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Guidance on Assessing the Risk Posed by Land Contamination and its Remediation on Archaeological Resource Management

Science Report P5-077/SR

ENGLISH HERITAGE

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Professor Mike Depledge   Head of Science

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EXECUTIVE SUMMARY

The industrial history of the UK has resulted in a legacy of land contamination. Archaeological resources are often associated with this legacy and include tangible surface remains, buried remains, artefacts, ecofacts and characteristic landscape types. Current Government policy promotes both the reuse of previously developed land and the protection of cultural heritage, including the archaeological resource. Consequently there is a potential for conflict between the protection of the archaeological resource and the assessment and remediation of land contamination.

Some of the many and varied archaeological resources in the UK have been afforded statutory protection by means of scheduling; however, the majority have not.

The two main legislative provisions for dealing with land contamination are the Part IIA regime (of the Environmental Protection Act 1990) and the Town and Country Planning provisions. Part IIA deals with land in its current use and introduced a statutory definition of 'contaminated land'. In terms of archaeological resources the regime identifies scheduled ancient monuments as receptors, significant harm of which can result in the designation of the land as "contaminated land". The planning provisions use the wider definition of land contamination and apply to all archaeological resources not just scheduled ancient monuments.

In both the Part IIA and planning contexts the UK has adopted a risk-based approach to the assessment and management of land contamination, underpinned by the source-pathway-receptor framework. On any site the relationship between the source(s) of contamination, the pathways and the receptor(s) is represented by the conceptual site model which is developed and refined throughout the risk assessment process. The archaeological resource may be a source of contamination, a pathway for the transfer of contamination to another receptor or a receptor in its own right. It is also possible that an archaeological resource may be present on a site and not form any part of the pollutant linkage but may still need to be considered in terms of the potential impact of site investigation or remedial works on the resource.

Where archaeological resources are present, or suspected, it is imperative that early consultation takes place between the land contamination practitioners, archaeologists and regulators so that measures can be taken to protect or record the resource and to minimise the likelihood of accidental or unnecessary damage.

It is likely that some of the activities undertaken to assess land contamination may help to inform the archaeological assessment and vice versa. The land contamination assessment will generally involve a site investigation that may combine a number of different intrusive and non-intrusive techniques. The archaeological site investigation may involve the use of similar techniques. This guidance reviews some of the commonly used techniques and their potential application in land contamination and archaeological assessments.

The management of land contamination frequently requires the application of remedial techniques that may rely on physical, chemical or biological processes. The impact of some techniques may be easily identified. For example, excavation of contaminated materials will result in the destruction of archaeological evidence. For other techniques the impact on the archaeological resource may not be so obvious. For example, an *in-situ* bioremediation

technique may result in a change in the pH of the archaeological burial environment causing the degradation of artefacts and ecofacts.

1. INTRODUCTION

1.1 Background

The UK has a legacy of land contamination resulting from its industrial history and the lack of adequate provisions in the past to protect the environment. Archaeological resources are frequently associated with this legacy, and are sometimes the cause of it. Current Government policy promotes the reuse of previously developed, and potentially contaminated, land. Thus it is possible that the assessment and remediation of land may have an impact on the archaeological resource that is itself subject to preservation *in-situ* as directed by Government policy. It is important to the preservation of archaeological resources that the presence of contamination, or the activities undertaken to investigate, assess or remediate the contamination, do not impact on them unnecessarily. Equally, it is important that the investigation and management of archaeological resources do not in themselves cause contamination of land or the wider environment.

1.2 Land Contamination

The UK has adopted a risk-based approach to the assessment of land contamination. This approach is based on the source-pathway-receptor framework and the existence of a pollutant linkage. For a risk to exist all three elements of the framework must be present.

The two main legislative provisions for dealing with land contamination are Part IIA of the Environmental Protection Act 1990 (Contaminated Land) regime and the Town and Country Planning Act 1990 development provisions. The Part IIA regime introduced a statutory definition of 'contaminated land' and relates to land in its current use.

The planning and development provisions relate to the proposed use of the land and use the wider term 'land affected by contamination'. This is intended to cover all cases where the actual or suspected presence of substances in, on or under the land may cause risks to people, human activities or the environment, regardless of whether or not the land meets the statutory definition of contaminated land in Part IIA (DTLR 2002). In this report the term 'land contamination' is considered to have the same meaning as 'land affected by contamination' as defined in DTLR (2002).

The remediation of land is underpinned by the "suitable for use" approach which recognises that the level of risk presented by the land contamination will vary depending on the use of the land. For example, to prevent harm to human health a more sensitive end use, such as residential housing with gardens, will require a greater degree of clean up than a landuse where there is less likelihood of people being exposed to soil contaminants, such as a carpark. This approach is adopted under the Part IIA regime where remediation may be undertaken to ensure that land is suitable for its current use and under the planning and development provisions where remediation will ensure that the land is suitable for its proposed use.

1.3 The Archaeological Resource

The archaeological resource of England and Wales is one of the largest and best documented in Europe and includes material from more than half a million years ago to the modern era (Darvill and Fulton, 1998). Article 1 of the European Convention on the Protection of Archaeological Heritage (the "Valletta" Convention) to which the UK is a signatory provides a current view of what constitutes the archaeological resource.

The archaeological resource may be grouped into a number of categories:

- Tangible surface remains such as buildings, structures and earthworks remains.
- Buried remains, often with no tangible surface indicator. This may include substantial remains such as pits, ditches, walls and other structural elements and cultural material, such as artefacts. In some cases organic artefacts, such as those made of wood and leather, may survive in waterlogged anaerobic conditions.
- Ecofacts such as bone, plant and animal macrofossils and pollen, often particularly well preserved in waterlogged anaerobic conditions.
- Distinctive features of the landscape such as ancient hedgerows and field patterns.
- Characteristic landscape types such as those typical of a past industry or agricultural regime, comprising an amalgam of integrated landscape features and perhaps also buildings, structures and buried remains.

In some instances the archaeological resource may achieve a less tangible but wider cultural significance derived from an association with historic events or people, for example battlefields and historic gardens.

Government policy on development and archaeology (which is currently under review) gives preference to the preservation of the archaeological resource *in-situ* and the mitigation of the effects of development on affected sites. Many structures, artefacts and ecofacts are vulnerable not just to physical damage, but to decay if the chemistry, microbiology, or hydrology of their surroundings is changed.

A limited number of nationally important sites known as scheduled ancient monuments[1] (SAMs) are protected by law, but a far greater number are recorded in local authorities', or in Wales the Welsh Archaeological Trusts', non-statutory sites and monuments records. Development affecting the former requires the consent of the Secretary of State for Culture Media and Sport or the Welsh Assembly, other archaeological remains are dealt with through the planning process.

Knowledge about the known archaeological resource informs development and structure plans devised by the local planning authorities. In some instances these may identify areas with particular archaeological constraints on development.

However, many facets of the total archaeological resource of England and Wales remain undiscovered and undocumented. Often such remains come to light for the first time during the archaeological assessment and evaluation of a development site, carried out within the framework set out in planning policy (PPG 16 in England and Planning Policy Wales), or during the archaeological component of an Environmental Impact Statement for a substantial development.

For the benefit of the non archaeologist, it is worth pointing out that it is not only the actual structure or remains that can contain vital historical evidence. The soils around and between structures, buildings and their remains in many cases will contain valuable archaeological evidence. Soil fulfills a wide range of inter-related functions (or roles) and soil at one site will often support more than one function at a time (DETR 2001a). For example, a contaminated soil may filter substances from water and regulate its flow to aquifers or watercourses, form foundations for buildings, support biodiversity and protect cultural heritage. The soil's role on the one hand is seen as containing and protecting the evidence of our cultural heritage, including archaeological remains and evidence of environmental change, and on the other as evidence in its own right of a site's formation and environment; it is therefore a part of the suite of evidence used to reconstruct the site and the activities performed in it. Within this document the word "soil" is used as a general term to refer to both organic soil and non-organic sediments, for example deposits occurring on archaeological sites as a results of a wide variety of formation processes.

1.4 About this report

The main objective of this report is to provide detailed guidance and raise awareness of the risks posed by land contamination and its assessment and remediation on archaeological resource management and how to strike a balance between archaeological protection and other technical and regulatory requirements.

Within this wider framework the report highlights a number of specific issues including;

- the need for early consideration of the possible presence of archaeological resources and early consultation between all stakeholders so that adequate measures can be taken to protect these resources;

- the consideration of archaeology as a potential source of contamination, as a potential pathway for the transfer of contamination and as a potential receptor. In particular consideration will be given to Scheduled Ancient Monuments identified as a receptor under the Part IIA regime and the occurrence of significant harm or the significant possibility of significant harm;

- the potential for techniques and investigations employed by archaeologists or geoenvironmentalists to contribute to the investigation and management of land contamination or archaeology. The report reviews the potential of commonly used remote sensing and other techniques to identify and characterise land contamination or archaeology;

- the consideration of the health and safety of workers and the limitations that may be placed on archaeological investigation activities as a result of the contamination present. This guidance will highlight some of the hazards that may be associated with land contamination and their relevance to the archaeologists working on the site or working off site with recovered materials. This document is not intended to replace existing health and safety guidance on safe working practices on land affected by contamination; and

- the identification of the remediation technologies including physical, chemical and biological treatments and processes used in the UK and their potential impact on archaeological resources. Where possible, the guidance will identify potential measures to mitigate the effects of remediation on the archaeological resources, for example, sealing archaeological remains so they are not impacted during remedial activities on site.

It is important to remember that on any site affected by contamination archaeological resources may be only one of a number of receptors present. Other receptors may include human health, the water environment, ecological systems and property (including buildings and livestock). This guidance document relates only to assessing the risks to archaeological resources, which comprises surface and buried archaeological remains. Appendix One provides details of some sources of information that may be of use when assessing potential risks to other receptors. This guidance serves as a supplement to, and should be used in conjunction with, other key guidance documents on both archaeological and land contamination assessment, investigation and management.

Also provided in Appendix One are details of further information sources that may be of use in the assessment of land contamination and archaeological resources. Appendix Two provides contact details of organisations involved in land contamination and archaeological resource management.

1.5 Target Audience

The guidance document provides guidance principally to English Heritage and Environment Agency staff who are involved in the assessment and management of land contamination projects where archaeological resources are present, or suspected. The readership is expected to be wide ranging, including:

- English Heritage, Environment Agency and local authority officers; and

- Consultants, contractors, regeneration practitioners and others involved in the management of land contamination and archaeological resources.

In preparing this document, the variation in the level of land contamination and archaeology expertise of the target audience has been recognised.

This guidance is generic and appropriate to the Part IIA contaminated land regime and other technical and statutory regimes requiring the assessment of risks to archaeological resources. The document will also assist in the development of a nationally consistent approach to site investigation and remediation projects in which English Heritage and the Environment Agency are involved by setting out what they both believe to be good practice.

1.6 Legislative Context (England & Wales)

The two main legislative contexts for the consideration of land affected by contamination are the Part IIA regime and the planning provisions, both of which are outlined below. It should be remembered that the legislative contexts differ between England and Wales and each has their own policy and guidance requirements.

Land is a finite resource and Government policy advocates development of land that has had a previous use, bringing these sites forward for redevelopment in a bid to protect our greenfield sites. It is envisaged that the vast majority of land affected by contamination will be dealt with through the planning provisions. It should be noted that not all land identified as having a previous use is necessarily affected by contamination and likewise land considered as greenfield may have had previous unknown uses or may be affected by land contamination issues by, for example, farming methods or sewage sludge spreading.

1.6.1 Part IIA Contaminated Land Regime

The Part IIA regime was inserted into the Environmental Protection Act 1990 by Section 57 of the Environment Act 1995 and came into force in England in April 2000 and in Wales in July 2001. The regime deals with contaminated land that poses an unacceptable risk to human health and the environment based on the current use of land. The regime defines "contaminated land" in terms of causing significant harm or the significant possibility of such harm to defined receptors or the pollution or likely pollution of controlled waters. (The consideration of significant harm and the significant possibility of such harm is dealt with in Section 2.2). Not all land affected by contamination will fall under the statutory definition of contaminated land. The assessment of land and its determination as contaminated land is underlain by risk-based principles and the presence of a significant pollutant linkage(s) between the source, pathway and the receptor. The DETR Circular 02/2000 *Contaminated Land* (thereafter the Statutory Guidance (DETR 2000a)) provides guidance on the application of the definition of contaminated land. In Wales the National Assembly published their Statutory Guidance in 2001 (National Assembly for Wales 2001).

The provisions of the Part IIA regime may only be applied to defined receptors. In terms of archaeological resource the definition of a receptor is restricted to Scheduled Ancient Monuments.

Local authorities and the Environment Agency have specific duties with respect to the implementation of the Part IIA regime as detailed in the Statutory Guidance (DETR 2000a, National Assembly for Wales 2001). Each local authority is required to inspect its area from time to time for the purpose of identifying contaminated land. The local authority must take a strategic approach to this inspection and describe and publish this approach in a written strategy that should be kept under periodic review. The inspection strategy needs to reflect local circumstances hence the content of the strategies will vary between local authorities. Key issues for consideration in the strategy include the presence of defined receptors, the extent of their exposure to contamination and the historical nature of the contamination sources (DETR 2001b). As scheduled ancient monuments are a defined receptor in the regime, the inspection strategy should provide an indication of how the local authority will consider this archaeological resource within the context of the current use of the land. The local authority is required to consult with a number of appropriate bodies, including English Heritage (or Cadw in Wales), in the development of the inspection strategy. In some cases the local authority may also consider it appropriate to consult other bodies associated with the preservation of our cultural heritage in the preparation of their strategic approach to the identification of contaminated land.

