.4.2 Sampling of surface water and groundwater

Surface water
Samples can be taken from static (lakes/lagoons) or moving water bodies (streams/rivers etc.). There are particular health and safety precautions to be considered in such circumstances. Sampling of surface water is described in detail in BS 6068 (BSI various dates). Meters and probes (e.g. for pH, conductivity, temperature etc.) used at the time of sampling provide useful support data to the laboratory analyses. Sterilised sample containers must be obtained and used from the analytical laboratory (some with appropriate preservatives). The comments regarding sample labelling, packing and transportation given above for soil samples are also pertinent for surface water samples.

Groundwater
The technique/equipment selected to sample groundwater from boreholes will be dependant upon several factors such as:

- The aquifer characteristics (depth to water, permeability etc.);
- The design of the monitoring well (diameter, volume of the well, location of the screened section and pipework);
- The likely nature of the contaminant (i.e. floating product [LNAPL], sinking product [DNAPL] or dissolved phase);
- The monitoring regime (i.e. a single occasion or a programme of visits).

Prior to sampling of newly installed wells, cleaning and development may be required (dependant upon the monitoring programme, the specifics of the hydrogeological regime and the sensitivity of the resulting data). Sampling should not be carried out until the aquifer and the water in the well and gravel pack are in equilibrium (up to 14 days, though this is often not possible). When sampling dissolved contaminants, the sample must be taken only after purging of the well (water standing in a well becomes stagnant affecting its oxidation state and losing volatiles).

Typically, well head parameters should be monitored periodically during purging. Sampling should be undertaken once the parameter readings have stabilised. Alternatively, it is common practice top remove three times well volumes during purging, although there are concerns regarding the suitability of this approach, which is based on an American study. This approach should therefore only be used when monitoring of well head parameters is not practicable.

The potential for sediment to be present in a groundwater sample should be minimised (e.g. using lower flow rates, sample well above base of well etc.). Filtering of samples is best carried out by the laboratory, except where the sample vessel contains a preservative such as an acid. The sampling itself can be carried out by a range of techniques ranging from simple bailers and Waterra check valves through to a number of pumps (from temporary pumps used from the surface to semi permanent installations in the well). The selection of a preferred technique will reflect; the depth to groundwater, volume to be pumped, length and frequency of the monitoring programme etc. The comments regarding sample labelling, packing and transportation given above for soil samples are also pertinent for groundwater samples.

Soil gas
Comments with respect to the sampling of soil gases and vapours are given in Section 2.5.2.

2.4.3 Quality Assurance

Depending upon the particular requirements of any investigation, consideration should be given to the use of “blank” or “duplicate” samples. The objective of such samples is to demonstrate that the sampling and subsequent analysis have been undertaken to an acceptable degree of accuracy and precision. Blank samples include “trip” blanks (prepared by the laboratory before sampling) and “equipment” blanks (prepared in the field with a known solution using standard equipment). “Duplicate” samples are two samples taken from one source, but the identity of the sample point is not given to the laboratory. The duplicate data should be within 20% of each other provided the concentrations are substantially above the detection limit. There will be greater variability when concentrations are closer to the detection limit.

2.4.4 Scheduling of chemical analysis

The scheduling of chemical analyses on samples of soils and waters collected from a programme of site investigation will refer to the Sampling and Analysis Plan (itself informed by the Initial Conceptual Site Model) as well as the observations from the site investigation itself. Therefore the design of the analytical suites will refer to advice on the contaminants anticipated from particular historic and current land uses [from CLR8 (Defra/Environment Agency 2002a) and any relevant DoE Industry Profiles]. However the analyses scheduled must also take account of the sample descriptions and exploratory hole logs to ensure that possible clues to their chemistry (i.e. odour, appearance etc.) are appropriately investigated at the laboratory.

Chemical analyses should be carried out at laboratories appropriately equipped (with staff and resources) and accredited (e.g. by UKAS) to carry out the particular analyses being scheduled. The Environment Agency MCERTS scheme has been devised to provide assurance of the reliability of data from laboratory tests to promote quality and consistency in data from different laboratories. It sets limits for the precision and bias that must be achieved for analysis of particular substances and describes appropriate quality assurance procedures, including the use of reference materials MCERTS accreditation applies to analysis of individual parameters rather than to the laboratory as a whole (Environment Agency 2006b). Chemical analysis should be carried out by laboratories using MCERTS accredited techniques wherever these are available. In order to assist and simplify the process of scheduling chemical analysis, many laboratories have a range of ‘standard’ suites. Whilst this is a useful aide, it is no substitute for interrogation of the data by an environmental chemist and the selection of a suite specific to the site being investigated. Without this degree of scrutiny, it is common to find that; an inappropriate analytical suite has been scheduled, that key determinands have been omitted, or that inappropriately high limits of detection have been agreed etc.

Remember:
It is most important that in scheduling samples of soils and waters for chemical analysis that the analytical suite; responds to the initial conceptual site model, reflects observations on-site and has been determined by, or in consultation with, an appropriately qualified environmental chemist.

On receipt of the analytical data from the laboratory an initial high level review of that data must be carried out. The objective of this review is to determine whether the data set is consistent with field observations etc. or whether it may contain apparent anomalies. For example:

- soils which appeared “oily” were recorded in the field, but the analyses for TPH do not report elevated concentrations of hydrocarbon; or
- analysis of soils where no visual/olfactory evidence of contamination was observed, recorded concentrations of all determinands below “background”.

In such circumstances it is essential that the data is double checked with the laboratory. If doubts persist then it is recommended that the suspect sample(s) is/are re-analysed. If this initial review is not carried out, then often by the time a detailed assessment of the analytical data is undertaken, the sample is no longer valid, or may have been disposed off and there is no opportunity for validating the data.

2.4.5 Field test kits

There are a number of analytical tools now available which are suitable for use outside the laboratory (and laboratory controlled conditions). Such field test kits can range from relatively simple screening tools, to sophisticated instruments such as portable gas chromatography machines (see Table 2.3). The Environment Agency has recognised the potential value of such field test kits and a trade association (FASA) has recently been set up to promote their use [www.fieldanalysis.co.uk].

Remember:
It is important that data from field test kits is always supported by sample description and by confirmatory laboratory analytical data as well as an awareness of any specific limitations of the kit.

Table 2.3 **Summary of field test kits**

Technique and description	Pros	Cons
PID (photo ionisation detector) UV light source ionises compounds, causing them to become electrically charged, creating a current that can be measured	Handheld analyser for detection of hazardous compounds in air Interchangeable filter tubes available for specific contaminant detection	Not selective for contaminants other than benzene, methylene chloride or butadiene When used to measure total level of VOCs, cannot distinguish between different compounds. Sensitive to damp weather
FID (flame ionisation detector) Hydrogen flame produces high levels of heat to break bonds of organic compounds, forming positive ions detected by a change in flame conductivity	FID detects flammable gases/vapour. Very sensitive – measurement range as low as 0.1ppm. Results available within 30-75 seconds. Battery pack with 10hours of operation. Reasonably robust. Designed for use outdoors/on-site	Transportation of kit (hydrogen cylinder) problematic. Not intrinsically safe. Not gas type specific and requires oxygen (>13% approx) to record accurately
XRF Based on the effects of ground conductivity on the transmission of electromagnetic energy generated by either natural or man-made sources	Tests soil, air filters and thin film samples. Simultaneous analysis of up to 25 elements Non-destructive chemical analysis. Measurement range from ppm to high % levels Rechargeable batteries allow 8-12 hours of continued use	Radioactive source Expensive piece of equipment Turnaround time per sample: 1-2min
PAH RaPID assays Uses enzyme linked immunosorbant; PAH sample mixed with PAH-enzyme conjugate; magnetic field separates antibodies with bound PAH or PAH-enzyme conjugate; residual conjugate catalyses colour reaction measured by spectrophotometer inversely proportional to PAH concentration	Measures PAHs in soil and water 1-50 samples in 60min	Does not differentiate between different PAHs or other related compounds Water samples must be of neutral pH Soil type can affect the recovery of the contaminant Degree of accuracy can be poor and results often measured in ranges rather than point concentrations.
Portable Gas Chromatograph/ Mass Spectrometer Gas samples pumped into column; soil and water samples loaded into glass vials in an attachable oven, then headspace flushed into machine	Analyses VOCs in air, water and soil Can be operated in Selected Ion Mode and MS-only mode (appropriate for screening activities) Identifies compounds in range of parts per thousand No cool-down time required between sample runs	Machine weighs 16kg. Not readily "site portable". Expensive piece of kit Only lasts for up to 3hours between recharges Susceptible to interference. Instrument calibration can be a source of error. Results available within 10min

continued >

Table 2.3 Summary of field test kits *continued*

Technique and description	Pros	Cons
Chemical kit – analysis of inorganics Uses self-filling ampoules for photometric analysis of water samples. Colour reaction results from mixing sample with vacuum-sealed reagents pre-packed in ampoule	Range of colorimetric tests available for over 45 analytes Media: water and soil Measurement range: ppm Less than 2min per sample	Each analyte is tested for using a different kit Care must be taken to select test ampoules that will register the appropriate LoD
Chemical kit – analysis of toxicity Measures luminescence change caused by a toxic sample, using naturally occurring luminescent bacteria	Kits available for organics, metals, water-soluble contaminants, hydrocarbons and SVOCs. 22 samples in 75min Test includes presence of unknowns and the effect of contaminant mixtures	Biased towards acutely toxic compounds Test can be affected by pH and coloured extracts Potential ethical concerns
Chemical kit – analysis of TPHs, PAHs and PCBs Uses UV fluorescence where light from a mercury lamp is directed through an excitation filter to irradiate a sample extract	Soil and water samples Can separately measure GROs, EPHs and PCBs Measurement range: from 0.1ppm	Colour quenching can be an issue with very high PAH concentrations Quenching can also occur when testing for a non dominant species
***In situ* probe – analysis of VOCs and SVOCs** Membrane interface probe collects continuous vertical profiles of contamination distribution using gas detectors	Screens for VOCs and SVOCs in soil and groundwater in both free and dissolved phases Up to 80m of probing can be performed daily	Deployed from a Cone Penetration Testing unit, therefore requires use of a drilling rig Relatively expensive Ground conditions can affect performance
***In situ* probe – analysis of petroleum hydrocarbons** Laser pulses light down a fibre optic cable, which causes petroleum hydrocarbons to emit fluorescence	Detects gasoline, jet fuel, lubricating oils, coal tar, creosote, PAHs, BTEX etc. in soil Specially designed to detect heavy-end hydrocarbons More than 90 linear meters of continuous testing per day Concentrations from free-phase to residual concentrations	Deployed from a Cone Penetration Testing unit, therefore requires use of a drilling rig Relatively expensive Ground conditions can affect performance

2.5 Planning monitoring programmes

Monitoring programmes are most commonly employed to record parameters about the surface water, groundwater or soil gas regimes on a site. This reflects the potential for these parameters to vary with time, weather conditions etc.