The local authority is the enforcing body for contaminated land under the Part IIA regime, with the exception of sites identified as Special Sites, where the Environment Agency takes on the enforcing role.

Scheduled Ancient Monuments

Scheduled ancient monuments are protected through the provision of the Scheduled Ancient Monuments and Archaeological Areas Act (1979). The register of scheduled ancient monuments is held and maintained by English Heritage (Cadw in Wales) who take the lead in providing advice and guidance in all issues relating to scheduled monuments.

The reasons for scheduling an archaeological resource are many and varied. However, scheduling is invariably an indicator that the archaeological resource contains evidence, material or structures considered to be of national importance. Scheduled ancient monuments may include features or structures of exceptional quality and/or rarity, exceptionally well-preserved examples of a particular class of archaeological resource and sites or areas rich in particular types of evidence, for example waterlogged archaeological remains with exceptional preservation of organic artefacts and/or structures. They may also be unexceptional structures scheduled as a result of their significant association with an historical event or individual. Scheduled monuments may vary considerably in scale, from a single isolated structure metres in size, to substantial integrated landscapes, covering tens of hectares such as the earthwork remains of a deserted medieval village.

The criteria by which the Secretary of State, advised by English Heritage, determines whether to schedule an archaeological resource are published in Annex 4 of Planning Policy Guidance 16: *Archaeology and Planning* (DoE 1990). These criteria are most readily understood by reference to monument class descriptions, produced by English Heritage. Monument class descriptions contain a synthesis of current knowledge relating to a particular class of archaeological resource helping to define national importance on the basis for example of rarity, archaeological potential and vulnerability. They are used in the process of scheduling as a guide to whether the aspects of a particular archaeological resource are exceptional for its class.

Each scheduled monument has an individual written monument description, with a plan showing the extent of the scheduled area and a description of the scheduled area including a note of any aspects or features of the site specifically excluded from the schedule (for example modern buildings of no architectural or historical merit). Monument descriptions are held by English Heritage with copies held by local planning authorities. Monument descriptions document the reasons whereby a particular archaeological resource has met the criteria for scheduling. They serve as the principal guide for assessing whether land contamination and its remediation will have a detrimental impact on the monument.

1.6.2 Planning and development

Land contamination and archaeology are both material considerations under the provisions of the Town and Country Planning Act 1990. The planning process is primarily concerned with the proposed development and its use whereas the Part IIA regime looks at the current use of the land. Development need not always be viewed as having a negative impact on the archaeological resource and if properly controlled can provide an opportunity for conservation.

In the context of development control and land contamination, the relevant Planning Policy Guidance (PPG) 23 *Planning and Pollution Control* published by the Department of Environment, Transport and Regions in 1997 is currently under revision. Draft Planning Technical Advice was issued for consultation in early 2002 on *Development of Land Affected by Contamination* (DTLR 2002) and it is understood that this Technical Advice will form an appendix to a revised PPG 23. The draft consultation paper highlights the benefits of early consultation between the applicant and the local planning authority. The approach outlined is based on the principles of risk assessment, the source-pathway-receptor framework and the concept of unacceptable risk. The definition of receptor considered under the planning provisions is wider than that defined in the Part IIA regime and includes human health, the water environment, flora and fauna, buildings as well as archaeological resources. The standard of remediation required for planning permission to be granted is the removal of unacceptable risk to the receptor(s) and making the site suitable for its intended use.

Planning Policy Guidance (PPG) 15, *Planning and the Historic Environment* published in September 1994 by the Departments of the Environment and National Heritage provides advice on planning issues relating to buildings and the historic environment. PPG 15 provides a full statement of Government policies for the identification and protection of historic buildings (in particular, listed buildings), conservation areas and other aspects of the historic environment. The PPG provides guidance both on planning matters relating to listed buildings and other aspects of the historic environment, such as historic parks and gardens, battlefields and churches.

Planning Policy Guidance (PPG) 16, *Archaeology and Planning* provides advice on the handling of archaeological matters within the planning process. PPG16 applies to all archaeological remains, not just scheduled ancient monuments, and sets out the Secretary of State's policy on how they should be preserved and recorded. It forms the basis by which local planning authorities incorporate consideration of the impact of development proposals on the archaeological resource. PPG16 seeks to reconcile the needs of archaeology and development by encouraging early consultation by developers with the planning authority in order to plan development around sensitive archaeological sites. It places a strong emphasis on a graduated approach to archaeological issues, moving from initial consultation and desk-based assessment, where appropriate to field evaluation in order to generate the level of information necessary to inform the planning decision and devise a scheme of mitigation, with preference for the preservation *in-situ* of archaeological remains or where this is not feasible for their preservation by record.

At the time of writing, both PPG 15 and 16 are in the process of revision. The revised guidance is likely to be single document, uniting the two PPG, consisting of two parts: a short and focussed Planning Policy Statement of core policy, and an accompanying appendix or supporting document containing detailed procedural guidance with an emphasis on quality, standards and the public communication of the results of archaeological and conservation work.

In Wales, guidance on development control and the historic environment and listed buildings is contained in Planning Policy Wales (National Assembly for Wales 2002) and supplemented by a number of Welsh Office Circulars.

In addition to development control, the local planning authority also has a strategic planning function. Every local planning authority is required to produce a development plan for its area to provide guidance in reaching decisions under planning legislation. Planning Policy Guidance (PPG) 12, *Development Plans* published in 2000 and Planning Policy Wales (National Assembly for Wales 2002) provide guidance for the local authority on the issues to consider in the development plan. The development plan takes account of local circumstance including social, economic, and environmental considerations, including the preservation of built and archaeological heritage. Decisions reached on planning applications should be taken in the context of the development plan. The Planning and Compensation Act 1991 clarified the importance of development plans by stating a presumption in favour of granting permission for proposals that conform to their policies (Hunter and Ralston 1993). Many local authorities will have identified, and classified areas of archaeological significance in their development plan, generally based on the records held by the authority including for example the Sites and Monuments Records (SMR) and Listed Building records. In Wales the Sites and Monuments Records are held by the Welsh Archaeological Trusts. In addition many local authorities will have compiled archaeological surveys of urban areas and historic landscape surveys that will provide further guidance on the presence and significance of archaeological resources. The development plan should include policies on mitigation of the potential impact of development on the archaeological resource. It should be noted that the extent of the records held by local authorities will vary and that in many instances unrecorded archaeological resources may be present on a site.

The local waste and mineral planning authorities may have developed waste and minerals local plans aimed at determining priorities and resolving conflicts within these particular areas of interest. These local plans should take account of the planning policy guidance in their respective areas. Mineral Planning Guidance Note (MPG) 1 *General Considerations and the Development Plan System* (published by DETR in 1996) and Planning Policy Guidance (PPG) 10, *Planning and Waste Management* (published by DETR in 1999) both require policies for the protection of cultural heritage.

1.6.3 Environmental Impact Assessment

The Town and Country Planning (Environmental Impact Assessment) England and Wales Regulations 1999 transposed the EC Directive 97/11/EC, which amended the original Directive 85/337/EEC, requiring the assessment of the effects of certain projects on the environment. The Directive requires environmental impact assessment to be carried out, before development consent is granted for certain types of major project that are judged likely to have significant environmental effects. Projects falling under the scope of the Directive are categorised as Schedule 1 (i.e. those types of development which require EIA in every case) or Schedule 2 (i.e. where an EIA is required only if the particular project in question is judged likely to give rise to significant environmental effects).

An EIA is a systematic procedure for drawing together a project's likely environmental effects. This allows environmental factors to be weighted along with economic and social factors when planning applications are being considered, forming a basis for better decision making. The resulting environmental statement requires a description of the aspects of the environment likely to be significantly affected by the development, including the archaeological heritage. The developer is responsible for the preparation and submission of the environmental statement to the local authority. The EIA process emphasises the need for early consultation by the developer with bodies likely to have an interest in the environmental effects of the project. It also places a requirement on the developer to include an outline of the main alternative approaches to the proposed development. In considering the findings of the EIA, the local authority must consult, where appropriate, depending on the development under consideration with relevant statutory consultees.

2. APPROACHES TO THE ASSESSMENT OF LAND CONTAMINATION AND ARCHAEOLOGICAL RESOURCES

2.1 Assessment of Land Affected by Contamination

The UK legal and policy framework relies on a risk-based approach to the management of environmental risk including land affected by contamination (DETR 2000b). A risk-based attitude both to the impact of development on the archaeological resource and to the restrictions on development brought about as a result of conserving that resource, is also implicit in the approach to assessing and evaluating impacts on archaeological remains set out in PPG 16.

Government guidance on environmental risk assessment and management (DETR 2000b) provides an overall framework for a tiered approach to assessing and managing risk. The handbook of model procedures (Contaminated Land Research Report (CLR) 11) for the management of land contamination (DEFRA and Environment Agency 2003, in preparation) provides the specific framework for land contamination. The model procedures incorporate existing good technical practice, including the use of risk assessment and risk management techniques, into a systematic process for identifying, making decisions about and taking appropriate action to deal with contamination, in a way that is consistent with Environment Agency policy and legislative requirements. The model procedures therefore set out a recommended good practice approach to managing land where contamination is, or may be, an issue.

The model procedures form the basis of a hierarchy of documents that provide an overall systematic approach to assessing and managing land contamination. This guidance document will support this hierarchy and provide guidance on assessing the risk to archaeological resources from land contamination and its remediation.

As indicated previously, the risk assessment approach is based on the source-pathway-receptor framework and the presence of a pollutant linkage(s), the relationship between the source of contamination and the receptor. For a risk to exist all three elements must be present. This approach is applicable in both the Part IIA and planning contexts.

The risk assessment process is iterative and can be divided into four stages, namely

- hazard identification (what is it?)
- hazard assessment (how bad is it?),
- risk estimation (is there a problem?); and
- risk evaluation (what needs to be done about it).

Figure 2.1 shows a schematic diagram of the risk assessment process and the types of activity that may be undertaken at each stage.

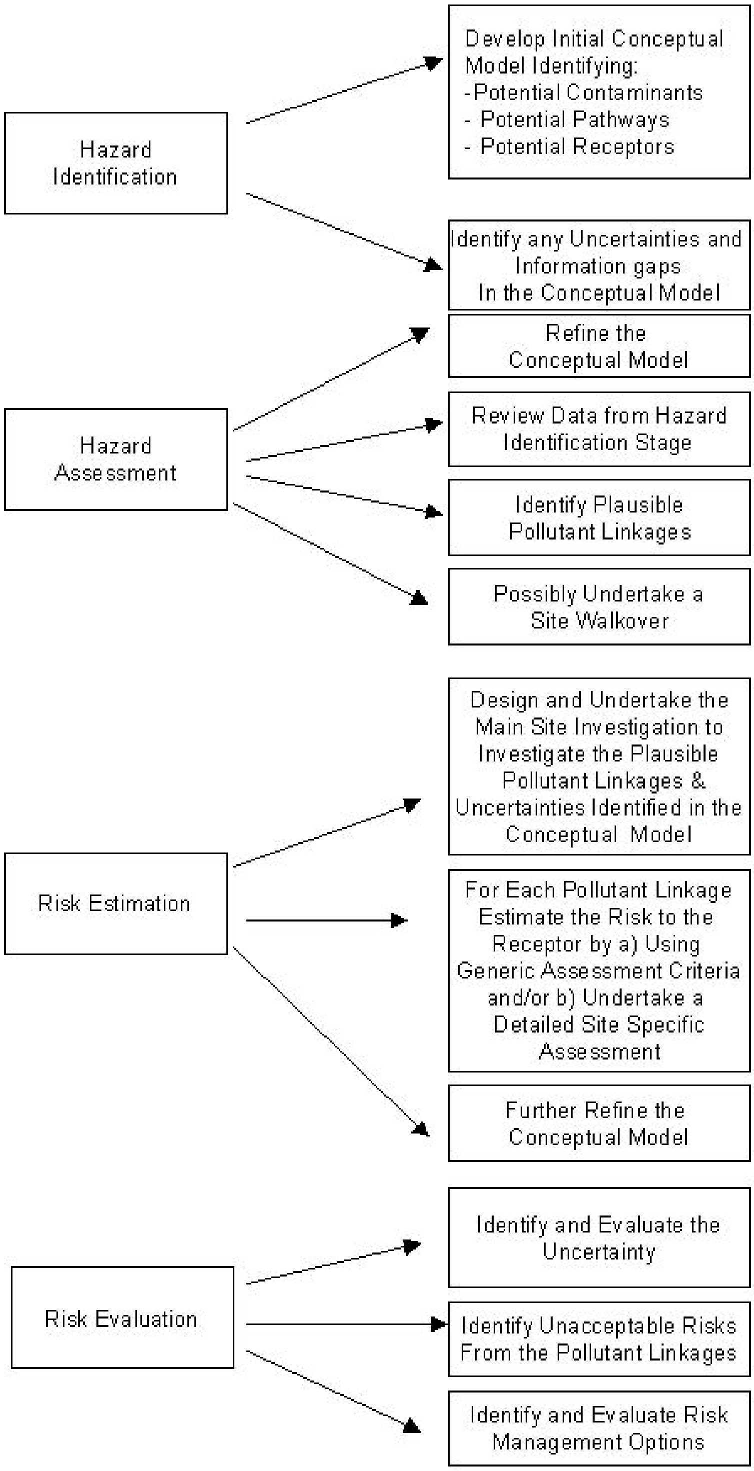


Figure 2.1 Schematic Diagram of the Stages Involved in Undertaking a Risk Assessment for Land Contamination

Fundamental to this approach are the development of the conceptual site model and the consideration of the potential pollutant linkages identified therein.