2.5.1 Water monitoring

The monitoring of groundwater and surface water is essentially a repeat programme of sampling (described in 2.4 above) carried out at pre-determined intervals. Such a programme should specify the duration and frequency of the sampling events within the programme as well as the chemical parameters to be recorded. It is recommended that proposals for groundwater or surface water sampling are discussed with the Environment Agency prior to implementation.

2.5.2 Soil gas and vapours monitoring

The monitoring of soil gas and vapours is described in some detail in a series of recent reports; CIRIA (2007a), NHBC (2007a) and (Wilson et al 2008a). A British Standard was also published at the end of 2007 (BSI 2007a). Advice is given with respect to:

- appropriate monitoring methodologies;
- the design of monitoring programmes;
- available instrumentation;
- the parameters to be recorded;
- the protocol for recording the data obtained;
- the presentation of the data.

Field data should be corroborated by analytical data. Gas sampling and analysis is relatively rapid and will enable confirmation of routine on-site measurements and quantify any hazardous/ odorous trace components. Gas samples can be taken in either pressurised or non pressurised sampling vessels. A well defined sampling protocol will ensure consistent practice and provide confidence in the resulting data (CIRIA 2007a).

2.6 Generic Quantitative Risk Assessment (GQRA)

2.6.1 General

The data obtained from site investigation is then used to refine the initial conceptual site model. The potential pollutant linkages identified in Phase 1 will be confirmed or discounted. Some new pollutant linkages, for which there was no evidence at Phase 1, may also be identified.

For both new and existing housing developments, it is essential to estimate and evaluate both the long and the short-term risks to human heath. For new developments, this will include consideration of risks during construction and post-development. It is also important to consider risks to non human receptors such as surface waters, groundwater, flora and fauna. Developers need to be satisfied that any contaminants in the ground are not likely to damage building materials, services or underground structures. The presence of phytotoxic contaminants (toxic to plants) must be addressed in areas of the development where plants are to be grown, such as gardens and landscaped areas. Some sites may have sensitive ecosystems, such as ponds or woodland, which need to be protected.

Risk estimation is carried out either by using authoritative and scientific generic assessment criteria (e.g. Soil Guideline Values with respect to human health) or by deriving site-specific assessment criteria which are tailored to the particular circumstances of the site. The process of GQRA involves the comparison of the values of contaminant concentrations determined by the investigation of the site (by means of an appropriate sampling and analytical strategy) against relevant generic assessment criteria for the identified contaminants of concern.

2.6.2 GQRA for Human Health

The CLEA model

In 2002 DEFRA and The Environment Agency published technical documents relevant to the assessment of human health risks arising from contaminants in soil. The main Contaminated Land Reports (CLRs) 7-10, described the CLEA (Contaminated Land Exposure Assessment) software and Soil Guideline Values (SGVs) for various substances (see Bibliography). This CLEA software was updated in 2005 with the publication of CLEA UK (beta). These documents are currently the key instruments in the UK for the generic assessment of risks to human health risks from land affected by contamination. Accordingly, in 2002 DEFRA withdrew the DoE ICRCL guidance note 59/83 on contaminated land which had been widely used since 1987.

The CLEA software models the risks to human health from long-term exposure to contaminants, via various pathways, for a range of standard land use scenarios. To date SGVs have been set for nine contaminants – arsenic, cadmium, chromium, lead, nickel, mercury, selenium, phenol, toluene and ethyl-benzene. TOX Reports, providing background toxicological information have been produced for 23 substances (see reference list).

Standard land uses

SGVs have been set for the following land uses:

- Residential homes with or without plant uptake;
- Allotments;
- Commercial/Industrial land use.

Currently there are no SGVs for other common land use scenarios, such as schools, playing fields and public open space etc. Where the conceptual model for a site does not fit with one of these standard land uses, SGVs for a more sensitive use can provide conservative screening values, appropriate for generic assessment. For example, if assessing a playing field land use, SGVs for residential use without plant uptake will provide a conservative screening value, whereas SGVs for commercial/industrial land use would not. Failure against conservative screening values indicates a need to carry out a Detailed Quantitative Risk Assessment (see Section 2.7) or some other form of risk mitigation.

Routes to exposure

SGVs are also dependant on a number of assumptions, for example relating to soil conditions (pH and organic carbon content), the behaviour and type of pollutants and the availability of receptors. The CLEA model allows consideration of the following pathways:

Outdoor inhalation of soil vapour	Indoor inhalation of soil vapour
Outdoor ingestion of soil	Indoor ingestion of dust
Skin contact with outdoor soil	Skin contact with indoor dust
Outdoor inhalation of fugitive dust	Indoor inhalation of dust
Consumption of homegrown vegetables	Ingestion of soil attached to vegetables.

Consideration may also need to be given to other exposure routes which may be present on a development site. Many developments will incorporate barriers to exposure independent of any assessment of contamination, for example, areas of hardstanding provided for car parking. The presence of such features should be duly reflected in the consideration of exposure pathways and incorporated in the risk assessment.

Statistical assessment

The value of a contaminant concentration which is considered representative of the contamination on the site (or part of a site) must be derived from the statistical analysis of the chemical analytical data obtained from the investigation (Defra/Environment Agency 2002c (CLR7)). Recently guidance was developed (CIEH/CL:AIRE 2008a) to improve the general statistical approach and to support new Defra policy in this area in accordance with the “Way Forward” consultative document (Defra 2006c).

The previous guidance (Defra/Environment Agency 2002c) indicates that the mean value test should be used to compare a representative mean of the data (upper confidence limit of the mean, the US_{95} value) against the SGV. The US_{95} is a calculated value below which the actual average soil concentration will be 19 times out of 20 (i.e. 95% of the time). In other words, comparison of the US_{95} value against relevant assessment criteria can provide a reasonable degree of confidence that the actual average concentration of contaminant on the site is below (or above) that criterion.

Consideration must also be given to the relevant averaging area and to the most appropriate method of grouping the data, both of which **must relate to the conceptual model**. For instance, the data can be grouped spatially (i.e. for individual zones within a site) or by particular strata. The required approach may vary for different contaminants, as some may be associated with specific current or historical activities carried out in a particular location while others may be associated with materials (such as made ground) brought on to level the site.

Example:
For a site where chromium contamination is associated with a particular type of fill material, division and characterisation of data by the various types of Made Ground may be appropriate. Conversely, on the site of a former plating works, where soil contamination is associated with former chromium plating tanks, spatial division of data would be required.

Where individual, or a small number of samples contain much higher or lower concentrations than the rest of the dataset, statistical tests should be used to determine whether or not those unusual data form part of the same statistical distribution. The maximum value test is recommended to determine statistical outliers (Defra/Environment Agency 2002c) but other statistical methods (e.g. Rosner's test and the Q test) can also be appropriate. [Note: CIEH and CL:AIRE are currently preparing further guidance/advice on statistical treatment of data.] If statistical outliers are identified, this should lead to a review of the data. Such a review should critically examine:

- The potential for error introduced by sampling;
- The validity of the chemical analytical results;
- The potential on-site source;
- The description of the soil sample (e.g. on the trial pit log).

This will assist in determining the treatment of the outlier in the subsequent risk assessment.

Remember:
Statistical outliers should never be ignored or summarily dismissed as "errors" or "anomalies".

Comparison of data against SGVs
When the US_{95} values of contaminants fall below the appropriate SGV, those particular contaminants and/or the areas of the site for which they are representative, can be considered not to pose unacceptable risks to human health. Where concentrations of contaminants exceed the SGV, the presumption is that there is sufficient evidence for *potentially* unacceptable risk to human health to warrant further consideration. This further consideration might be investigation to establish, on the basis of more detailed data, whether there is an unacceptable risk, or to proceed to the implementation of remediation action. In a contaminated land advice note (Defra 2005a) guidance was issued which:

- confirmed that in order to determine a site as "Contaminated Land" under Part 2A of the EPA 1990 there has to be "significant possibility of significant harm" (SPOSH); and
- stated that SGVs mark the concentration of a substance in soil below which human exposure can be considered to represent a "tolerable" or "minimal" level of risk.

On this basis DEFRA went on to say that concentrations of substances in soil equal to, or not significantly greater than, an SGV would not necessarily satisfy the legal test of representing a "significant possibility of significant harm". In 2006, in its Way Forward document (Defra 2006c), DEFRA consulted on possible and technical options for resolving this and other areas of uncertainty. To date final, guidance has not been published.

Other UK Generic Assessment Criteria

Many consultants have developed their own generic assessment criteria (GACs) incorporating UK policy conditions with some using the CLEA model and others using alternative models for determinands for which there are no published SGVs. In 2007, a series of GACs were derived and published (CIEH/LQM 2007a) using the CLEA model beta version for 31 determinands for the four standard scenarios. The resulting published report also included full details of toxicological source information etc. These criteria may be considered suitable as a primary screening tool for the assessment of minimal risk levels. However, all of these various GACs must be used with some caution as they have not been formally reviewed or endorsed by Government or the Environment or Health Protection Agencies.

Cautionary note on the use of International Generic Assessment Criteria

International generic guideline values may also be of use as decision support tools when assessing a new contaminant, although such "guidelines" have no regulatory standing in the UK. Such guidance may have been developed in accordance with policy decisions which are different to the UK and therefore these guideline values can be difficult to modify to be compliant with the UK context. The guidance often refers to a standard soil with particular properties and therefore adjustments to the values may need to be made for UK soils. Associated detailed reviews of chemicals including the toxicological data may assist in a detailed risk assessment. Risk assessors must always be aware of the basis for these various international threshold values to ensure their applicability in the UK context and that the EA preferred approach in the absence of published SGVs is to move to a Detailed Quantitative Risk Assessment and the derivation of site specific criteria via CLEA.

Remember:
1. Government endorsed Soil Guideline Values (SGVs) currently exist for nine contaminants although toxicological background data has been produced to enable production of guideline values for a total of 23 substances (including the nine with SGVs).
2. Care should be taken when using guidelines values derived by others, especially without consideration of UK policy, and supporting evidence on their background should be provided.
3. Exceedance of an SGV does not necessarily mean that there is an unacceptable risk to human health but that further consideration is required.

Radioactivity

Threshold values at which radioactive substances come under statutory control with reference to UK legislation are defined in the Radioactive Substances Act 1993. The interaction between radiation and Part 2A is defined in the Statutory Guidance (Defra 2006a) which defines the criteria above which the local authority should regard harm as being caused. The "Radioactively Contaminated Land Exposure Assessment Methodology" (RCLEA) is Defra's recommended approach for GQRA related to land affected by radiological contamination. It applies to long-term radiation exposure situations and complements the CLEA model for non radioactive contaminants. The methodology is based on a set of mathematical models and data that calculate radiation doses from radionuclides in the soil (Defra 2006d, 2006e, 2006f).

Explosives

There are no UK generic guidelines for levels of explosives in soil but the Environment Agency have produced research reports on the toxicity and fate/transport of selected explosive compounds (EA 2000c). The US Environmental Protection Agency in Region 3 has carried out generic risk assessment to establish acceptable levels of these contaminants based on their toxic effects www.epa.gov/region03.

Asbestos

There are no UK generic guidelines related to the presence of asbestos in soils.

2.6.3 GQRA and controlled waters

Information on groundwater quality at a site is obtained directly from sampling and chemical analysis of groundwater within wells installed in boreholes and indirectly from leaching tests (which are largely restricted to metals). Leaching tests on soil samples are also important, particularly when soil/made ground has previously been protected from leaching by the presence of buildings or hardstanding.

Guidance is provided in CLR1 on estimating and evaluating risks to groundwater and surface water (Department of the Environment 1994c). This provides a framework for assessing the impact of contaminated land on groundwater and surface water. The Environment Agency has developed a tiered methodology (Environment Agency 2006c) to derive remedial targets for soil and groundwater to protect water resources. Although primarily aimed at deriving remedial targets for site remediation, the methodology also predicts the impact on water receptors for a given set of site conditions and so can also be used to determine whether remedial action is required.

Risks to water quality are largely related to the toxicity and mobility or leachability of soil contaminants rather than just the total contaminant concentration. The first tier of the assessment (Tier 1) is carried out by comparing measures or estimates of the concentration of contaminants in the soil pore water (e.g. from leachability tests) with the guidelines acceptable in the target water resources. The initial Tier 1 assessment is thus used as a screen to determine which, if any, of the soil contaminants could potentially pose a threat to water resources. [Tier 2 and Tier 3 assessments are carried out at the Detailed Quantitative Risk Assessment stage – see Section 2.7.]

The Environment Agency has published advice to third parties on the pollution of controlled waters with respect to Part 2A (Environment Agency 2002d) and has revised guidance on the assessment of contaminant leachability (Environment Agency 2006c). The results of these analyses should be compared with relevant water quality standards, which may also include background water quality. The Drinking Water Standards (OPSI 2000a) should be used for initial comparison, although care in their use is needed as they are only strictly applicable to water intended for human consumption. Chemical analysis results can also be compared to Environmental Quality Standards (EQS) for fresh and salt waters as derived from the EC Dangerous Substances Directive (Ref 76/464/EEC). EQSs are given as annual average figures and they indicate the concentration of the specific substance that is protective of aquatic life, which are typically aquatic invertebrates or fish. Some EQSs vary with water hardness and so this parameter must be included in the analytical suite. The Environment Agency is currently drafting further guidance on the assessment of TPH data (Environment Agency in preparation) and on the setting of remedial targets.

As with the soil standards, international generic assessment criteria for protection of groundwater may also be considered in GQRA. However, caution must be adopted if they are referred to as they have no regulatory status in the UK.

2.6.4 GQRA and the built environment

Various contaminants can represent a risk to buildings and structures, for example through an explosive risk (e.g. methane) or by material degradation (e.g. sulphate attack on below ground concrete). Useful guidance on the assessment and management of risks to buildings, building materials and services from land affected by contamination has been published by the Environment Agency (Environment Agency 2000d).

Generic guidance in relation to assessing risks to buildings from soil gas is included in a number of publications. Assessment concentrations relating to the components of landfill gas are given in Waste Management paper 27 (Department of the Environment 1991a) and Approved Document C in relation to the Buildings Regulations (ODPM 2004b and OPSI 2000a). Detailed guidance on investigation, risk assessment and development of gas contaminated land has been published by CIRIA (2007a); NHBC (2007a); CIEH (2008a) Wilson & Card (1999a); British Standards (BSI 2007a) and the BRE (1991a and 2001a). The approach in all of this recent guidance is based on the calculation of a Gas Screening Value (GSV). The GSV is calculated by multiplying the gas concentration (% v/v) by the borehole flow rate for each borehole (l/hr). The GSV can then be compared against derived thresholds to define the “Characteristic Situation” for the site (CIRIA 2007a) or a “traffic light” colour code (NHBC 2007a) which in turn informs the risk assessment and the need for and scope of remediation action.

Approved Document C (ODPM 2004b) also considers the types of contaminants that may be left *in situ* beneath building footprints and requires the treatment by removal, filling or sealing of oil and tarry materials, corrosive liquids and combustible materials beneath proposed buildings. Where high levels of contamination are found, removal is often the only viable option as contaminants can migrate if/when the groundwater regime is influenced by the development. Approved Document C recommends that in such circumstances, specialist advice is sought and that the local authority environmental health officer is consulted.

Sulphate can adversely affect buried concrete structures by sulphate attack. Measurements of sulphate and pH can be made to allow assessment and appropriate classification based on guidance from the Building Research Establishment (BRE 1994a).

Currently, the various water companies refer to different standards when assessing the potential risks to water supply pipework. A number rely on guidance published by the water supply industry body, WRAS (2002a). However, the derivation of the various thresholds in that guidance is not clear and is not risk based. More recent guidance (UKWIR 2004a) has proposed that the assessment of the hazard to water pipes should based on consideration of the three pathways for exposure of the pipework to ground contamination, namely: contact with migrating groundwater, permeation of vapour and direct contact with soils.

2.6.5 GQRA and ecological systems

Assessment criteria for risks to ecological systems are currently less well developed than those for human health and water quality. The Environment Agency in conjunction with others including Natural England, the Countryside Council for Wales and Scottish Natural Heritage is developing a framework for ecological risk assessment which is supported by Government. This framework is being developed to support decisions regarding risk to eco-receptors from contaminated land under Part 2A and was subject to public consultation (Environment Agency 2004a). The major ecological drivers which are increasingly underpinning legislation and policy are looking to maintain (if already in good or appropriate condition) or otherwise enhance or restore ecological receptors. Therefore, achieving an Environmental Quality Standard (EQS) for an aquatic environment may not be good enough if that allows the existing quality of the environment to deteriorate. For example under the Water Framework Directive (WFD) the default is “Good Ecological Status” and only very prescribed exceptions will be allowed to fall below this standard. Under the WFD the prescriptions do not only relate to water quality but include quantity, geomorphological and aquatic biological regimes and these, together with water quality, are all surrogates for measuring/assessing the condition of aquatic habitat.

This approach is not confined to the WFD. Planning policy guidance (DCLG 2005a) and the latest PAS2010 (BSI 2006a) (a British Standard code of practice which aims to effectively manage/protect biodiversity in planning) also reflect this philosophy. Assessment of the risks to aquatic fauna as a result of deterioration in water quality can be made by comparison against Environmental Quality Standards (EQS), but this does not address risks posed by changes or removal of habitat. Consideration needs to be given to the effect of development on protected species (for example badgers, bats and Great Crested Newts), designated areas of nature or ecological importance (such as Sites of Special Scientific Interest) and the wider environment (such as the protection of trees, hedgerows and other flora and fauna). Advice on these issues may be obtained from Natural England, the Countryside Council for Wales and Scottish Natural Heritage or from local nature conservation groups. Dutch Intervention Values (DIV) for some compounds are based on ecotoxicological risk rather than human health and therefore may be appropriate for comparative purposes for particular ecological receptors.

2.7 Detailed Quantitative Risk Assessment (DQRA)

2.7.1 General

In some instances generic guideline criteria are either unsuitable, unavailable or exceeded. In these cases it will be necessary either to use other generic criteria or to calculate site specific assessment criteria, based on toxicity data and calculated exposure. A specialist risk assessor will almost certainly be needed to undertake the work, which should be based upon the comprehensive risk assessment guidance provided in the Model Procedures (Defra/Environment Agency 2004a). Developers should note that while generic criteria or models developed in other countries, for example the Netherlands or the USA, could potentially be appropriate, it is essential to critically examine the assumptions built into the criteria or models and determine if they are applicable to the site conditions and to the UK policy and good practice (see the discussion above in Section 2.6.2).

The regulatory authorities will need to be satisfied with the site-specific criteria proposed and the approach used in its derivation. The risk assessor should therefore produce a documented assessment which can be evaluated by the regulator, who will be looking for transparency in deriving values, evidence of sound science and clarity in any assumptions made. Annex 5 includes guidance on choosing appropriate site specific risk assessment models and the data requirements for such models. It also includes a précis of currently available risk assessment models. Issues for consideration when undertaking DQRA with respect to human health and controlled waters are described below.