The conceptual model is defined as a textual or graphical representation of the relationship(s) between contaminant source(s), pathway(s) and receptor(s) developed on the basis of hazard identification, and refined during subsequent phases of assessment (Environment Agency and NHBC 2000). The conceptual model should also include any uncertainties identified and assumptions made regarding the site.

The initial hazard identification stage is an information collection stage, often referred to as the desk study and involves the identification of the potential contaminants of concern, the potential receptors and any pathways that may link the two i.e. the pollutant linkage. At this stage the initial conceptual site model is developed. The presence of a potential pollutant linkage will depend on issues including the nature of the contaminant and its physical and chemical properties, the soil conditions and geology and the characteristics of the receptor. The hazard assessment stage considers the plausibility of these potential pollutant linkages and may involve an exploratory site investigation. On a site-specific basis the presence of naturally occurring contamination (e.g. radon and elevated background levels of heavy metals associated with the geology) may need to be considered in addition to any anthropogenic sources.

The risk estimation stage comprises the main site investigation, the purpose of which is to gather data to investigate the uncertainty in the conceptual model. The site investigation and sampling strategy must be based on the conceptual model and focus on obtaining data relevant to the investigation of the pollutant linkages. Obtaining site investigation data of sufficient quality and quantity will allow further characterisation of the site including the nature and extent of the contamination and refinement of the conceptual model. The risk to the receptor identified in the pollutant linkage can then be estimated. The approach adopted will vary between receptors but may involve the use of generic assessment criteria or the derivation of site-specific assessment criteria. For some receptors, including archaeological resources, the estimation of risk will generally require specialist advice.

The final stage is the risk evaluation when the information from the previous stages for each pollutant linkage is analysed, the uncertainties in the process identified and a decision is made as to whether or not the site poses an unacceptable risk to the receptor. If the site is found to pose an unacceptable risk it may be necessary to (a) revisit the earlier stages of the risk assessment, reduce the uncertainty and derive further site-specific assessment criteria or (b) instigate appropriate risk management measures.

In the context of archaeological resources, the resource may be present as a potential source of contamination, a potential receptor or as a potential pathway for the transfer of contamination to another receptor. In addition, the archaeological resource present on a site (or adjacent to the site) may not form part of a pollutant linkage but may still need to be considered in terms of the potential impact of works undertaken to investigate the pollutant linkages present.

Environment Agency and National House Building Council (2000) provides practical information on the development and content of the conceptual model in assessing land contamination.

One of the key advantages to having a comprehensive conceptual site model is that it can aid communication within the stakeholder group for the site. Where many different parties are involved with a site each with their own aims and objectives the conceptual model is a valuable tool in ensuring that all have the same understanding (or at least framework for discussion) of the issues relevant to the site.

2.2 Assessment of Archaeological Resources

The assessment of archaeological resources may take place both within the Part IIA regime and within a planning context.

Assessment within the Part IIA Regime
All activities affecting a scheduled ancient monument will require scheduled monument consent granted by the Secretary of State for Culture Media and Sport. An application for scheduled monument consent must be accompanied by detailed information, which might include:

- Documenting, as fully as possible, the character of the monument, its historic, architectural, traditional, artistic or archaeological features of interest and highlighting those features by reason of which a particular monument was scheduled.

- Documenting with suitable detailed information the present and future impact (or threat) of land contamination on the monument, in particular on the individual features of the monument that have led to its scheduling.

- Documenting with suitable detailed information the impact of proposed remediation methods on the monument, in particular on the individual features of the monument that have led to its scheduling.

The archaeological resource present is often far from clear at the outset of the assessment process. In the case of scheduled ancient monuments the monument description will often provide an incomplete account of the full archaeological potential of the monument. Many scheduled monuments have arbitrary boundaries, defined on the basis of old or incomplete knowledge. Assessment should seek to clarify and document more completely the extent of the archaeological resource represented by a scheduled monument in order to better understand the impact of land contamination and remedial techniques on that resource.

An application for scheduled monument consent must be made to the Department of Culture Media and Sport in England or the National Assembly in Wales in order for remediation work to be carried out. The application will require a detailed written statement that sets out clearly and with supporting evidence, including where necessary plans, drawings and background information, how remedial work is to be undertaken, its impact on the monument and the measures to be taken to mitigate any damaging affects of remediation on the monument. Information on the anticipated affects of land contamination on the monument if consent for remedial work is withheld should also accompany an application to allow determination of whether a “do nothing” solution is acceptable.

Consultation with English Heritage (or Cadw) is essential to obtain a full appreciation of the complex reasons for which a particular site is scheduled. English Heritage and Cadw have a statutory responsibility to comment on works affecting both the area of a scheduled ancient monument and the setting of that monument and will advise the Secretary of State or National Assembly on whether scheduled monument consent, required for works affecting a monument or its setting, should be granted. They should be consulted at the earliest opportunity when considering investigation or remedial works within or adjacent to a scheduled ancient monument even if the scheduled area is not itself affected.

Defining Significant Harm to a Scheduled Ancient Monument
For scheduled ancient monuments, the Part IIA regime defines significant harm as occurring when substantial damage occurs that significantly impairs the historic, architectural, traditional, artistic or archaeological interest by reason of which the monument was scheduled.

Individual monument descriptions provide a commentary on the components and features of a monument considered relevant in achieving its scheduled status. Land contamination impairing any of the features of a monument pertinent to its scheduling may be considered to be causing substantial damage to that monument.

Significant harm might be taken to mean substantial damage to all or any of the features by reason of which the monument was scheduled such that the monument would no longer meet the criteria for scheduling were that damage to be unchecked. This decision will be taken by the relevant Inspector of Ancient Monuments, with appropriate specialist guidance. As a guide significant harm might mean:

- Damage to a standing structure affecting its structural integrity.

- Damage to decorative or artistic elements of a building or structure but not affecting its structural integrity.

- Damage to functional elements of a building or structure (such as equipment or machinery forming part of an industrial archaeological resource) but not affecting its structural integrity.

- Damage to buried archaeological structures, features, artefacts or ecofacts affecting their continued good preservation in-situ.

- Damage to buried archaeological structures, features, artefacts or ecofacts not affecting their continued good preservation *in-situ* but creating a health risk likely to render them unsafe for excavation and analysis and so affecting their potential for future archaeological study.

- Damage likely to render a monument unsuitable for present or future public access and so preventing public appreciation of that monument.

- Damage likely to impair the historic and/or landscape associations of a monument through rendering it unsafe, even if not accessible to the public, and so isolating it from its wider historic and/or landscape associations.

In the case of scheduled ancient monuments the significant possibility of such harm relates to the likelihood of significant harm resulting from the pollutant linkage for the foreseeable future (DETR 2000a).

This places the onus on intervention to ensure that scheduled monuments are maintained not just for the present generation but for the appreciation of future generations. In many instances part of the intent in scheduling a monument is to control the archaeological investigation of that monument. Specifically, preservation of an archaeological resource *in-situ* implies that anticipated advances in archaeological technique may enable more information to be extracted from that resource by its excavation and analysis at some point in the future. It is therefore, vital that this potential archaeological evidence is maintained in a good state of preservation and remains safe for future examination.

Assessment within the Planning Context

Within the planning context, assessment of the archaeological resource is likely to focus on the requirement placed upon a developer through planning guidance. The assessment should provide the planning authority with sufficient evidence for the presence or otherwise, extent and quality of archaeological resource within a development area, and the full impact of the proposed development on that resource, to allow an informed planning decision to be made. In this context development impact includes the impact of land contamination and potential remedial techniques on an archaeological resource.

A development site may contain part or all of a well-documented archaeological resource or may be adjacent to a documented archaeological resource. Often a development site will be in an area where there is no documented archaeological resource, but there exists a strong likelihood that archaeology is present by comparison to topographically similar but better-documented locations. The locations of all known archaeological resources are recorded in the Sites and Monuments Records maintained by local authorities and this information can act as an initial guide for the assessment process.

The type of evidence required and the work considered necessary to achieve the level of information required to inform the planning decision is usually arrived at through discussion with the planning authority's archaeological officer. Usually the archaeological officer will provide a written brief setting the parameters for the archaeological investigation of a development site. Often the developer will seek advice and guidance from a specialist archaeological consultant who will negotiate on the developer's behalf with the planning authority's archaeological officer and oversee site investigation work carried out by a separate specialist archaeological contractor.

Assessment of the impact of a development on an archaeological resource requires comprehensive documentation of the total impact of a proposed development. For example, documentation should include details of all landscaping, access and services, impacts such as changes to groundwater levels due to quarrying, ground disturbance by machinery and the impact of ancillary activities associated with the development of the site such as access and accommodation during construction and the remediation of land contamination.

PPG 16 encourages a graduated approach to considering the archaeological issues of a development in order to arrive at the levels of information required by the planning authority. This graduated approach is also appropriate to the assessment of a scheduled site under the Part IIA regime; however it should be noted that intrusive investigation techniques will themselves require scheduled monument consent, while certain non-intrusive techniques such as geophysical surveys will require an appropriate licence.

The graduated approach enshrined in PPG16 envisages three principal stages:

1. An initial assessment of the potential of a development site to contain archaeological remains that "normally involves desk-based evaluation of existing information" (PPG16 para 20). In the context of land contamination this might include information on the contamination present on a site and its anticipated impact on the preservation of the archaeological resource, including information on whether contamination might render the archaeological resource unsafe for excavation and analysis. It should include consideration of the place of an archaeological resource within an initial conceptual model. In some circumstances, where no archaeological resource is identified this initial assessment may be all that is required to accompany a planning application.

2. Field evaluation which is intended to define the character and extent of an archaeological resource and "is normally a rapid and inexpensive operation involving ground survey and small-scale trial trenching" (PPG 16 para 21). In the context of land contamination this might include archaeological site investigation targeted at determining the extent to which the archaeological resource is a source, pathway or receptor of any contamination present on the site and analysis to determine the impact of contamination on the potential of the archaeological resource for excavation and analysis. The work should allow refinement of the place of the archaeological resource within the conceptual model. The outcome of the field evaluation will allow informed decisions to be made about the archaeological issues on a site.

3. Arrangements for preservation, preferably *in-situ* or where acceptable by record through excavation, prior to development and/or remediation works, during which the archaeological evidence is recorded. The planning authority will usually require a written scheme of mitigation for a development that sets out in detail how the impact of the development on archaeological remains will be managed. Where land contamination and its remediation are an issue the written scheme of mitigation must include detailed information on the impact of proposed remedial techniques on the archaeological resource and details of the measures proposed to mitigate any adverse impacts of remediation. Managed mitigation might include the preservation *in-situ* of the archaeological resource achieved through sensitive design, suitable construction practice and appropriate remedial techniques. The recording of the archaeological resource through a programme of excavation prior to the start of development or a graduated archaeological intervention during the construction process, at its lowest level comprising a watching-brief maintained by archaeological staff, but also perhaps providing for pauses in construction work to allow for the salvage recording of the archaeological resource when encountered.

From Table 2.1 below it is evident that there is common ground between the types of activities involved in the assessment of risk associated with land contamination and those undertaken under PPG16 for the assessment of archaeological resources.

Table 2.1 Summary of types of activity undertaken in land contamination and PPG 16 assessments

Types of activities undertaken under each stage of the risk assessment process	Types of activities undertaken PPG16
Hazard Identification: establish former uses of the site and identify potential contaminants by consulting historical maps, aerial photographs, geological maps, historical documents, trade directories etc. Identify potential receptors and potential pathways and develop the initial conceptual model **Hazard Assessment**: consider the plausibility of the pollutant linkages, may include exploratory ground investigation	**Assessment:** Examination of existing archaeological records such as Local Planning Authority sites and monuments records (SMR), and information held by the National Monuments Record. Examination of aerial photographs Examination of historic mapping and other historic documentary sources Published literature including relevant accounts of previous archaeological fieldwork
Risk Estimation: detailed site investigation (non-intrusive and intrusive), collection of samples (soil, water, gas), further characterisation of the site including extent and nature of contamination, determination of representative contaminant concentrations in relevant media, comparison with generic guideline values or site-specific assessment criteria, refine the conceptual model on the basis of the additional information **Risk Evaluation**: evaluation of the uncertainty in the risk assessment process, decision relating to the acceptability of the risk to the receptor, for an unacceptable risk decision as to whether to return to the risk assessment process to reduce uncertainty or instigate risk management options	**Field Evaluation:** Site investigation involving non-intrusive techniques such as geophysical survey, site topographical survey, fieldwalking and artefact collection and intrusive techniques such as augerer and coring, excavation of trial pits and trial trenches

2.3 Benefits of early consultation

The stakeholder group involved with a site will vary depending on the exact nature of the issues under consideration and the benefits of early consultation within the group cannot be over emphasised. As a minimum on a site where both contamination and archaeology issues are present or suspected the parties involved are likely to include the developer/site owner, regulator, consultant undertaking land contamination assessment and any subcontractors, engineer/architect (if development context) and archaeologist.