2.7.2 DQRA and human health

In many cases the CLEA guideline values (SGVs) or other comparable generic screening values will be appropriate to estimate the long-term risks to human health that may be associated with new or existing housing developments. However, where there is concern about risks to humans already living on a site, for example, because an SGV has been exceeded, it may be necessary to establish site-specific criteria for use in DQRA. Contaminants for which TOX reports do not exist will need a toxicity review which could be several days work by a toxicologist.

When deriving a guideline value for a substance for which there is no TOX report, reference should be made to the approach outlined in CLR9 (Environment Agency 2002b). This prioritises various data sources, starting with authoritative bodies in the UK, then European Commission committees and international authoritative bodies (such as the World Health Organisation), then other national organisations and finally “authoritative bodies but for different purposes”. The Health Protection Agency (HPA) is currently drafting clarification notes and toxicological compendia for various determinands which, when available, will assist in this process. Some of the international thresholds are based upon toxicological data and this data may assist in a DQRA. However, as described for GQRA, care must be taken when using any such data to ensure that is relevant to (or can be adjusted to) UK conditions.

Detailed site specific criteria may also be required where the conceptual site model differs from that in the standard land uses. This might involve changes to one or more parts of the conceptual model, such as:

- To the receptor (e.g. changes to exposure times or the ages of the receptor might be required when considering users of a recreation area at an adult prison or a playing field at a school);
- To the pathway (e.g. changes to dermal contact at a sports field, or differences in building characteristics and depths of contamination for a volatile contaminants, or introduction of a new pathway such as eating fruit from trees on-site or swimming in a lake or removal of a pathway (e.g. the area is completely covered with hardstanding but volatile contaminants may get into buildings or outdoor air); or
- To the source (e.g. a combination of contaminants may have additive effects, synergistic (more than additive) effects or antagonistic effects – further details on looking at additive effects are provided in CLR9 (Environment Agency 2002b) and Environment Agency (2005a).

Many generic guideline values are not fixed for each defined land use, but vary according to soil characteristics. For example, soil organic matter affects benzo(a)pyrene by binding it to the soil so that its potential for mobilisation is reduced. It is therefore important to analyse for soil organic matter when assessing risks from organic compounds such as B(a)P. Soil pH also has an effect on the mobility of many contaminants. Thus, an appropriate guideline value must be derived by taking such factors into account (Environment Agency 2002c, updated version of CLR10 anticipated 2008).

Bioavailability and bioaccessibility

Bioavailability refers to the amount of contaminant from soil taken up by the body (i.e. enters bodily fluids). Bioaccessibility relates to the laboratory estimate of the fraction of a substance that is soluble in the gastrointestinal tract and therefore available for absorption (Environment Agency 2007a). There has been very little validation of bioaccessibility techniques with actual data on humans or animals. Bioaccessibility data using a physiologically based technique can be used to inform the risk assessment and adjust the uptake via a particular pathway. However, its limitations should be borne in mind and it should not be used on its own without other supporting evidence, e.g. geochemical information. The limitations/uncertainties of bioaccessibility data have been well documented by the Environment Agency (2005b and 2007a). A working group set up by CL:AIRE in 2007, is currently developing a framework aiming to assist in the use and interpretation of bioaccessibility data. The CIEH is currently sponsoring the preparation of guidance for regulators. A draft ISO on the application of methods for the assessment of bioavailability is also currently being developed (British Standards 2008a).

2.7.3 Controlled waters

If leachability test results exceed relevant generic environmental standards then more detailed assessment of the fate and transport of contaminants in the subsurface may be undertaken using the following guidance. Further stages in the methodology for deriving remedial targets consider dilution of infiltrating water in the aquifer (Tier 2) and then more complex processes such as attenuation or degradation are incorporated in Tiers 3 and 4 [Environment Agency 2006c] and ConsimV2 [www.consim.co.uk]. These assessments require substantially more data than a generic (Tier 1) assessment.

In deriving site-specific assessment criteria for pollution of controlled waters it is important to consider the requirements of EU and UK legislation. In particular the Groundwater Directive (Ref 80/68/EEC 1979a) requires that List I substances are prevented from entering groundwater and entry of List II substances is minimised to prevent pollution of groundwater. It should be noted that the Groundwater Directive will be replaced by the Groundwater Daughter Directive within the Water Framework Directive (WFD). There are already a small number of substances (e.g. nitrates and pesticides) within the WFD for which minimum standards are already in place. Similar requirements relating to surface water bodies are made under the Dangerous Substances Directive.

Natural (background) water quality should be protected and land remediated to a standard that ensures this. However, this may not be appropriate and in all circumstances cost/benefit should be considered when assessing the need for and type of remediation to be undertaken. The environment agencies hold and publish water quality monitoring data that may be used for assessment purposes. Water quality information is also included in a number of documents published by the drinking water inspectorate www.dwi.gov.uk.

2.8 Risk evaluation

The purpose of risk evaluation is to establish whether there is a need for risk management action. This involves the collation and review of all information relating to the site in order to:

- Address areas of uncertainty and their possible effect on risk estimates;
- Identify risks that are considered unacceptable in both the short and long-term;
- Set provisional risk management objectives for addressing the unacceptable risks.

2.8.1 Risk estimation from short-term exposure [Acute risk]

In some cases there may be risks to human health from short-term exposure to contaminants, for example from direct contact with temporary stockpiles of excavated material or where contaminants at depth have been exposed. Such risks may occur when construction work re-exposes contaminants or excavation releases volatiles or generates dust. Similar risks may occur on existing development where maintenance, repair or refurbishment may involve excavation of the ground. Where such potential risks are identified, exposure will initially be to the developer's workforce and therefore, risk mitigation measures should be described in appropriate health and safety advice. Evaluation of any such acute risks should be combined with the evaluation of long-term risks to human health and other receptors as described in Sections 2.6 and 2.7.

There are currently no UK guideline values for assessing acute risks from soil contamination, although occupational exposure limits have been set for exposure to contaminants in vapour and dusts (HSE 2005a). Where separate short-term effects from exposure to contamination are known, it may be advisable to consider a one off high soil ingestion rate, when deriving site specific assessment criteria (Environment Agency 2002c). Consideration should also be given to maximum concentrations rather than US_{95} values etc. When considering one off movements of vapours, controls on nearby personnel and monitoring may be more appropriate. A conservative approach to substances that could pose acute risks and where there is no recognised standard, would be to move directly to remediation action, rather than to try to derive a standard.

2.8.2 Components of development

Different components of a residential development, for example homes with gardens or flats with common areas, may have different sensitivities to contamination, based on an assessment of the risks with each component. Components of residential development might include:

- The dwelling unit as an entity (taking into account various structural options which may be employed, for example ground bearing slab, suspended floor) where exposure of receptors to certain contaminants is not influenced by associated external areas such as gardens;
- The dwelling unit in combination with
  - i. a private garden
  - ii. a communal garden
  - iii. a hard landscaped area;
- a private garden comprising soft landscaping;
- a communal garden/common areas comprising soft landscaping;
- hard landscaping.

There are a number of possible exposure scenarios which may occur if pathways are created following completion and occupation of a development. Penetration of cover materials due to excavation can occur, for example in the case of extensions, swimming pools, ornamental planting or drainage maintenance and construction. This may result in temporary surface stockpiling and longer term disposal of materials by spreading at ground level. Occupants of the dwelling, particularly very young children playing in gardens and communal areas and consumers of vegetables grown on the property, could be subject to accidental or uncontrolled exposure to the contaminant. Infiltration of site drainage by contaminated surface water or groundwater may adversely impact the quality of receiving waters or aquatic systems.

2.8.3 Identification of unacceptable risks

The identification of potentially unacceptable risks therefore commences with a comparison of the measured concentrations of contaminants in the soil (derived from the results of site investigation) with relevant generic or site specific assessment criteria. Risk evaluation involves the collation and review of this information in the context of the proposed development and its detailed components. It must involve qualification of the significance of this information with reference to the associated technical uncertainties, and especially the degree of confidence in the accuracy and sufficiency of the data produced, and consideration as to whether the assumptions used in the risk estimation are likely to have over or underestimated the risk. If the results of the above comparisons are marginal, the risk assessor may:

i. seek to obtain more data to refine the risk estimates;
ii. adopt a precautionary approach which assumes that the risks involved are unacceptable.

Often a cost/benefit analysis of these two options will inform the selection of the subsequent action. For example, on a site where slightly elevated gas concentrations have been found, rather than undertake an extensive monitoring programme it may be decided to adopt a precautionary design (i.e. install gas protection measures), thus saving time in the overall construction programme. The nature of the risk also needs to be taken into account. For example, if on a site, phytotoxic metals are recorded at concentrations marginally above relevant criteria, the financial and environmental consequences are relatively small and easily corrected, compared to the potential risks associated with elevated concentrations of landfill gases, together with the difficulties of retro-fitting gas protection measures.

Remember:
It is also important at this stage to take proper account of risk perception issues as this must be considered in both the identification of unacceptable risks and also in the setting of remediation objectives. Some more detailed information of risk perception and communication issues is presented in Annex 6.

2.9 Waste management

Development of brownfield sites often involves the production, handling and disposal of excess soil arisings as “waste”. Typical wastes include demolition materials and soils (including Made Ground) which may or may not be contaminated. Appropriate classification (and often pre-treatment) of waste is required prior to either re-use on-site or off-site disposal. Duty of Care associated with handling waste can have time and cost implications for the developer.

The definition and classification of waste are complex issues and must be fully understood at both this site investigation stage (where consideration of waste will influence the design of the site investigation, the sampling and analysis plan etc.) but also during remediation and site redevelopment (see Section 3). A summary of the waste management aspects of the development of land affected by contamination are provided in Annex 7.

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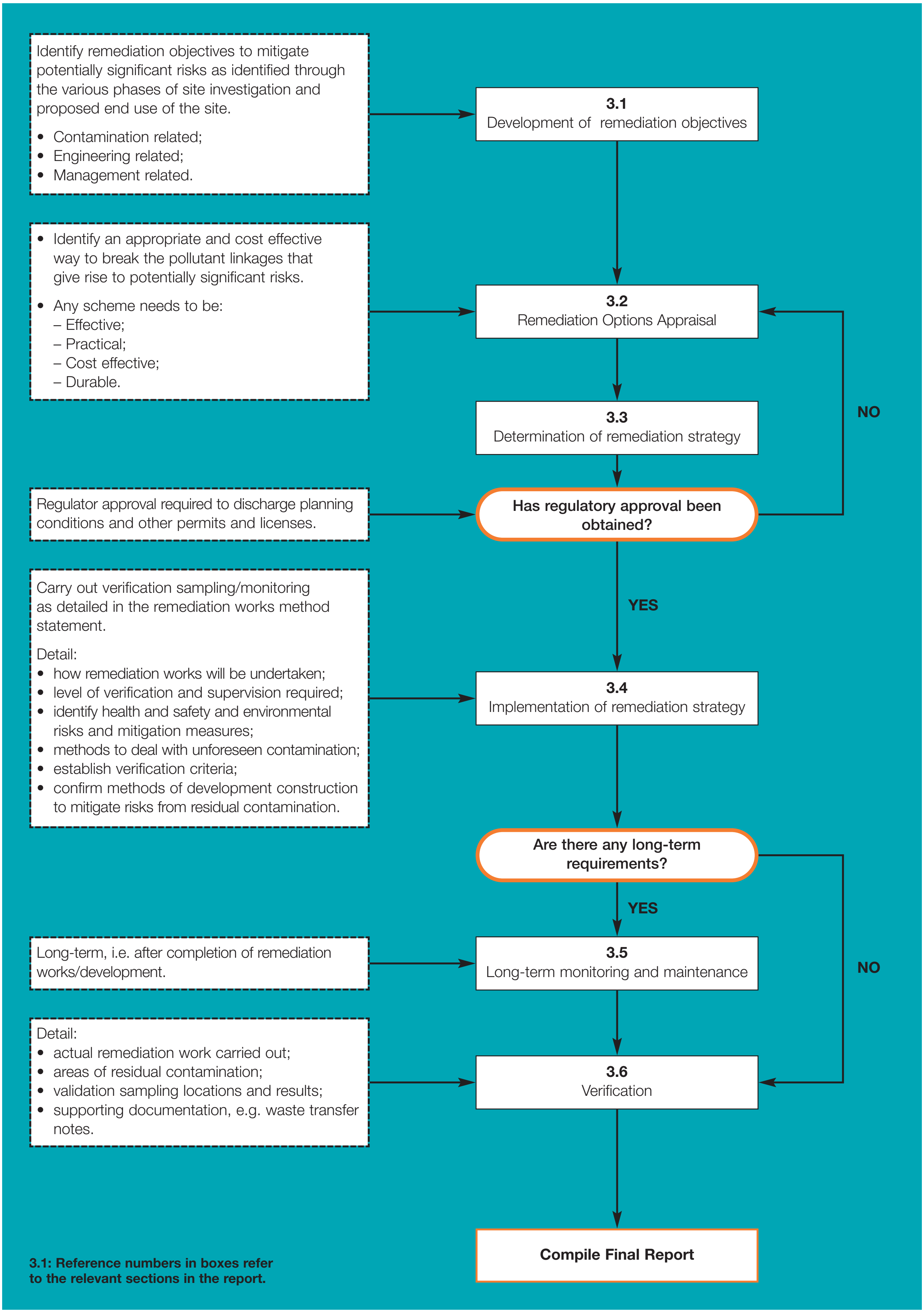
Chart 3 **Phase 3:** Remediation; design, implementation and verification



Phase 3
Remediation; design, implementation and verification

3.1 Objectives

3.1.1 General

The overall aim of the work in Phase 3 is to design, implement and verify the remediation works necessary to mitigate the potentially unacceptable risks identified in Phase 2. The remediation process therefore begins with development of the remediation objectives and the options appraisal process. It progresses by means of various remediation activities including verification as illustrated in Chart 3 [and by the Case Study, Chart 3A in Volume 2].

The process of remediation design, implementation and verification thus comprises:

- Definition of remediation objectives [Sections 3.1.2 to 3.1.5];
- Appraisal of the options for remediation and selection of a preferred strategy [Sections 3.2 and 3.3];
- Planning and implementation of the remediation strategy];
- Long-term monitoring and maintenance [Section 3.5];
- Preparation of Verification Report [Section 3.6].

The conceptual site model, refined from the results of the site investigation, will play a crucial role in the identification of the remediation options and the eventual selection of a preferred remediation scheme. During the remediation itself, it is very likely that additional data will be obtained requiring further refinement of the conceptual model.

In 2008 the Environment Agency published a consultation draft of Guidance on Verification (Environment Agency 2008a) which emphasised:

- The need to plan verification as in integral part of remediation; and
- The importance of the conceptual model and the development of multiple lines of evidence.

Remember:
All relevant data including the final description of the conceptual site model must be captured in the Verification Report.

3.1.2 Setting objectives

The risk assessment(s) carried out at the conclusion of the Phase 2 works will have identified all potentially unacceptable risks. The remediation objectives must manage the risks associated with each pollutant linkage identified in the conceptual model. On many sites, a range of objectives may be established in response to the different nature of the risks associated with different pollutant linkages. For example, on a site containing fill material consisting largely of degradable waste material with associated unacceptable risks, the associated preliminary remediation objectives could be summarised as set out in Table 3.1.

Table 3.1 Example summary of preliminary remediation objectives

Unacceptable risks	Preliminary remediation objectives
Damage to plants from phytotoxic heavy metals	Prevention of contact between contaminated soil and the root zone in planted areas
Explosion caused by methane ingress into buildings	Prevention of methane migration into areas close to the buildings
Human health effects through direct contact with soil	Prevention of contact between contaminated soil and humans in gardens, play areas and public open spaces
Pollution of groundwater by substances leached out of the fill	Reduction of leaching from contaminated soil by preventing water infiltration

In addition to the remediation objectives, legal obligations will also exist. A wider consideration of the circumstances of the land and its management context must also inform the remedial process. For example, there will be site specific particulars about the development itself (i.e. its layout and likely methods of construction) as well as requirements and/or aspirations of the Regulators (and other possible stakeholders). Some examples of such circumstances are set out in Table 3.2).

Table 3.2 Examples of site specific constraints

Type of circumstance	Typical issues
Commercial	Time, cost and extent of liabilities.
Legal	Need to meet certain conditions or to obtain license/permits. Need to manage any civil and criminal liabilities.
Physical	Location, size, current use, access to the site and boundary issues.
Engineering	Need to engineer the ground to ensure safe construction and/or to protect existing buildings.
Other	Need to ensure suitable amenities/other facilities, for example, provision of suitable gardens as part of an existing or future development. Public perception.

Typically remediation objectives are considered in one of three groups:

1. Contamination related;
2. Engineering related; and
3. Management related.

These objectives are described in turn below.

3.1.3 Contamination related objectives

Contamination remediation objectives must be based on the conceptual model for the site and must define the desired end condition. They can be qualitative or quantitative but must always relate to the risk assessment. Contamination related objectives are the most important of the three (types of objectives) and wherever possible should drive the selection of a remediation option. Examples of contamination related objectives are given below:

- Qualitative
  i. The remediated site must be suitable for occupation by people in homes with private gardens.
  ii. All below ground fuel tanks and associated hydrocarbon contamination must be removed from site.
- Quantitative
  i. The average (US_{95}) residual concentration of lead in the topsoils and subsoils on-site (within 1m of the ground surface) after remediation must not exceed 450mg/kg.
  ii. The maximum concentration of polyaromatic hydrocarbons [the sum of benzo(b)flouranthene, benzo(k)flouranthene, benzo(ghi)perylene and indeno(1,2,3-cd)pyrene] in any of the observation wells shall not exceed 0.1ug/l.

3.1.4 Engineering related objectives

The improvement, maintenance or modification of the engineering properties of the physical ground conditions on a site are commonly an important aspect of a remediation project. Improvements in stability of the site or changes in ground levels may be required in order to construct the proposed development. There may be a need to overcome conflicts between a favoured remediation technique which deals with contamination and the engineering objectives of the project. For example, lime stabilisation may reduce mobility of some contaminants but it will also change the soil properties. Changes to soil properties can be either negative, for example some stabilisation techniques can increase the soil pH causing aggressive soil conditions for buried concrete; or positive, such as improving bearing capacity. In any development project it is important that the construction process does not create new pathways by which contamination may migrate (e.g. by piles driven through contaminated Made Ground and a low permeability clay into underlying sands and gravels – a sensitive aquifer). Other ground improvement techniques can also have un-wanted effects on contamination (e.g. dynamic compaction can encourage off-site migration of ground gas). Examples of engineering related objectives are given below:

- The remediated soil must have a bearing capacity and settlement characteristics sufficient to support a two storey building.
- The clay capping must have a CBR value of not less than 5%.

3.1.5 Management related objectives

Management related objectives often relate to aspects of the remediation process itself, but also to the site after remediation has been completed. For example, the costs of a particular remediation option may exceed the budget, making the development not financially viable. Programme constraints may conflict with the use of a particular remediation technology (or technologies). On sites where there are existing buildings or structures to be retained, or where existing activities are to continue, remediation activities will have to be designed and carried out to avoid unnecessary disruption. A common objective on development sites is that on completion of the development (i.e. occupation by the homeowner) there will be no requirement for any further monitoring. Examples of management related objectives are given below:

- The houses on the development need to be ready for occupation by the end of the Financial Year.
- Groundwater treatment wells and pipework must not impede below ground works/piling etc.

Remember:
It is crucial that remediation objectives are defined at the start of the process and that all objectives are considered. If they are incorrect or incomplete then the remediation scheme will not be effective or efficient. This process should be clearly documented. Objectives are contamination, engineering or management related.