- Early consultation between the developer and the planning authority will help reduce any potential conflict between the needs of archaeology and development (e.g. PPG 16 advice on undertaking an initial assessment).

- The presence of archaeological evidence/contamination are likely to have time and cost implications for the project and the earlier these are known about the easier it is to accommodate them in the development plans for the site. On a more practical note, early consultations allow the various parties involved with the site to take account of concerns raised by others, for example the land contamination investigation can be designed to minimise vehicle movements/people movements in areas of the site that are particularly vulnerable in terms of archaeological resources.

- In both the development and Part IIA contexts early consultation will allow the development of a more robust conceptual site model and a reduction in the uncertainty associated with the site.

- A more robust conceptual site model will enable the development of a coherent site investigation and mitigation strategy to address the potential contamination issues and where possible protect the archaeological resources *in-situ*, reducing the likelihood of 'accidental' damage to archaeological remains or the wider environment.

- On a site-specific basis there may be potential for information transfer between the land contamination and the archaeological assessment and investigation stages. For example, there is considerable overlap in the sources to be consulted in the hazard identification stage of the land contamination assessment and the desk study stage of the archaeological assessment.

- The same investigative techniques may be used for both purposes although the specific objectives may vary. Early consultation between the contaminated land consultant and the archaeologist and the effective management of the site investigation can result in a more efficient site investigation, both in terms of cost and time. It is also recognised however that the two disciplines have different data requirements and the methods used by one discipline to gather data may not be adequate to fulfill the requirements of the other.

3. ARCHAEOLOGY AS A SOURCE OF CONTAMINATION

In some instances an archaeological resource may itself be a source of land contamination. Often contamination may be introduced into the environment as a result of an historic industry or industrial practice for which directly related archaeological remains survive. Non-industrial archaeological activities or materials may also introduce contaminants into the environment or have over time caused the development of contaminants (for example, the interment of human remains might introduce pathogens from the cause of death, decay of organic matter, mercury from fillings in teeth, or lead from coffins into the environment).

3.1 The Industrial Archaeological Resource

At past industrial sites, buildings, structures and deposits (e.g. wastes) associated with industrial activities form an important part of the industrial archaeological resource, although their archaeological and historic significance may not be obvious to a non-specialist.

Some sites forming a part of the industrial archaeological resource may be protected as scheduled ancient monuments and so fall within the remit of the Part IIA regime. More often, a site or structure that is a source of land contamination might be identified as being a significant archaeological resource during the archaeological assessment of a development proposal carried out within the remit of PPG16 or Planning Policy Wales. Guidance on the extent to which industrial buildings and structures should be considered an archaeological resource will usually be issued by the planning authority during consultation undertaken as part of the planning process. A developer would be well advised to consider all industrial remains predating 1945 as potentially an archaeological resource, and be prepared to make appropriate provision for their archaeological assessment, unless advised otherwise by the local planning authority.

Sites where archaeological activity is the source of land contamination present a significant problem in devising an appropriate remediation strategy as it is necessary to balance the onus to preserve the archaeological resource *in-situ,* or to extract information on past activity or technology by making a record, with the need to deal with materials or structures that are a source of land contamination requiring appropriate remediation. In such instances the nature and extent of land contamination and a potential remediation strategy may be obvious and well documented while the archaeological resource within the same site might be poorly understood and undocumented. It is important that the context, functions and significance of industrial buildings and structures forming part of the archaeological resource are well understood and that appropriate information to inform this understanding is gathered before committing to a remediation strategy that may have an adverse affect on the preservation of the archaeological resource.

Industrial buildings and structures may be contaminated either by residues from the past industrial activities that they contained (e.g. metals from ore processing) or by the past use of buildings material, (such as asbestos, heavy metals in vapours from wallpapers or dust from flaky paint), now known to be hazardous to health. It is often the case that the potential areas of archaeological significance (e.g. pits and tanks) can be logistically the most difficult to investigate as they may be significant sources of contamination.

Industrial sites contain a wide range of potential contaminants and archaeological resources. Individual buildings and structures within an historic industrial site may be of considerable archaeological significance and specialist assistance is usually required for their identification and recording. In illustration of this, Table 3.1 outlines some of the potential areas and structures of archaeological significance that may be found within a historically significant gasworks. Where present, such structures are likely to require archaeological recording prior to demolition and in some instances might warrant preservation *in-situ*.

Table 3.1 Potential historic features and land contamination issues associated with a gasworks.

Potential land contamination significance*	**Potential structures of archaeological significance****	
Coal tars Heavy metals Phenols Sulphates Cyanide Ammonium (Ammoniacal liquor) Hydrocarbons Chlorinated solvents Poly Chlorinated Biphenyls (PCBs) (if electricity generation on Site)	Benzole plant Coal handling plant Coal store Coke handling plant Coke ovens Coke store Condenser Cyanogen plant Electro-detarrers Fuel storage tanks Gas drying plant Gasholder Gasholder house Gasworks	Lime shed Lime washers Liquor tank Naphthalene plant Oxide shed Purifier Purifier house Refuse lime heap Retort house Rotary washer Tar pit Tower purifier Tower scrubber Washer

*DoE (1995), **Trueman (1997, 2002)

The Fakenham Gasworks (Case Study 1) is an example of a disused gasworks where buildings and structures of the utmost historic importance were identified (sufficient to warrant statutory protection as a scheduled ancient monument). Both the historic structures and the land between structures were contaminated as a result of past industrial processes and the residues of those processes. Nevertheless a programme of archaeological investigation and targeted remediation was able to render the site safe for public access as a museum.

In terms of identifying the potential contaminants of concern, the DoE Industry Profiles (DoE 1994/95) provide a useful starting point. These profiles were developed for a range of industries and provide background on the industry in addition to information on potential associated contamination. The Industry Profiles are not intended to provide an exhaustive and exclusive list of potential contaminants on any site or replace the need for the development of a site-specific conceptual model.

The English Heritage Monuments Protection Programme (MPP) (English Heritage 1995) provides information on the archaeological significance of features, structures and specific sites relating to a wide range of past industries. Consultation of MPP documents will assist in rapidly identifying the types of features and structure likely to be of significance on an historic industrial site although, as is the case with land contamination, the MPP documents cannot replace the need for a site-specific study.

Industrial waste and residues, such as slag, spoil and tailings, may contain information about past technology and industrial practice and form a significant part of the archaeological resource. These materials are also often the most significant source of land contamination on an industrial site. Systematic archaeological excavation, recording, subsequent macro and microscopic examination and scientific analysis of waste materials and residues is an important aspect of the archaeological investigation of historic industries. The archaeological significance of such material must be considered during the archaeological and land contamination assessment of an historic industrial site. It is important that remediation strategies do not divorce waste products and residues from their original depositional context prior to safe and adequate archaeological recording and sampling.

In addition, the past disposal of waste products in slag and spoil heaps often forms features characteristic of industrial landscapes. At Greenside Lead Mine, Cumbria (Case Study 2) the remains of nationally important 17th - 20th century lead mining and processing posed a possible contaminant threat to local watercourses. The site, including both the structures and the lead tailings, are protected as a scheduled ancient monument. The potential contamination issues required remedial action likely to damage parts of the scheduled site. A carefully devised programme of archaeological and geotechnical site investigation and analysis was able to demonstrate that in some areas the contamination risk was sufficiently low as to require no remedial action, therefore removing the threat to the archaeological resource posed by remedial techniques. Where potentially unstable lead tailings were a threat to local watercourses, remediation combined archaeological survey with an engineering approach designed to minimise impact on the scheduled mining remains.

3.2 Defence Sites

Historic defence sites contain much valuable evidence for the development of the social, military and technological fabric of British society. Buildings, structures, equipment, machinery and the complex and deliberate layout of these sites are all aspects of their particular character and value.

Defence sites often pose particular remediation problems due to the volatile and hazardous nature of substances associated with them coupled with the possibility, in some circumstances, of unexploded ordnance (Cocroft 2000). In the context of the Part IIA regime, some classes of defence site will come under the definition of a Special Site. In these instances the Environment Agency is the regulatory authority. Environment Agency (2001b) provides technical guidance on land contamination issues relevant to Ministry of Defence (MoD) land.

The Waltham Abbey Royal Gunpowder Factory (Case Study 3) is among the most important ordnance and explosive manufacturing sites in the British Isles. Its protection both as a scheduled ancient monument and by 21 individual listings of historic buildings or structures indicates its historic status. Management of this site, which also includes important natural environments protected as Sites of Special Scientific Interest (SSSI), was achieved through a carefully managed programme of archaeological survey and remediation with a high degree of synergy achieved between these two activities.

3.3 Other Archaeological Sources of Land Contamination

Some other past activities may also act as sources of land contamination. In particular, biological hazards may arise from the disposal of animal remains, for example those associated with historic butchery or tannery sites (e.g. anthrax), or from human interment (including sealed coffins). Biological substances (micro-organisms) are not recognised as substances by the Part IIA regime. However, the need to deal with biological contaminants arises increasingly in brownfield development, particularly in association with the redevelopment of burial grounds, churchyards and locations where animal burial or processing has occurred (e.g. tanneries).

At Forthbank Banks Infirmary, Newcastle Upon Tyne (Case Study 4) the redevelopment of an 18th century hospital graveyard necessitated the removal of extensive burial deposits of considerable archaeological interest, but in themselves a source of potential contamination requiring remediation, and necessitating strict health and safety precautions for excavation staff. Analysis of samples recovered during the excavation for biological contaminants allowed the biohazard level posed by deposits at the site to be reassessed and downgraded.

CASE STUDY 1: FAKENHAM GAS WORKS

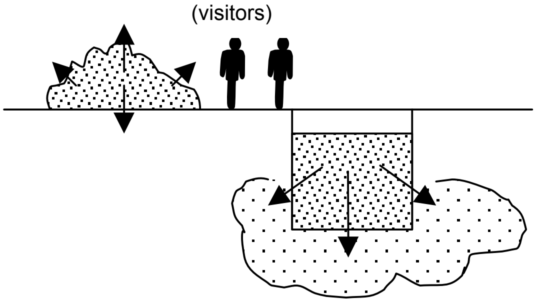
The Fakenham Gas Works (TF 9195 2925) was opened in 1846, enlarged in 1856 and further enlarged and modified in the late 19th century (19thC) and during the 20thC. A local partnership operated the works until the Fakenham Gas & Coke Company Ltd was formed in 1909. This company was in turn bought by the Worthington Church Organisation in 1920 and became part of the Eastern Gas Board in the nationalised industry in 1949. The works was supplying 500 customers when production ceased in September 1965. The site was scheduled in 1984 and is the only complete extant town gasworks in England. It is occupied by the Fakenham Town Gasworks Museum Trust who open it to the public on occasional days or by arrangement. The remains consist of a series of brick buildings of mainly mid-19th century date together with extensive plant of mainly early 20th century date.

Contamination Issues

Contamination surveys were undertaken in 1992, 1998 and 2001 as part of the ongoing responsibility of the landowners for a scheduled site that is open to the public. Decisions over remediation proposals arising from the investigations have been and continue to be made following consultation with the Environment Agency, English Heritage (for scheduled monument consent) and the local authority. Investigations in part targeted specific historic structures identified by research. Both near-surface contamination and groundwater contamination were examined. Specific works undertaken are as follows:

1992 10 hand-dug trial pits
1998 7 probe holes with standpipes installed at 4 positions for monitoring soil gas and groundwater. Soil samples taken for testing.
2001 6 boreholes for soil gas and groundwater monitoring standpipes
9 machine and hand excavated trial pits
Hand excavations in oxide shed to determine depth of cyanide oxide
Soil samples screened for Volatile Organic Compounds (VOCs)
Water samples from subsurface drains and sumps within the site
Leachate tests

Two particular hazards were identified on the museum site. A heap of 'blue billy' (spent cyanide oxide) was identified as a health and safety hazard and was isolated and removed from the site. The still *in-situ* content of the tar tank was also identified as a potential hazard (for its potential to leak out into the groundwater) and there is currently a proposal to drain the tank (leaving the structure in place) subject to scheduled monument consent. Finally, given that the local water table is quite high, monitoring of the site drainage system has indicated that occasional cleaning out of sumps may be appropriate. Although other contaminants have been identified around the site, it is felt that they do not pose a sufficient risk in relation to the current use of the site to require further remediation measures.