3.1.6 Measurement of objectives

Once the remediation objectives have been defined, remediation criteria specific to the site and to the defined objectives need to be identified. The remediation criteria provide the measures against which compliance with remediation objectives will be assessed during and after the implementation of the remediation strategy. For example:

- How will the remediation objective be measured?
  [For example; the outcome of an *ex situ* bioremediation scheme may be a **measured reduction** in the concentration of the contamination in the soil heap. For a cover system, the properties of the capping in terms of its thickness and engineered properties are more appropriate than measuring contaminant concentration beneath it.]
- Where is the remediation objective to be measured?
  [For example; the media type, location of samples, and extent of area/volume to be covered.]
- When will the objective be measured?
  [For example; periodic measurement of contaminant concentrations during bioremediation.]

3.2 Remediation options appraisal

3.2.1 The options appraisal process

Having identified the remediation objectives, an appraisal of potentially suitable remediation options must be carried out. Conceptually, remediation action will involve breaking the pollutant linkage or linkages by use of one or more of the following methods:

- source control: technical action either to remove or in some way modify the source(s) of the contamination. Examples might include excavation and removal, bioremediation or soil venting;
- pathway control: technical action to reduce the ability of the contaminant source to pose a threat to receptors by inhibiting or controlling the pathway. Examples would include the use of engineered cover systems over contaminants left *in situ* or the use of membranes to prevent gas ingress into buildings;
- receptor control: non-technical actions or controls that alter the likelihood of receptors coming into contact with the contaminants, for example altering the site layout.

A wide range of different techniques can be used individually or in combination to achieve a break in a pollutant linkage. The options appraisal will consider a technique's effectiveness in dealing with the contaminants of concern, but will also give consideration of the wider circumstances of the site (Table 3.2).

Short listing of the potential remediation options should take account of the available information and any associated uncertainties. For example, a technique may be initially identified as potentially suitable on the basis of its general effectiveness, but later, more site-specific evaluation may eventually lead to it being discounted. The short listed options will then be subject to detailed analysis to consider the advantages and disadvantages of each approach.

The analysis will have to balance a range of issues taking account of the wider circumstances of the site and any specific requirements of the remediation objectives. The analysis should be as comprehensive as possible, necessitating the collection of additional information as appropriate. The range of issues to be considered includes:

- costs and benefits (including finance considerations and liability);
- effectiveness of meeting remediation objectives (including site-specific criteria, timeliness, durability, risk-based and non risk-based objectives);
- wider environmental effects (including disruption to amenity, emissions, sustainability);
- regulatory requirements (meeting certain conditions or obtaining a licence or permit);
- practical operational issues (for example, site access, availability of services, agreed access); and
- aftercare issues (for example, the need to maintain and inspect remediation systems or to establish longer term groundwater or gas monitoring).

The selection of evaluation criteria is a site specific matter although many criteria will be common to many sites and techniques. This assessment may be carried out on a simple qualitative basis or may involve more detailed semi-quantitative assessment (an example of which is given in Table 3.3 overleaf). In either case it is advisable that some prioritisation or weighting is applied to these different factors, so that the most relevant, balanced assessment can be made. It may be worth investing more time and resources in this selection process where the choices to be made are particularly difficult, for example if a wide range of different stakeholders is involved.

However, it is very important that the process is carefully documented with a high degree of clarity and transparency, to enable the selection of the final strategy to be explained to the different stakeholders, such as the general public, company shareholders, local authority (Planning and Environmental Health Departments as well as Contaminated Land Officers) and the Environment Agency. Further information on this selection process can be found in the Model Procedures (Environment Agency 2001a) and an example of the quantitative approach is set out overleaf.

Remember:
The options appraisal process should be wide ranging, transparent and recorded. It must also refer to the remediation objectives specific to the site.

3.2.2 Waste management

Development of brownfield sites often involves the production, handling, treatment and disposal of waste. Typical wastes include demolition materials and soils (including made ground) which may or may not be contaminated. Appropriate classification and often pre-treatment, of waste is required prior to either re-use on-site or off-site disposal. Duty of Care associated with handling waste can have time and cost implications for the developer.

The definition and classification of waste are complex issues and must be fully understood at both the site investigation stage (see Chapter 2) but also in the appraisal of remediation options, the implementation of remediation works and during subsequent development. A summary of the waste management aspects of the development of land affected by contamination are provided in Annex 7.

Table 3.3 **Example of quantitative remediation evaluation criteria for hydrocarbon contamination of soils**

Priority	Remediation objective	Maximum possible score	Natural attenuation	Excavation and off-site disposal	Excavation and on-site disposal	Containment	Bioremediation (*ex situ*)
H	Eliminate further contamination of groundwater by hydrocarbons.	10	5	8	8	8	7
H	Adopt a strategy which minimises health and safety risks during implementation.	10	8	5	5	8	5
H	Ground must be able to support factory outlet and leisure centre.	10	7	7	6	5	6
H	Landfill space is scarce – neither Agency nor Local Authority wish to see material disposed off-site to landfill.	10	10	1	7	7	10
H	Time period limited to 13 months.	10	2	9	9	9	5
	Total Score High Priority Factors	**50**	**32**	**30**	**35**	**37**	**33**
L	Developer wants no long-term residual liability i.e. a clean site.	5	2	5	2	2	4
L	Regulatory acceptance.	5	2	1	3	3	5
L	Budget set at £0.75 million.	5	5	3	4	2	3
L	Developer does not want responsibility for long-term monitoring.	5	1	5	3	3	5
L	Public health issues such as noise, dust and odour are managed.	5	5	2	2	4	2
	Total Score Low Priority Factors	**25**	**15**	**16**	**14**	**14**	**19**
	Combined Total	**75**	**47**	**46**	**49**	**51**	**52**

Note: The quantitative remediation evaluation in Table 3.3 is an example of a tool which can inform the decision making process. But it does not make the decision for you.

3.2.3 Remediation treatment options

An increasing number of remediation treatment methods are available commercially in the UK. In order to arrive at the optimum strategy in terms of its ability to meet the remediation objectives careful consideration of the applications and reliability of each is required and discussions with remediation contractors at an early stage can be very helpful. Remediation treatment falls into two main categories: either involving direct action on the contaminants and their behaviour or through control of the pathway; or alternatively involving management of the receptor behaviour to alter its ability to come into contact with contaminants.

Direct action – physical techniques
Physical techniques result in the removal or separation and segregation of contaminants from soil and groundwater. Technologies consist of both *in situ* and *ex situ* methods. Physical treatments may be combined with chemical and biological treatments to provide an enhanced process and in general, do not destroy the contaminant. Physical techniques may be used to treat both organic (e.g. petroleum hydrocarbons) or inorganic (e.g. metals) contaminants. Physical techniques include:

- civil engineering approaches, for example containment using cover systems, containment using in-ground barriers, and excavation and disposal;
- physical based approaches, for example dual phase vacuum extraction, air sparging; physico-chemical washing, soil vapour extraction and soil washing;
- thermal based approaches, for example incineration, thermal desorption and vitrification.

Direct action – chemical techniques
Chemical approaches typically rely on the application of chemical compounds to react with the contaminants to convert them to harmless products which pose no risk to sensitive receptors. Chemical treatments are applicable to organic and inorganic contaminants. In many cases technology selection is driven by the ground conditions and contaminant type. Chemical techniques include:

- chemical based approaches, for example chemical oxidation using hydrogen peroxide or permanganate, chromium reduction (for example using molasses), reactive walls, soil flushing and solvent extraction;
- solidification and stabilisation based approaches, for example cement and pozzolan systems, lime based systems.

Direct action – biological techniques
Biological approaches rely on the use of micro organisms (bacteria and fungi) to carry out aerobic or anaerobic treatment of contaminants. These processes can be carried out both *in situ* and *ex situ*. Treatment technologies usually rely on creating appropriate conditions for microbial growth and are usually applicable for the treatment of organic contaminants. The technologies may rely on indigenous microbial species or can be augmented by the addition of microbes. Biological techniques include; bioventing; *in situ* bioremediation; landfarming; and windrow turning, biopiling and monitored natural attenuation (when extended time scales are available for remediation).

Management action
Management action can include the following:

- changing the land use;
- changing the site layout;
- controlling the behaviour of receptor/site use (for example through the use of planning conditions and restrictive covenants).

In particular circumstances, the development plan itself for a site affected by land contamination can be designed to meet some of the remediation objectives. For example, a residential development comprising blocks of flats with hard standing providing roads and parking areas can meet remediation objectives:

- to ensure that there is an effective barrier between residents/visitors and ground contamination; and
- to minimise leaching of contaminants into groundwater (by means of inhibiting rainwater infiltration).

However, some design elements of housing development projects on land affected by contamination, can give rise to the potential for adverse impacts (see Table 3.4 below). Such aspects will require particular consideration in the design solution.

Table 3.4 Examples of potential issues for development design options

Design element	Commentary
Building design	High rise flats may not enable gas protection measures to be as easily installed as low rise housing with ventilated sub floor voids. Houses with gardens as opposed to flats with landscaped areas will require additional thicknesses of cover to protect residents from contaminants.
Piled foundations	Potential to create preferential flow paths for contaminant migration through low permeability strata to underlying aquifers.
Specialist foundations	Incorporation of granular material (e.g. in vibro piles) may create preferential contaminant flow paths to underlying aquifers. Preferential flow paths may be created for upward migration of volatile contaminants into dwellings. Where limestone is used as below ground aggregate, acidity (low pH) in the soil may cause it to decompose to produce carbon dioxide.
Drainage	Preferential flow paths may be created for contaminants to surface water systems.
Soakaways	Soakaways encourage infiltration and can therefore enhance mobilisation of contaminants into the receiving stratum.
'Open ditch' drainage systems, storm water balancing ponds etc.	May create increased potential for unnecessary exposure of sensitive receptors for example humans to contaminants remaining on-site.
Site levels	Excavation of material to create new site levels may increase exposure to contaminants formerly at depth.

Published guidance
The Environment Agency has prepared Remediation Position Statements (available on their website www.environment-agency.gov.uk) describing fifteen of the remediation technologies used on land affected by contamination. These documents inform industry and other interested parties on how the Environment Agency applies risk based regulation to the remediation of contaminated land. The statements provide:

- a brief description of the technology;
- the applicability of the treatment process to different types of contaminated materials and contaminant groups;
- a summary of the waste management licensing implications associated with each technology; and
- relevant exemptions and exclusions from the waste management licensing regime.