Simplified Conceptual Model

Source = spent cyanide oxide
Receptor = human health (visitors)
Pathways = direct ingestion, dermal contact and inhalation of dusts

Source = waste tars
Receptor = groundwater
Pathway = leaking of tars from storage tanks to the groundwater

Case Study 1: Fakenham Gas Works

CASE STUDY 2: GREENSIDE LEAD MINE, CUMBRIA

Greenside lead mine lies in mountainous terrain, above Ullswater within the Lake District National Park. Mining commenced in the 17th century on the exposed vein on the mountainside, and access levels were driven from progressively lower levels as the mine deepened. Around 1830, a smeltmill was built in the main Glenridding valley below the mine; from 1853 onwards an access level was driven from near the smeltmill, and ore-dressing floors were built in this area. The smeltmill closed in about 1910, but mining and ore-dressing continued until 1962, and from 1940 onwards finely-divided ore-dressing slimes were deposited in tailings dams over and uphill from the smeltmill and earlier dressing floors; the infilled tailings dams formed major steep-sided and flat-topped topographic features on the steep valley side. The earlier areas of mining activity were scheduled in 1983, and the Scheduled area was extended in the 1990s to include the smeltmill site and most of the 20th century tips (including remains of earlier dressing floors beneath these tips). An overall archaeological survey of the site was prepared by the Royal Commission on the Historical Monuments of England (RCHME) in 1992.

Contamination issues

Following partial failures by slippage of the tailings dams in 1987 and the 1990s, concern developed over the stability of these features, and the hazard from landslip and waterborne pollution of Glenridding Beck (and thence of Ullswater, and of water supplies drawn from the Beck) in the event of major slippage. A full geo-environmental and structural assessment of the whole site was therefore commissioned by the Lake District National Park Authority (LDNPA). This divided the site into three zones:

- Zone 1 - predominantly 19th century mining and ore processing, in the upper parts of the site. Assessed by surface soil sampling.
- Zone 2 - 19th and 20th century mining, ore processing, and smelting remains in the lower part of the site. Assessed by surface soil sampling.
- Zone 3 - 20th century tailings dams. Assessed by surface soil sampling and borehole probes.

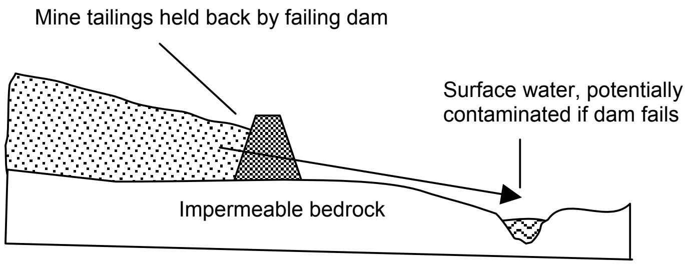
In Zones 1 and 2, the assessment identified widespread elevated levels of lead and other heavy metals in soil. The assessment also showed that due to dilution no appreciable contamination of Glenridding Beck was taking place. A human health risk assessment was undertaken and the output indicated that no adverse health effects were expected. Remedial works (which would potentially have been highly damaging to the Scheduled Monument) were therefore not required.

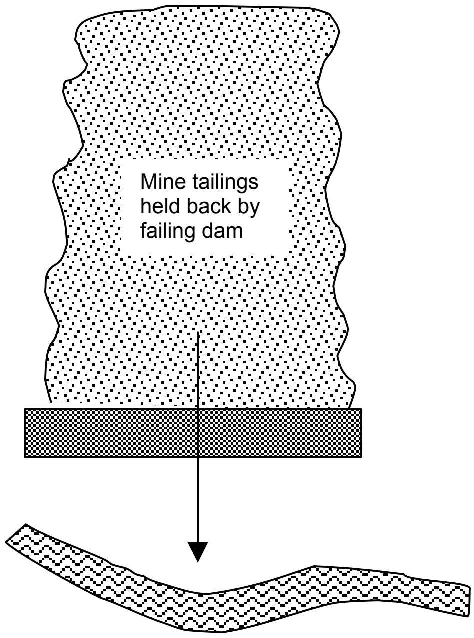
A structural engineering assessment of the site indicated that, while many of the revetment walls were stable or in need only of maintenance, other walls required capping and/or more extensive works to avoid collapse with concomitant hazard to visitors and/or damage to the Scheduled Monument.

For Zone 3, stability analysis of the two tailings dams indicated that stability of Dam No 1 was generally adequate, but that Dam No 2 had potential for significant failures. Remediation was therefore required, both for the safety of the public in the area below the tip, and because any slippage into Glenridding Beck would produce a pathway between heavy metal contaminants in the tip, and receptors in the form of consumers of water from the downstream river and lake system, and the ecosystem of Ullswater. Recommended solutions were determined by the need to minimise disturbance to the Scheduled Monument. Following further combined archaeological and geotechnical evaluations, a remediation programme was designed to stabilise Dam No 2 by construction of gabion walls, enhanced drainage, and limited reprofiling and capping. The programme was designed to minimise damage to archaeological features and deposits, and was preceded and accompanied by archaeological recording in order to mitigate the damage that remained unavoidable.

Section

Plan





Simplified Conceptual Model

Source = mine tailings (elevated levels of heavy metals)

Receptor = surface water

Pathway = direct movement of contaminated materials upon failure of the dam

Case Study 2: Greenside Lead Mine

CASE STUDY 3: WALTHAM ABBEY ROYAL GUNPOWDER FACTORY

Waltham's history of gunpowder manufacture begun in the 1660s with the conversion of a former fulling mill into a powder mill on what later became known as the North Site (TL 3764 0177). The works grew under private ownership until 1787, when it was bought by the government, refurbished and expanded (including the establishment in 1801-06 of the Lower Island Works centred on TL 3762 0013). Following a lull in production between 1816 and c1850, gunpowder manufacture was again expanded in the late 19th century inspired by a need to produce cannon powders for larger guns, and to manufacture large quantities of moulded powders.

The second half of the 19th century also saw the site become a base for developmental work on chemical explosives and subsequently, from the 1890s, their mass production. This phase began with an experimental guncotton plant was set up in 1863 in the old saltpetre refinery. In 1885 Quinton Hill was purchased, on what became the South Site (TQ 3831 9960), and new guncotton and nitroglycerine factories were built there. In 1891 cordite was adopted for the .303 cartridge of the Lee-Enfield rifle and its manufacture at Waltham increased. By 1900 cordite had replaced gunpowder as the main British service propellant, and at Waltham most gunpowder buildings had been converted to cordite production. In 1895-96 a major building programme began that included the establishment of a nitroglycerine factory at Edmondsey Mead (North site), an acids factory on Millhead stream, new guncotton drying stoves and extension of the canal system; at the end of the century an acetone factory was also built.

World War 1 (WW1) saw a huge increase in production at the site, achieved by some additional building combined with round-the-clock production. By contrast the inter-war period saw a significant drop in production and little investment in the site, although experimental plant on the South Site acted as models for later new factories. The factory was re-activated in the late 1930s as part of Britain's re-armament programme, and played an important stop-gap role in the early stages of World War 2 (WW2), whilst new factories were built at sites in West Britain that were less accessible to German bombers. Manufacture ceased at Waltham in 1943, with the formal closure of the factory in July 1945.

From 1945 to 1991 the factory was re-used as a government research establishment, carrying out research and development of non-nuclear explosives of every kind and latterly including rocket development. In 1984 the former factory was divided up, the North site remaining with Ministry of Defence (MoD) whilst the South Site and the Lower Island works passed to British Aerospace Defence, Royal Ordnance Division.

The North Site is 190 acres of low-lying flood plain including100 acres of woodland. Thirty four hectares are also designated as a SSSI, including the largest heronry in Essex. A survey in 1993 by the Royal Commission on the Historical Monuments of England (RCHME) preceded the listing of 21 buildings and scheduling of a large part of the North Site in December 1993. Subsequently, supported by a Heritage Lottery Fund grant in 1996, the North Site has been set up as an interpreted landscape under the title 'Waltham Abbey Royal Gunpowder Mills' that opened to the public in May 2001.

Contamination Issues

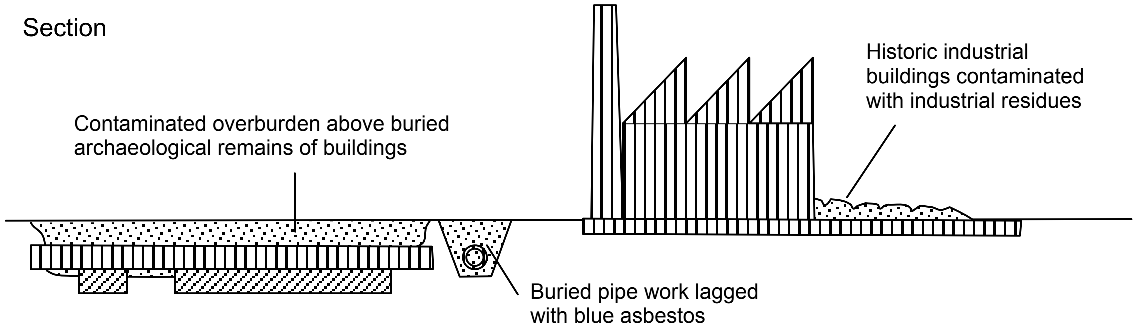
Some decontamination and clearance was undertaken from 1991 ahead of the recognition of the site's national archaeological importance. Recognition of this importance and the need for the decontamination programme to minimise damage to archaeology followed an EH/RCHME site visit in 1992. A detailed survey by the RCHME followed in 1993 and in June of that year the MoD appointed a site archaeologist (a post that continued to 1998), to use the RCHME results as a basis for working alongside and informing the decontamination process. Concurrent surveys of the extent of the heronry and bat roosts put further constraints on the way decontamination was to be carried out and ultimately account was also taken of the proposal that emerged to open the site to the public.

Several factors fed into the decision-making process on remediation to be used for different areas of the site. A fundamental part of the exercise was a systematic programme of chemical testing using boreholes/testholes. There was also constant air monitoring. Asbestos was known to be a risk in buildings and in topsoil and this dictated a need for breathing suits during the decontamination process. Alongside this work, the results of the RCHME investigation (that consisted of an analysis of cartographic and documentary sources, a topographical survey, and a photographic survey) allowed the site archaeologist to inform the decontamination process in several ways.

It allowed early identification of sensitive archaeological remains which assisted in determining the appropriate remediation procedure for each area. Hence, for example, where gunpowder was the only known contaminant in an area an argument could be made, tempered by the results of the independent chemical testing, for a policy of low intervention. At the acids factory, overburden was scraped back to floor surfaces and the ground around cleared to floor level.

The RCHME survey also predicted the presence of buried remains so that these features could be planned for in the decontamination works programme (only a few unexpected features were found). For instance, the light structures of the tetryl (acid) factory, demolished in 1960s/70s, had been built on top of an earlier gunpowder drying store in the NW of the site. Contamination, in the form of tetryl impregnation of ground from spillage, was removed and the exposed remains kept *in-situ* but backfilled.

Similarly the topographical survey identified lost features. For example, former steam pipelines that had been lagged with blue asbestos later suffered decay of the outer lagging resulting in land contamination along their routes. Not all of these routes could be identified from documentary work but the topographical survey picked up the runs of surviving support posts.



Simplified Conceptual Model

Sources = waste and residues from explosive manufacturing industry including for example tetryl, asbestos in building materials and blue asbestos in pipe lagging

Receptor = site visitors (human health) and archaeological resource

Pathways = inhalation of dust (human health), direct contact of the waste with the archaeological resource

Case Study 3: Waltham Abbey Royal Gunpowder Factory

CASE STUDY 4: FORTH BANKS INFIRMARY, NEWCASTLE UPON TYNE

The Forth Banks Infirmary site (now the International Centre for Life) lies on the west side of Newcastle city centre, just outside the former town walls. The possibility of archaeological remains and of ground contamination was first noted in the preliminary constraint assessments, as a 'burying ground' on one of the historic maps. A full archaeological assessment was therefore commissioned in advance of formal planning applications. This assessment indicated that the development area included the former site of the Forth Banks Infirmary, a public hospital founded in the later 18th century. The hospital had had its own burial ground in use until 1845, after which date it was overlain by an additional wing of the hospital, and there was no evidence of the burials having been exhumed before re-use of the site. Evaluation trenches confirmed the presence of undisturbed burials, mostly surviving as earthfast skeletons but also including at least two burials in surviving wooden coffins (preserved by waterlogging in very deep graves), together with disarticulated human bone in the soil of the former cemetery and a charnel deposit. The skeletal assemblage was identified as being of considerable scientific importance for the study of an emerging industrial population, and of developing medical science, and it was agreed that its removal would be undertaken as part of an archaeological excavation of the hospital site.

Contamination issues

Health and Safety assessments identified potential hazards from infectious diseases (including tuberculosis, anthrax, and smallpox) which might have been the cause of death, together with potential hazards from lead poisoning (in the event of any lead coffins being excavated), inhalation of fungal spores from any decaying wood encountered, and Weil's disease. Geotechnical ground investigations indicated mildly elevated heavy metal levels within the soils of the former burial ground, and there were possibilities of contamination from other documented and potentially undocumented urban land uses during the 18th-20th centuries. There was local concern over the possible spread of contamination by dust from the excavation and other ground works, especially to an adjacent childcare centre.

Solutions

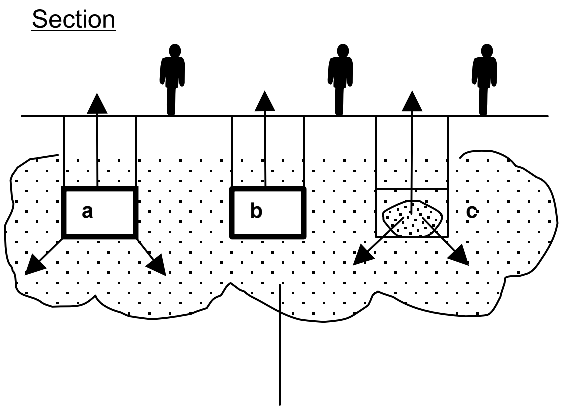
The solution adopted was to undertake removal of the burials as part of an archaeological excavation, with strict Health and Safety control. Although the excavation did not formally qualify as a construction site, the engineers chose to conduct it within the Construction Design and Management Regulations 1994 (CDM) procedures as the most suitable regulatory framework. Although the level of risk to human health from removal of the burials was thought to be low, the hazard was assessed to be heavily dependent on the level of preservation of the individual burials, the range of which could not be fully predicted. The risk to site workers was therefore graded as medium-high, and the site investigation was therefore commenced in accordance with health and safety requirements under the British Drilling Association (BDA) guidelines 'red' classification. Site-specific measures instituted under the regulations were:-

(a) A 2.4m environmental fence to provide a visual barrier and minimise dust emissions at low levels:
(b) Designated clean and dirty working areas separated by a decontamination unit
(c) Personal protective equipment in accordance with the BDA 'red' classification
(d) Separate collection and disposal of waste and effluent from dirty working areas
(e) Daily perimeter and personal dust monitoring
(f) Medical examinations for all staff working within the dirty areas

(g) Collection and analysis for hazards of soil samples from the dirty areas

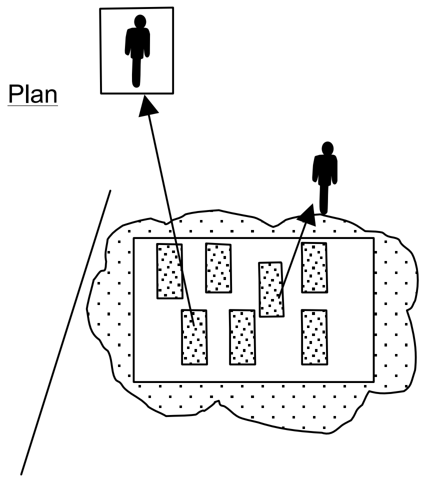
The results of the monitoring under these regulations were negative as regards to biohazards and negative or low risk as regards to other monitoring and analysis. For the removal phase, the site was regraded to the BDA 'yellow' classification, with continued daily monitoring. Health and safety requirements for site staff during this phase were:

- For general site work, hard hats and protective footwear as standard, and dust masks, ear protection and goggles available as required
- For cleaning/lifting of earthfast skeletal remains, dust masks and disposable gloves as standard in addition to the above
- For cleaning/lifting of coffins and coffin remains, staff to be issued with full personal protective equipment, including disposable overalls, dust masks, and disposable gloves



Risk to health of excavation team from:
(a) lead coffins
(b) fungal spores from decaying wooden coffins
(c) pathogens from decaying human remains

Risk of wider environmental contamination from lead in coffins and pathogens from decaying human remains



Risk to nearby human population including childcare centre from contaminated dust generated by excavation

Risk of wider environmental contamination from lead in coffins and pathogens from decaying human remains

Simplified Conceptual Model

Sources = lead in the coffins, fungal spores from wooden coffins, pathogens

Receptors = archaeologists working on the site, off site human health receptors (nearby child centre), soils and environment.

Pathways = on site workers - direct ingestion, dermal contact; on site and off site receptors - inhalation of spores and pathogens

Case Study 4: Forth Banks Infirmary

4 ARCHAEOLOGICAL RESOURCES AS A PATHWAY FOR THE TRANSFER OF CONTAMINATION

In some instances archaeological resources, in particular buried archaeological remains, may provide a pathway for the transfer of contamination from a source to an adjacent receptor. Buried archaeological features and structures may in some instances act as a barrier, impeding transfer of land contamination. Archaeological site investigation using intrusive techniques, such as coring or excavation also has the potential to inadvertently create a new pathway for the movement of contaminants from source to receptor.

4.1 Archaeological Deposits and Structures as a Pathway

Buried archaeological features (such as pits and ditches), particularly where cut into otherwise impermeable deposits (such as rock or dense clay), may provide a path for the movement of contaminated groundwater into areas otherwise not likely to be affected.

In some instances archaeological structures, such as drainage tunnels or soughs, which are often of considerable historic interest, may provide a pathway for the discharge into the environment of contaminated mine waters.

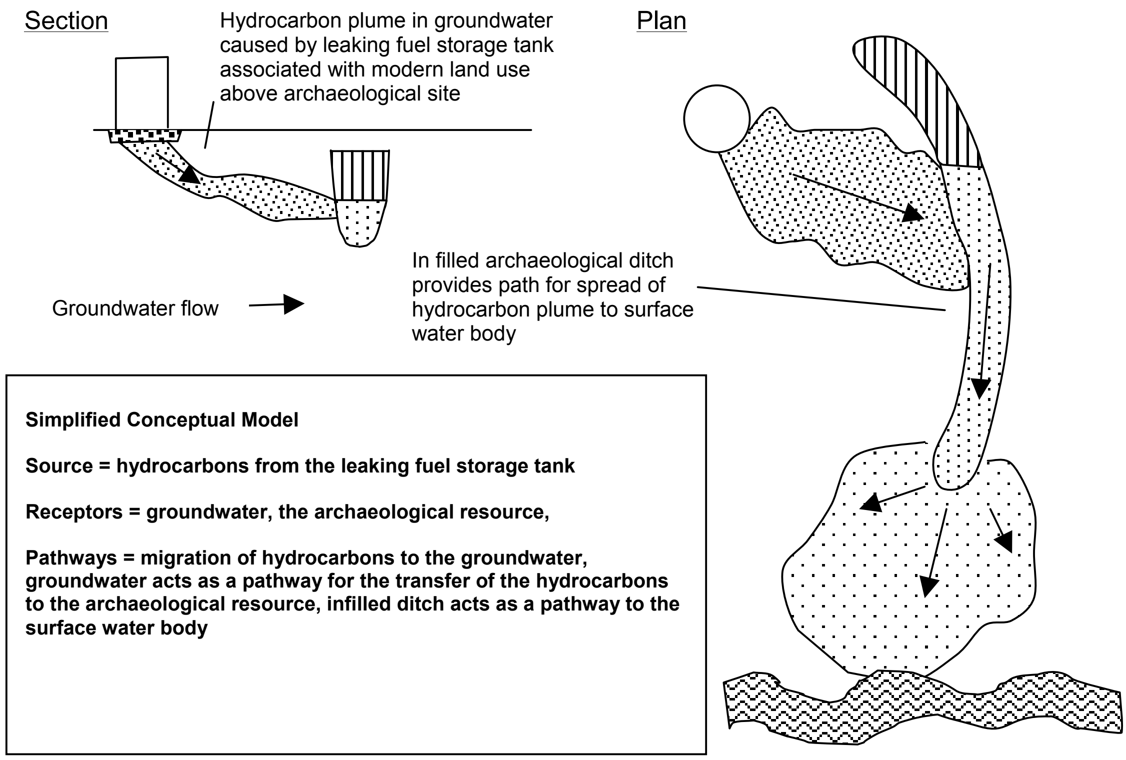


Figure 4.1 Infilled ditch acting as a pathway

4.2 Archaeological Features as a Barrier

Archaeological features may occasionally act as a barrier to the transfer of contamination to a receptor. At St Thomas, Oxford (Case Study 5, Section 5) a network of deep infilled ditches, excavated well below the water table may have acted as barriers to the movement of hydrocarbons suspended in groundwater (i.e. as sumps interrupting lateral movement).

In addition, archaeological features can also create preferential pathways through adjacent soils, for example, the presence of a buried compacted floor surface might act as a barrier to vertical contaminant movement thereby forcing the contaminant to move horizontally into adjacent uncontaminated areas.

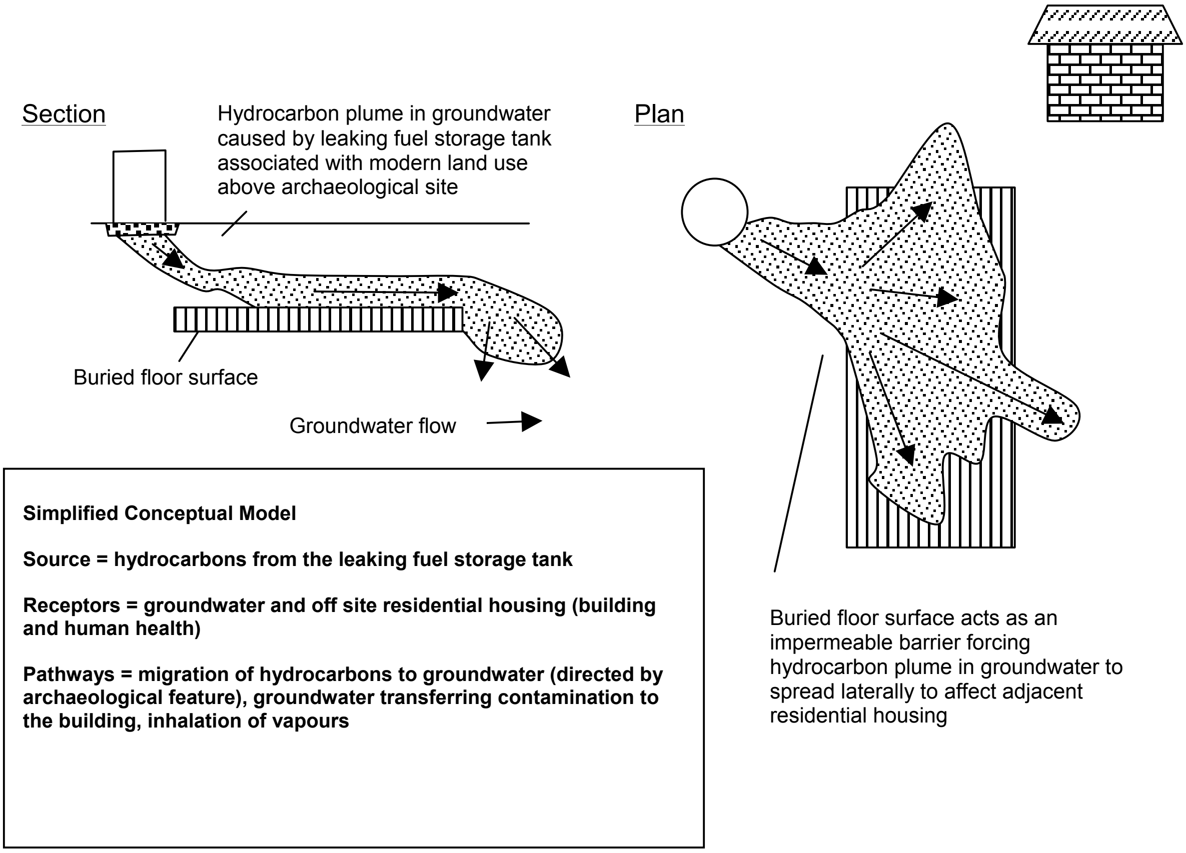


Figure 4.2 Archaeological feature acting as a barrier to the flow of contamination

4.3 Archaeological Site Investigation as a Pathway

There also exists a risk that poorly planned archaeological site investigation (or land contamination investigation) may trigger the release of contaminants into the environment, for example, by disturbing naturally formed lagoons or voids that have acted to contain contaminants, or by breaching structures such as buried pipes, reservoirs or storage tanks, containing contaminated material. The risk is particularly high on brownfield sites and highlights the need for detailed documentary research to clarify the presence and location of such structures prior to the commencement of site investigation. Initial non-intrusive site investigation using geophysical prospection techniques (Table 6.2), for example, may also assist in detecting buried structures even if they are not otherwise documented.