The Environment Agency has also produced a series of Remedial Treatment Action Data Sheets which describe six particular remediation treatment actions for dealing with soil and groundwater contamination. The Data Sheets have been designed to assist with the evaluation and selection of the best practicable technique for remediation when dealing with one or more significant pollutant linkages. They include information on effectiveness, reasonableness, practicability and durability and are also available on the Environment Agency website www.environment-agency.gov.uk.

Available remediation technologies are summarised in Annex 8 of this guidance [reproduced from R&D66: 2000 (Environment Agency/NHBC 2000a)]. All of those listed are commercially available in the UK, although some have a limited track record. For each technology, details of the following are provided:

- technology description and contaminants that can be treated by the technology;
- media that can be treated (for example soil types, groundwater);
- treatment timescales and technical limitations.

3.3 Determination of preferred remediation strategy

From the detailed analysis of short listed remediation options, a preferred remediation strategy can be established. A remediation strategy is defined in Model Procedures (Defra/Environment Agency 2004a) as “a plan that involves one or more remediation options to reduce or control the risks from all the relevant pollutant linkages associated with the site”. The options appraisal process should be well documented, to enable regulators and other interested parties to understand the various considerations and priorities which have informed the determination of the preferred remediation strategy.

3.3.1 Documentation and approvals

The various processes of remediation are subject to a number of regulatory controls requiring permission to proceed with the works. These are in addition to any planning consent and approvals under Building Regulations, CDM Regulations and other occupational health and safety legislation. As described above, early consultation/liaison with the relevant Regulator(s) is encouraged as it will enable a common understanding to be established at the commencement of the process, minimising the potential for subsequent delay, abortive work, etc.

The most common regulatory controls comprise:

- Conditions to a Planning Permission often require plans for works to be submitted and agreed before commencement of work on-site. Such plans normally include requirements for monitoring, verification and submission of a Verification Report;
- Waste management licensing under Waste Management Licensing Regulations 1994* (as amended) (including registered exemptions, mobile treatment licences and Environment Agency enforcement positions);
- Consignment Notes for moving Hazardous Waste (Hazardous Waste (England & Wales) Regulations 2005;
- Permits under the Pollution Prevention and Control Regulations (2000)*;
- Authorisations under Part 1 of Environmental Protection Act 1990;
- Authorisations under the Groundwater Regulations 1998 (including discharge of listed substances to groundwater);
- Consents under the Water Resources Act 1991 (including abstraction licences) and the Water Industry Act 1991 (including discharge consents and dewatering activities).

[Note: * indicates Regulations which will be replaced by the Environmental Permitting Programme (EPP) from April 2008 (Ref DEFRA 2007a (draft regulations)). The EPP is a joint Environment Agency, Defra and Welsh Assembly Government initiative that will affect the existing waste management licensing and pollution prevention control regimes. The focus is on streamlining and simplifying environmental permitting and compliance systems (e.g. the processes of obtaining, varying and transferring permits). It will be a risk based approach.]

If there is any doubt over whether an appropriate authorisation, licence or consent is or is not required then the views of the relevant Regulator should be sought before any such works are commenced. The documentation submitted to the Regulator(s) during this approvals process must include all reports of ground investigations, risk assessments, remediation options appraisal and the remediation strategy. The remediation strategy must include:

- A statement of the site-specific remediation objectives and the short list of remediation options including an explanation of the basis on which the selection of objectives and feasible remediation options was made;
- A description of the most appropriate remediation option for each relevant pollutant linkage;
- A description of the remediation strategy, how it meets the objectives for individual pollutant linkages and the site as a whole;
- The need for and extent of long-term monitoring and maintenance.

At this stage it may also be appropriate to seek community acceptance of the proposals, especially where remediation works are likely to be highly visible and result in a certain amount of disruption.

3.4 Implementation of remediation strategy

3.4.1 General considerations

Having determined the preferred remediation strategy, a plan must be developed of how this strategy is to be implemented on a particular site. Such a plan will need to take into account:

- Whether the remediation consists of a single or multiple activities;
- Whether the remediation is being carried out as part of development (i.e. integrated with site preparation, earthworks or foundation construction) or as works independent of any other construction/development works;
- How the remediation works are to be recorded such that a Verification Report can be prepared demonstrating successful implementation to all stakeholders; and
- How 'completion' of the remediation works will be determined; and the need for and scope of any long-term monitoring and maintenance.

The overall objective of the implementation plan is to ensure the successful implementation of the remediation works, its verification and documentation.

3.4.2 The implementation plan

The implementation plan should set out the design and specification for the remediation works. Important elements in the plan will:

- Confirm the remediation objective(s);
- Ensure the information describing the remediation strategy provides enough detail to enable proper specification of the work, procurement, method statements etc.;
- Determine the scope of supervision (e.g. level and experience) during the remediation works, monitoring and verification;
- Ensure all relevant regulatory requirements will be addressed and met; and
- Describe how uncertainties will be managed (e.g. how variations in ground conditions/ unexpected contamination will be dealt with).

Typically the planning for the implementation of remediation works will involve consideration of matters outside of the scientific/technical elements of the remediation process itself (as described in Section 3.1). Some of these aspects may be addressed outside of any formal implementation plan (commercial/confidential arrangements between contracting parties for instance). However, it is important that whoever is managing the implementation programme as a whole ensures that all of these aspects have been properly addressed.

Developer's requirements
The interests and constraints of the Developer/Client will frame the overall management of the project. Aspects such as the programme, the procurement, the resources and roles of the various parties together with the communication strategy will normally be defined by or agreed with the Developer.

Legal/contractual arrangements
Such arrangements will also have a strong Developer focus and will include conditions of contract, warranties, insurances as well as matters relating to technical specifications. The time taken to complete these legal agreements can be protracted, sometimes leading to the very unsatisfactory situation of work being carried out (or even being finished) before legal/contractual agreements have been reached. Insurance policies can play an important role in remediation projects but are often misunderstood. Professional indemnity insurance will insure the consultant against claims of negligence made by the client. Unless negligence is accepted or proven, a claim against this policy will not be successful. There are a number of insurance policies which can be obtained relevant to remediation works and/or specific to a site. This area is complex and advice should be obtained via specialist insurers or brokers.

There will also be conditions or agreements with the local authority or Environment Agency regulators which often define elements of the work (see Section 3.3.1). This regulatory framework needs to be understood at an early stage to ensure that all such conditions and/or legal agreements are in place in time to avoid delay to project implementation.

Financial aspects
The costs of a remediation project are clearly a critical factor. In some projects, where the remediation works are a relatively simple activity carried out as preliminary works prior to development, the overall level of expenditure can be relatively modest. Conversely, where projects are complex, including several techniques over a large area of land, with various (perhaps difficult) contaminants over a prolonged period, the total costs can be substantial, running into millions or tens of millions of pounds.

In providing a cost plan, consideration needs to be given to both sources of expenditure and possible sources of funds or cost relief. Costs will typically include:

- capital costs of the remediation;
- maintenance/running costs;
- costs of spoil disposal;
- professional fees (for supervision, data assessment, reporting etc.);
- analytical costs;
- insurance premiums;
- project management.

In addition, as with any construction project an allowance should be made for contingencies. The extent of the contingency should reflect the degree of uncertainty related to: the ground conditions; the achievement of remediation objectives etc.

The current tax relief available for remediation of brownfield sites is changing in 2008 when Derelict Land Relief is likely to be introduced (similar to the existing 150% tax relief scheme – which has been extended to cover derelict land and Japanese Knotweed). Exemption from landfill tax for site remediation will be phased out from 2012. At the time of writing this report, these measures have yet to be fully defined and reference should be made to HM Revenue and Customs www.hmrc.gov.uk.

Scientific/technical elements
These elements are usually defined in the Implementation Plan and would typically include descriptions of:

- The objectives (of each element) of the remediation and the scope of the programme of work.
- Any site constraints, operational requirements etc.
- The planned programme of site supervision, monitoring and verification.
- Arrangements for data management.
- Management of uncertainty and contingency planning.
- The proposed outline of the Verification Report.
- Anticipated long-term monitoring and maintenance.

Remember:
The implementation plan must address not only the remediation objectives (and associated technical issues) but also the requirements of the developer, the legal/contractual arrangements and the financial aspects.

3.4.3 Implementation on-site

Remediation works, whether undertaken independently or as part of development works, will normally come within the requirements of the Construction (Design and Management) Regulations 2007 (CDM Regulations) (HSC 2007a). Under these Regulations there are duties for Clients, Designers and Contractors. These duties will make sure that; reasonable steps are taken to ensure that the arrangements for managing the project are suitable and that the construction work can be carried out so far as is reasonably practicable without risk to the health and safety of any person. Reference must be made to the Regulations and Approved Code of Practice to determine the particular requirements pertinent to any specific remediation project.

Remediation works should be carried out by a contractor (and/or specialist sub contractors) with the appropriate experience and/or expertise particular to the technique(s) being adopted. Similarly, the supervision of such works must also be carried out by appropriately qualified, experienced scientists/engineers. The level of supervision must reflect the type of work being undertaken as well as the complexity of the ground conditions on the site (the geology, geochemistry, groundwater regime, soil gas regime etc.). Less experienced staff should be supported by more experienced/specialist colleagues on-site (e.g. by periodic visits etc.) and from the office. The roles and responsibilities of all the staff time (contractor, sub contractors, testing and supervisory staff etc.) must be clearly defined (e.g. in the Implementation Plan) and understood. It is also important that planned regular progress meetings are held (appropriately recorded) and that good communications are maintained between all parties throughout the programme of work.