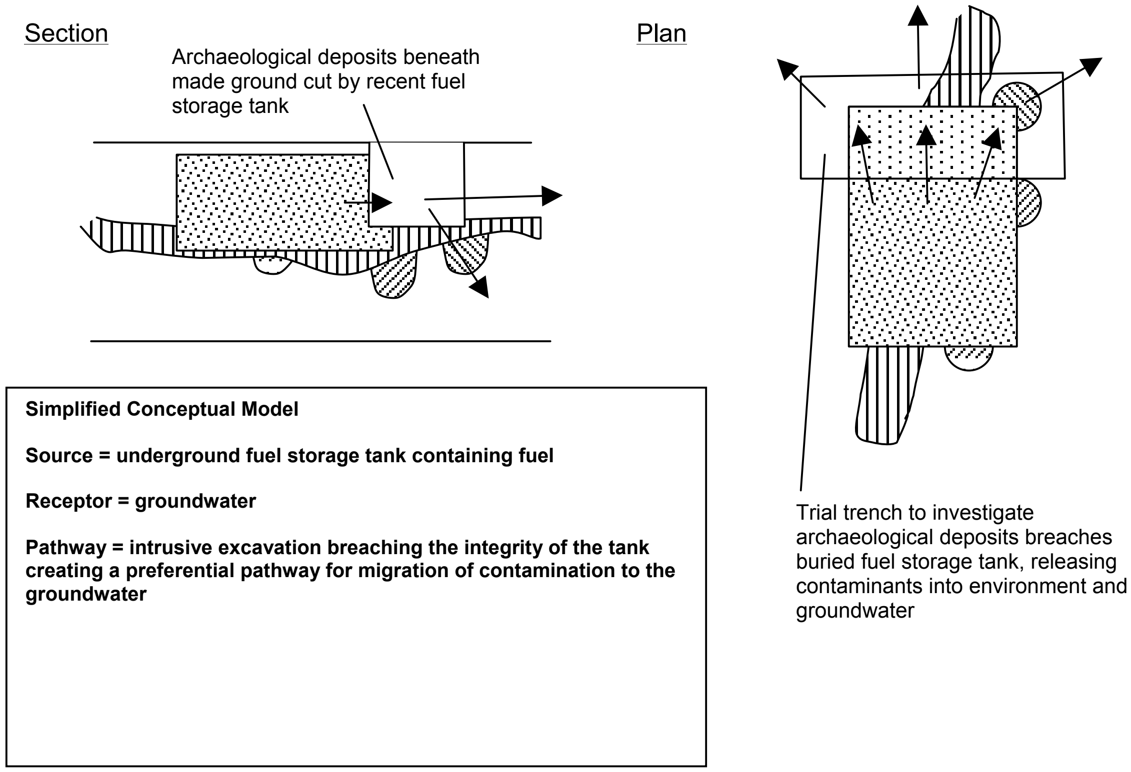


Figure 4.3 Intrusive site investigation works creating pathway for movement of contamination

5 ARCHAEOLOGICAL RESOURCES AS A RECEPTOR OF LAND CONTAMINATION

Archaeological resources may be affected by land contamination unrelated to the character of the resource or to any past activity directly associated with it, usually as a result of a more recent contaminating land use on or adjacent to the archaeological resource.

5.1 Archaeological Resources in Urban Environments

In urban areas, deeply stratified archaeological deposits are a common occurrence. These deposits develop as a result of the occupation of an area over many centuries. In Britain's historic towns stratified archaeological deposits may be many metres thick and comprise a sequence of activity from earliest prehistory to the modern era, representing a significant archaeological resource. Often the most deeply buried deposits may include well-preserved remains, with good survival of organic materials if below the water table.

For many historic towns in England, in addition to the archaeological records held by the local planning authorities, English Heritage has funded the production of intensive urban surveys which record in detail the historic land use of urban areas. Usually the results of these surveys are held by the local planning authority. In addition, historic landscape surveys, provide information on the wider landscape, including the place of archaeological resources in that landscape, for many counties in England.

In urban environments, archaeological resources are susceptible to contamination either by the downward movement or leaching of contaminants from more recent overlying deposits or by contaminant plumes in underlying groundwater. Structures penetrating the ground, such as underground fuel storage tanks or pipework, may also directly introduce contamination into deeply buried deposits. In some circumstances archaeological resources may themselves be uncontaminated, either adjacent to, underlying or overlying contaminated materials, but may be threatened by remediation techniques that require the disturbance or bulk removal of the contaminated materials. In addition, in some parts of the UK changes in groundwater levels in urban areas following the cessation of industrial groundwater abstraction in the 1960s has resulted in a rise in groundwater levels bringing contaminated groundwater into contact with previously unsaturated soils containing archaeological deposits.

At St Thomas Oxford (Case Study 5), contaminated hydrocarbon plumes underlay archaeological deposits that were themselves largely free from contamination. Here land contamination did not pose a significant threat to the archaeological resource; instead the chief threat lay in the remediation process that required bulk excavation of the uncontaminated archaeological deposits to allow access to and removal of the hydrocarbon plume.

At Byker City Farm, Newcastle upon Tyne (Case Study 6) an area of high archaeological potential, including possible remains of Hadrian Wall, was contaminated by industrial residues from a 19^{th} and 20^{th} century lead works, which was itself a site of historic significance. On this site a combination of archaeological and geoenvironmental site investigation led to the implementation of a remediation strategy allowing for the removal of contaminated material overlaying the archaeological deposits with minimum impact on the archaeological resource and controlled recording of any archaeological remains disturbed.

5.2 Archaeological Resources in Rural Environments

In rural areas, archaeological resources are most likely to be encountered as features cut into or accrued/built upon subsoil immediately below the modern soil horizon and deeply stratified sequences of archaeological remains are less common. In some areas earthworks may present tangible surface remains preserving evidence of past agricultural regimes, for example, as ridge and furrow indicating past plough-lands fossilised by subsequent conversion to pasture, or of abandoned settlement such as deserted medieval villages.

Some rural landscapes do preserve deeply stratified sequences of archaeological deposits. In wetland areas, such as the Fens of East Anglia or the Somerset Levels, ancient landscapes survive beneath subsequent peat formation and alluvial deposits (Coles 1995, van de Noort *et al*. 2002). Similarly, deep alluviation in river valleys, particularly in the middle and lower courses of major rivers such as the Severn, Trent and Thames, may cover or encapsulate stratified archaeological deposits. Such situations often favour the *in-situ* preservation of organic structures, artefacts and ecofacts within waterlogged deposits. In some upland areas, such as parts of the South Pennines, blanket peat formation may also cover and preserve the fragile remains of earlier landscapes.

In most rural landscapes contamination is likely to be a result of adjacent recent land use or via groundwater. Rural industries, such as regionally important metalliferous mining, quarrying and even historic refuse disposal and landfill may also introduce contamination. In such cases the archaeological resource may be both the receptor and source of contamination.

5.3 The Impact of Land Contamination on the *In-situ* Survival of Archaeological Structures and Artefacts

Contamination may affect historic buildings and structures either by direct detrimental impact on the fabric including the foundations of the structure or by rendering them unsafe for use due to contamination. Environment Agency (2001a) and various Building Research Establishment (BRE) documents (e.g. BRE, 1994) provide guidance on assessing the risk to buildings and building materials. When considering archaeological resources it is necessary to take account of the nature and age of the building or structure and apply the guidance with care. For example, the materials, construction technique and structural integrity of Roman building remains will vary considerably from modern concrete structures thus the impact of the contamination may be different. In some cases building materials may themselves be considered a contaminant requiring remedial action, for example through the possible presence of anthrax spores in historic plaster (English Heritage 1999).

Buried archaeological materials are subject to physical, chemical and biological decay. However, the fragile equilibrium of the burial environment on archaeological sites often facilitates the survival of buried structures, artefacts and ecofacts. A range of soil properties are significant in contributing to the *in-situ* survival of archaeological materials (Hopkins 1998; Pollard, 1998; Simpson, 1998). Broadly, survival will vary dependant upon the soil structure, oxygen content, moisture, pH and microbial activity. The majority of organic and inorganic materials survive well in anaerobic conditions (for example, in permanently waterlogged sediments) or in desiccating environments (where air circulation leads to the removal of moisture, conditions occasionally encountered inside standing structures in the British Isles). In damp soils, aerobic conditions promote the decomposition of organic matter and the oxidizing of metals. Acidic soil conditions assist in the preservation of some classes of organic materials as they deter bacterial and fungal growth inhibiting decomposition. However, acidic soil conditions are detrimental to the survival of other types of organic matter and many inorganic archaeological materials. The burial environment and the processes affecting the survival of archaeological materials are at present incompletely understood. On-going research is to some extent clarifying the factors affecting the survival of, for example, metal artefacts (Wagner, *et al* 1997; Edwards 1998) and bone (Millard 1998).

Watkinson & Neal (1998) review the affects of different burial environments on various classes of artefact. English Heritage (2002) provides similar information for ecofacts. The preferential burial conditions for some major classes of archaeological material common in the British Isles are summarised in Table 5.1.

Table 5.1 Examples of different classes of archaeological material and the preferential burial environment required for their survival. (Principal sources: English Heritage 2002, Watkinson & Neal 1998, Shackley, 1981).

Material	**Preferential Burial Environment for *in-situ* Survival**
Wood	Waterlogged anaerobic conditions, desiccating environments.
Leather	Waterlogged anaerobic conditions, desiccating environments.
Bone	Waterlogged anaerobic conditions, desiccating environments, alkaline or pH neutral soils. Pre-burial use or treatment and object size significantly affect survival.
Skin	Waterlogged anaerobic or desiccating environments. Acidic waters or soils retard microbiological activity.
Textile	Waterlogged anaerobic or desiccating environments. Slightly alkaline or pH neutral soils.
Iron	Anaerobic environments, alkaline or pH neutral soils. Poor survival in acidic conditions.
Copper Alloy	Anaerobic environments, alkaline or pH neutral soils. Poor survival in acidic conditions.
Glass	Anaerobic or desiccating pH neutral environments. Alkaline or pH neutral soils.
Ceramics	Anaerobic or desiccating environments. All soils, although alkaline or pH neutral soils favour preservation of low-fired ceramics.
Plant remains	Waterlogged anaerobic or desiccating environments. Acidic soils. May also be preserved by charring or mineral replacement in all conditions.
Molluscs	Waterlogged anaerobic conditions, alkaline soils.
Pollen	Waterlogged anaerobic conditions, acidic soils.
Insect remains	Waterlogged anaerobic conditions, acidic soils.

Knowledge of the burial environments that favour the survival of a class of archaeological material makes broad predictions of the likely impact of various contaminants on survival possible. Principal adverse impacts are likely to be caused by contaminants that affect the chemical properties of soils and groundwater, for example by increasing or decreasing pH or by changing redox potential (Banwart 1998).

However, it should be appreciated that impacts will be specific to a particular class of material. The impact of contaminants on an archaeological site as a whole may include both detrimental and favourable changes in soil properties and geochemistry, and it is important to gain as complete as possible an understanding of the range of archaeological materials and structures present at a site in order to achieve an understanding of the potential impact of contamination, as indeed of any other activity likely to change the physical or chemical properties of the burial environment (Davis, *et al* 1998).

5.3 Land Contamination and the Recovery Potential of Archaeological Resources.

Land contamination may also affect buried archaeological structures, deposits and materials by rendering them unsuitable for preservation by record.

Archaeologists work in close proximity to the materials that they excavate and record. In such circumstances, land contamination may affect the physical recovery of archaeological materials by posing a threat to the health and safety of excavation staff exposed to contaminated archaeological deposits. The use of appropriate protective measures (including for example, personal protective equipment) will often facilitate safe working even in contaminated environments. Section 6.4 of this guidance includes outline information on appropriate health and safety measures for working in contaminated environments.

It is usual for archaeological material recovered from excavation to be studied, archived and conserved as part of the post-fieldwork programme of analysis, ultimately leading to a public record, possibly comprising academic and popular publication and museum storage and display. Contaminants may affect the viability of this process by rendering material unsuitable for analysis and/or conservation or unsafe for long-term storage. It should be noted that waste management licensing requirements (Waste Management Regulations 1994) may need to be considered in the context of keeping, treating or disposing of waste soils, for example those collected from an archaeological site as soil samples for scientific analysis.

Site-specific assessment of the impact of land contamination on archaeological remains should include information on the likely impact of known contaminants, not just on the survival of archaeological materials, but also on the physical recovery, analysis, archiving, conservation and long-term storage of those materials.

CASE STUDY 5: MEDIEVAL SUBURBS, ST. THOMAS, OXFORD

The medieval suburb of St Thomas, Oxford lies on the floodplain of the river Thames to the west of Oxford castle. Archaeological investigation over a twenty-year period has identified medieval tenements, parts of a Cistercian abbey (protected as a scheduled ancient monument) and evidence for the artificial reclamation of the floodplain from the early 13th century onward.

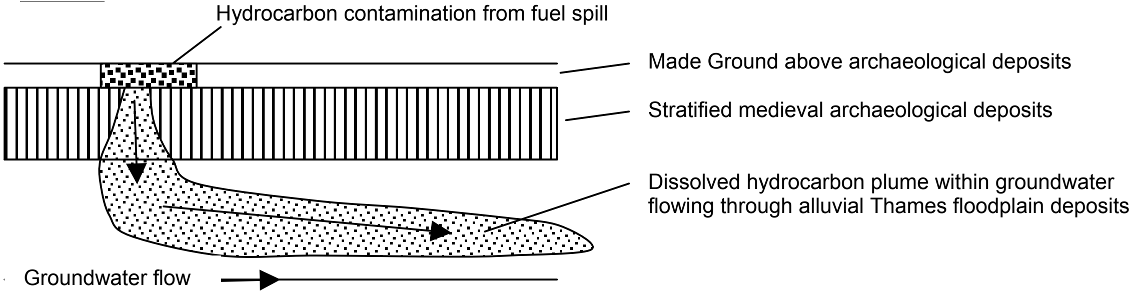
Contamination Issues

Contamination in the St Thomas area was largely as a result of accidental fuel spillage from a variety of low intensity industrial activities including a railway yard and road transport depot. Hydrocarbons on the floodplain percolate to the surface of the groundwater, moving gradually with the groundwater flow to form a contaminated plume. At a number of development sites within the suburb, hydrocarbon plumes from adjacent land travelled beneath otherwise uncontaminated archaeological deposits. The usual remediation solution for such contamination is to remove overburden to provide direct access to the contaminated material to facilitate its excavation and removal to a licensed landfill site. However, the presence of uncontaminated archaeological deposits, in effect forming the overburden, presents considerable difficulties. PPG16 places the onus on the developer to provide for the *in-situ* preservation of archaeological remains whenever possible. The removal of otherwise unthreatened archaeological deposits to reach the contaminated plume is questionable, while the excavation and recording of the uncontaminated archaeological deposits prior to their removal adds significantly to development costs.