The maintenance of a good record of the works is essential. Typically this will comprise site notes, daily diaries, progress reports, site instructions and variations, photographs, drawings etc. The use of a proforma to assist in recording of daily or periodic site visits is often helpful in promoting rigour and consistency. Such records are particularly valuable to ensure that the details of change are captured. In almost all projects, variation from initial plans is to be expected. In these circumstances, the reasons prompting change should be recorded and the adopted solution must be documented (in words and/or drawings and/or photographs). If the variation is substantial (and could, for example, depart from the remediation strategy agreed with the regulatory authority), then the relevant authority (or authorities) must be informed and their agreement to the variation sought (if practicable). In these circumstances, it must be recognised that there is often a balance to be struck between the 'ideal' envisaged in the Remediation Strategy and the practicalities of the situation on the site.

3.4.4 Verification

Verification is an important aspect of the implementation of any remediation scheme (Environment Agency 2007b (draft)). Typically, verification activities will be carried out throughout the whole of the period that remediation works are in progress and are described here in more detail in Section 3.6. The Environment Agency recommend (Defra/Environment Agency 2004a) that on completion of the Implementation Plan a Verification Plan is developed which outlines the specific data which will be collected to satisfy the objectives.

3.5 Long-term monitoring and maintenance

3.5.1 General

Long-term monitoring and/or maintenance will not be required on sites where the remediation has been designed specifically to avoid such a requirement and where the verification has adequately demonstrated that all the remediation objectives have been met within appropriate timescales. Under such circumstances, a Verification Report (sometimes called a Completion Report) can be prepared without the need for an on-going programme of monitoring and/or maintenance. Verification Reporting is described in Section 3.6.

However, on some sites, it may always have been anticipated (and therefore set out in the Remediation Strategy) that a long-term programme of monitoring and/or maintenance would be required at the completion of the remediation works themselves. Alternatively, it is possible that the need for such an on-going programme, although not anticipated in the original strategy, becomes apparent during verification. In all cases where on-going monitoring/maintenance is required, such a programme must be defined and described in a Monitoring/Maintenance Plan. Such a Plan will describe:

- The scope and context of the monitoring/maintenance activities.
- The detailed specification of the work.
- The roles and responsibilities for carrying the work out.
- The locations, frequency and duration of monitoring.
- The detail of analyses to be performed (analytical suite, limits of detection, etc.).
- The criteria for data evaluation.
- The mechanics for recording, collating and reporting data.

It is important that due consideration is given to the definition of 'failure' against acceptance criteria. For example it may not be appropriate to determine failure based on a single or limited number of monitoring points/occasions for determinands which are not critical to the site or its remediation. Similarly a relatively small exceedance of a pre-determined concentration may not signal a 'failure' of the remediation which necessitates further remediation action. Therefore it is recommended that significant failure should be defined in the Monitoring/Maintenance Plan and that it should reflect a sustained and substantial exceedance of important determinands.

The Monitoring Plan will also define the response action(s) that will be taken if the monitoring data indicates a significant failure of the remediation works/the remediation objectives. It is good practice to set out the potential response actions in an escalating hierarchy. For example, a sequence of typical response actions would be:

1. To verify the measured data;
2. To obtain supporting/ancillary data or increased frequency of monitoring;
3. To determine the nature and extent of the problem areas by further specific site investigation and monitoring (on an increased frequency and a tighter grid of locations);
4. To revise conceptual model and carry out DQRA based on all available data;
5. To determine the need for and scope of additional remediation action (modifications of existing or new technique); and
6. Implementation and verification of such remediation.

3.5.2 Maintenance activities

Maintenance activities will reflect both the nature of the remediation that has been implemented as well as the nature of the hazard being mitigated. The need for and scope of any maintenance activities will be identified in the Remediation Strategy, but is likely to be finally defined post remediation when the particulars of the scheme are a reality. The objective of maintenance work or activities is to ensure that the remediation structure continues to function and operate as designed. For example, for a perimeter gravel filled vent trench, the maintenance activity could comprise the periodic inspection (e.g. at 6 month intervals) to check for degradation of the freely venting surface (e.g. by encroachment of vegetation) and treatment by weeding, cutting back on the application of weed killer. For active gas protection systems, the programme of maintenance would consist of periodic inspection and servicing at recommended intervals by specialist engineers (often the supplier/installer). For systems such as permeable reactive barriers, periodic rejuvenation of the active element may be required. Whenever a remediation scheme is designed which includes a long-term maintenance element, it is most important that the management of such a system, in terms of both personnel and finance is well defined, robust and can guarantee longevity.

The timescale over which maintenance activities are to be carried out must also be defined. It is likely that in many cases the termination of such activity will depend upon monitoring data rather than a pre-determined number of years. For example, maintenance of the perimeter gas vent trench would be required until some other form of remediation was carried out to enable development (subject to its own remediation strategy), or the soil gas regime inside the gassing site fell to below hazardous levels. Maintenance activities must be recorded and reported to relevant stakeholders in accordance with provisions agreed in the Remediation Strategy and/or the Maintenance Plan.

3.6 Verification

3.6.1 Objective

The overall objective of verification activities is to demonstrate the achievement of the remediation objectives set out in the Remediation Strategy and Verification Plan. It is also likely that verification will be required to provide evidence that:

- planning/permit/licence conditions have been complied with;
- environmental management goals (e.g. dust generation, migration of run-off, soil gas and vapours, groundwater contamination) have been controlled.

Some particular remediation activities take place over a prolonged period of time (e.g. bioremediation of soils, groundwater treatment, etc.). In such circumstances, verification will provide data demonstrating whether the intended remediation action (such as reduction in contaminant concentration) is taking place at the expected rate. If the data is indicating that the remediation action is not occurring as predicted, action(s) must be carried out to react to that data (e.g. to increase the speed of the remediation, or the length of the remediation programme, or to decrease the remediation target etc.). Again any substantial change to the remediation objectives must be communicated to all relevant parties and agreed (as appropriate).

3.6.2 Common verification activities

Verification often involves the sampling and chemical analysis of soils on the site, using both *in situ* test kits and off-site laboratories. This data will be used to:

- Determine the nature and extent of the residual contamination (together with its location);
- Ensure appropriate classification for waste disposal; and
- Confirm the chemical nature of soils imported to site (and thus to ensure compliance with both the remediation objectives and with the contract specification).

Similarly, sampling and chemical analysis of groundwater and surface waters (at an agreed frequency and at agreed locations) is commonly undertaken. This data will demonstrate that:

- The remediation treatment is achieving the required effect on contamination concentrations;
- That any authorised discharges or construction works are not impacting groundwater or surface water contaminant concentrations to unacceptable levels; and
- That treatment of soil gases/vapours has reduced their concentrations and/or that barrier/ venting systems have managed the gas/vapour regimes to meet the remediation objectives.

3.6.3 Competence

It is important that the people obtaining the verification samples/data are both competent to do so and (usually) are independent of the contractor (or specialist sub contractor). This will ensure that there can be no conflict of interest (actual or perceived) and that the samples or data are collected by people with appropriate training, equipment etc. and are properly recorded (e.g. the samples' locations are defined and the samples themselves properly described etc.).

3.6.4 Reporting

A Verification Report will be prepared on successful completion of the remediation works (which may or may not include post remediation monitoring). The Environment Agency has recently produced a Consultation Draft of guidance related to verification, including the preparation of Verification Reports (Environment Agency 2008a). In common with all such reports, the standard of presentation, the use of English (including punctuation and grammar) is important. Clear and concise communication within Verification reports will benefit all the parties involved, by reducing misunderstanding and enabling discharge of any relevant planning condition (see 3.6.5). Guidance on good practice in writing ground reports has also recently been published by the AGS (AGS 2008a).

The objective of the Verification Report is to document all aspects of the remediation works undertaken at the site. In the past, many remediation projects were carried out without being properly or permanently recorded. Subsequent further work on such sites (e.g. for redevelopment etc.) inevitably has led to major programmes of site investigations, monitoring, risk assessments etc. all of which would have been unnecessary had proper records been kept and presented in a Verification Report.

The Verification Report should describe the site, the remediation objectives, remediation techniques, verification and monitoring data in succinct text supported by drawings, figures, photographs, etc. The source data must also accompany this text, either as appendices to the main report or as reports in their own right, to which cross reference is then made. "As built" drawings are an essential component of Verification Reports. Photographs also provide good evidence of the remediation activities on the site.

Remember:
No remediation activities should take place without being properly recorded in a Verification Report.

3.6.5 Contents

The typical contents of a Verification Report are given below and described in more detail in Figure 4B, Output 5 of Model Procedures (Defra/Environment Agency, 2004a). However, it is important that the Verification Report is specific to the site and to the remediation actions that have been carried out. Normally the Verification Report will include:

1. A description of the site background;
2. A summary of all relevant site investigation reports;
3. A statement of the remediation objectives;
4. A description of the remediation works;
5. The verification data (sample locations/analytical results);
6. Project photographs;
7. As built drawings;
8. Records of consultations with Regulators;
9. Duty of Care paperwork;
10. Environmental monitoring data;
11. A description of any residual contamination;
12. Any arrangements for post remediation management.

Consideration must be given to the maintenance and accessibility of Verification Reports. To facilitate handling and storage it is increasingly common that such reports are stored on CD. However, it is also recommended that hard copies are also maintained by appropriate bodies as a safeguard (e.g. against corruption of the disk etc). Typically such reports would be retained by the Consultant or Contractor (but often this is only required by contract for 6 or 12 years), by the landowner and by the local authority regulator.

Normally, on receipt of a Verification Report, the local planning authority will take advice from their environmental health/contaminated land officers (and the Environment Agency in some circumstances) and if satisfied, formally discharge the relevant planning condition by writing to the applicant. If there is no such planning condition, the local authority or Environment Agency should nevertheless acknowledge receipt of the Verification Report. While liability remains with the developer/their insurers, they will often look to obtain ‘sign off’ of these reports by the relevant regulator(s). Regulators will not do this however, or issue their own verification of the works, but they may be willing to do one or more of the following:

- indicate whether they have reviewed the report;
- state whether they are satisfied with the level of detail provided;
- confirm that it appears to be reasonable given the data presented;
- make a statement about whether (based on the information supplied) they are currently considering the need for any enforcement action under various regulatory regimes.

It is important to understand that it remains the developer’s responsibility to ensure that they have met the remediation objectives, made the site suitable for use and adequately protected all of the relevant receptors.

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