Solutions

At St Thomas the solution adopted was the removal of overlying archaeological deposits to allow access to the contaminated hydrocarbon plume. Archaeological intervention ranged from a passive watching-brief to evaluation and excavation. *In-situ* remediation techniques were not attempted; however, they may provide a more appropriate solution in such cases.

Section



Simplified Conceptual Model

Source = hydrocarbon contamination from fuel spill

Receptors = archaeological deposits, groundwater

Pathway = migration of hydrocarbons to the groundwater

Case Study 5: St Thomas, Oxford

CASE STUDY 6: BYKER CITY FARM, NEWCASTLE UPON TYNE

Byker City Farm lies in the Ouseburn valley, on the east side of Newcastle upon Tyne. The site was initially identified as of potential archaeological importance for two reasons: it lay across the projected line of Hadrian's Wall (a World Heritage Site) in an area where the precise course of the Wall was unknown; and it contained visible remains of Northumberland Lead Works, a 19th-early 20th century lead works producing white lead (lead carbonate) from lead metal for use as a pigment. Archaeological assessment demonstrated that the visible archaeological structures also included remains of the 19th century Ouseburn Flax Mill, and that part of the site also lay within the former tidal Ouseburn inlet, with the potential for waterlogged Medieval and Post-Medieval waterfront and inter-tidal features.

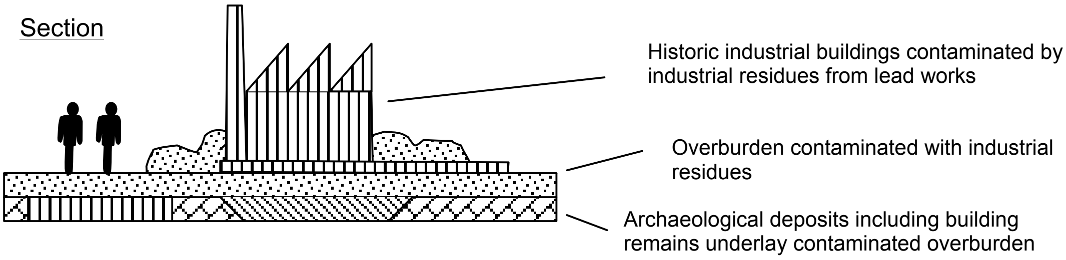
Contamination issues

Ground investigations as part of an environmental study of the Lower Ouseburn Area, followed by a soil sampling programme by Newcastle City Council, identified concentrations of lead ranging up to 16,000 mg/kg, the highest levels being found in a children's playground. Newcastle City Council identified the land as being contaminated, on the basis that a contaminant (lead), a receptor (employees and visitors at the City Farm), and pathways from contaminant to receptor (ingestion and inhalation of soil and dust, consumption of vegetables and herbs from the Farm, and dermal contact with soil) existed.

Solutions

The solution proposed was to remove contaminated deposits to at least 1m depth, disposing to a registered landfill site, and reinstate with imported soils over a clay cap. This was preceded by a desk-top archaeological assessment to assess the archaeological potential of the site, followed by photographic recording of exposed historic features and structures, and an archaeological evaluation by trenching to confirm the depth and nature of the archaeological deposits. Removal of the contaminated deposits was accompanied by an archaeological watching brief, involving continuous archaeological presence during work on areas where the evaluation had shown archaeological remains within the depth of disturbance, and intermittent observation during work on areas where the evaluation had indicated that the archaeological deposits lay below the base of disturbance. Staff engaged in the intrusive archaeological interventions (evaluation and watching brief) wore protective clothing and masks, and health and safety support was provided by Newcastle City Council.

These solutions allowed the removal of heavily-contaminated deposits from a site with major public access and clear pathways for contamination, combined with preservation and display of masonry structures relating to the lead works, recording of contaminated archaeological deposits which could not be retained *in-situ*, and preservation of archaeological deposits below the base of contamination.



Simplified Conceptual Model

Sources = lead in soils

Receptors = human health (employees, site visitors, children), historical structures

Pathways = human health – direct ingestion of soil, dermal contact, inhalation of dust and consumption of homegrown produce, historical structures – direct contact

Case Study 6: Byker City Farm

6 SITE INVESTIGATION TECHNIQUES

This chapter discusses some of the common site investigation techniques utilised in land contamination and archaeological assessments. Where contamination and archaeological resources are both present, or suspected, it may be possible to design a dual-purpose site investigation that accommodates the data requirements of both.

On any site the archaeological resource may

- form part of a pollutant linkage and thus its capacity as a source/pathway/receptor may require investigation in; or
- be present on the site (or on adjacent land) not forming part of any pollutant linkage but still requiring consideration due to the vulnerable nature of resource and the potential impact of any site investigation (and remedial) techniques.

This report is only concerned with works undertaken to assess and remediate land contamination. It should be noted that these activities may form only part of the works taking place on any site. For example, in the development context there may be site clearance works, investigation work undertaken for geotechnical purposes, construction activities, including piling (Environment Agency 2001c) and grouting, and the provision of services, and post construction maintenance. Davis *et al.* (1998) describe some of the operations typically undertaken during the course of a development. It also suggests mitigation measures to reduce, avoid or limit damage and disturbance to archaeological remains and strategies to enable preservation *in-situ* of the archaeological remains.

6.1 Design of a Site Investigation

In the assessment of land contamination, the conceptual model, the potential pollutant linkages and the associated uncertainty should determine the objectives of the site investigation. The purpose of this is to obtain information of sufficient quantity and quality to inform decisions about the potential risk to the receptor(s) and where necessary assist in the development of appropriate risk management strategies. As the assessment progresses, and more information becomes available through the site investigation, the conceptual model should be reviewed and refined to provide a greater understanding and a reduction in the uncertainty associated with the site. Factors for consideration may include the type of contaminant, the spatial distribution of contaminants, the presence of any structures on the site and the nature of the receptor e.g. human health, the water environment, archaeological or ecological. This is equally applicable in the context of Part IIA, the planning process and other legislative contexts.

Considerable costs can be incurred by a site investigation and effective planning is essential not only to ensure that the right information is collected, but also the efficient use of the resources available. Environment Agency (2000b) provides comprehensive guidance on the technical aspects of site investigation and Environment Agency (2000c) guidance on the development of appropriate soil sampling strategies.

Where archaeological remains and contamination are present early consultation and effective planning may allow the development of a dual-purpose investigation. Where this is not possible, consultation should ensure that the contamination assessment does not cause avoidable damage to archaeological deposits, and the archaeological evaluation does not mobilise the contaminants or introduce new at-risk receptors. Equally it should be recognised that the data requirements for the land contamination and archaeological assessment are not the same and that different investigation methods may be required. The decision as to the possibility of a dual-purpose investigation can only be made on a site-specific basis taking account of the specific objectives of the individual assessments and other factors, such as time and contractual implications. A geotechnical specialist looking for depth to solid bedrock (foundations), geoenvironmental specialist looking for contamination, and an archaeologist will all wish to carry out an intrusive investigation, each with their own preferred technique e.g. light cable percussion borehole rig, window sampler and a backactor. For reasons of cost, environmental risk (e.g. groundwater contamination, archaeological damage) and health & safety (e.g. unstable ground or explosive gasses) it is advisable to co-ordinate, and ideally integrate, the investigation by all three specialists.

Archaeological site investigation will focus on the need to recover information adequate to inform planning decisions relating to the archaeology of the site (PPG16, 1990). Site investigation may also be required in situations not within the remit of PPG16, for example to assist in preparing a management strategy for a site or monument not directly threatened by development.

PPG 16 places the onus on mitigation ensuring the preservation *in-situ* of archaeological remains, either by their exclusion from a development area or by appropriate design solutions to limit impact (Davis *et al* 1998). Site investigation is required in order to inform the preparation of a mitigation strategy appropriate to the archaeological remains present on the site.

Where preservation *in-situ* is not possible preservation by record of archaeological remains may be acceptable and in such cases the site investigation must be sufficient to allow the drafting of a comprehensive written strategy describing how this will be achieved.

Within the planning process, archaeological site investigation is commonly undertaken to meet the requirements of a brief prepared by the local planning authority (LPA) archaeological officer. Usually the brief will require the collection of information on the character of archaeological remains (including spatial extent, date and state of preservation) to allow an informed judgement to be made as to the significance of archaeological remains and the likely impact of the proposed development.

The brief will require that the archaeologist undertaking the site investigation prepare a detailed scheme of work or specification for submission to the LPA for approval prior to the start of work on site. The specification should set out the types and levels of archaeological work to be undertaken in sufficient detail to form a measurable standard against which the satisfactory progress of the site investigation may be monitored by the LPA and the commissioning organisation.

The Institute of Field Archaeologists provides detailed guidance on the levels and types of archaeological work and the required standards of execution and reporting for the various stages of site investigation (Institute of Field Archaeologists 2001a-c).

6.2 Site Investigation Techniques

There are a range of site investigation techniques used in both the assessment of land contamination and the assessment of archaeological resources. These can be catergorised into two main types: intrusive and non-intrusive. It is likely that any investigation whether for archaeological or land contamination purposes will combine a number of different techniques.

- Intrusive methods involve breaking the ground surface for the purpose of collecting samples, visual inspection of the ground and the installation of monitoring equipment. Trial pits, window sampling, probing, rotary coring and drilling (auger, cable percussion and rotary) are all intrusive techniques. Environment Agency (2000b) provides summary sheets of a number of intrusive methods including a description, key applications and limitations. Measures such as ensuring site personnel (including sub contractors) are aware of the archaeologically sensitive nature of the site, provision of accurate site plans showing the location of proposed intrusive investigations, adequate supervision on site, the use of appropriate equipment and the proper reinstatement or disposal of waste arisings should all assist in ensuring that the archaeological resource is not impacted unnecessarily.

- Non-intrusive techniques can image and detect variations in the ground based on physical and chemical properties without breaking through the ground surface. These can be used to identify obstructions, underground structures, locate buried drums and tanks, determine extent of contamination, detect changes in the groundwater, detect changes in the underlying strata and detect disturbed ground. Geophysical surveys, including ground penetrating radar, magnetometer, soil conductivity and resistivity, are all non-intrusive methods, as are topographical surveys, aerial photography and thermal imaging. In land contamination applications non-intrusive techniques tend not to be as widely used as intrusive methods and where they are used it is generally in conjunction with, or as a precursor, to an intrusive investigation. Environment Agency (2002c) provides guidance on the selection of non-intrusive techniques, and although this document is written in the context of groundwater pollution, it provides a useful overview of many of the currently available techniques that may have wider application.

The design of any site investigation should be site-specific and driven by the conceptual model of the site. Some of the factors likely to influence the selection of investigation method(s) for both land contamination and archaeological assessments are;

- the objectives of the investigation and the effectiveness of the methods to achieve these objectives taking account of issues including ground type, sampling requirements and contaminant type
- limitations of the method
- cost
- time implications

- environmental impact (e.g. potential effect on archaeological resources present on site or adjacent sites, noise, vibrations, emissions to air, potential impact on flora and fauna)
- site conditions, including access
- health and safety implications
- nature of the surrounding land uses
- climate and wet/dry weather constraints

Tables 4.1 and 4.2 provide examples of intrusive and non-intrusive site investigation techniques and their potential application in land contamination and archaeological investigations. The tables are provided as summaries only and not intended as exhaustive lists. Each of the methods listed has advantages and limitations in relation to their use in both land contamination and archaeological assessments. Furthermore what may be considered an advantage in one application may be viewed as a disadvantage in the other. The advantages and limitations are not discussed in this guidance and the reader is directed to the numerous sources of information providing further detail on site investigation methods including Environment Agency (2000b, 2000b and 2002c), Nathanail *et al* (2002) and CIRIA (2002).

Table 6.1 Examples of intrusive site investigation techniques

Technique	Brief description of technique	Potential information obtained for the land contamination assessment	Potential information obtained for the archaeological assessment
Trial pits/trenches/test pit	Excavation of a trench by hand or by mechanical excavator	Visual inspection of the soil profile and geology Collection of soil samples Determine depth to the water table Use of *in-situ* tests	Visual inspection of stratigraphy Assessment of artefact concentration Assessment of the extent, character and preservation of archaeological remains Collection of artefacts and soil samples
Drilling - Cable percussion Rotary cored/open hole	Advancement of borehole to various depths by hammering (cable percussion) or drilling into the ground More than one method may be utilised in the installation of a borehole	Visual inspection of the soil profile and geological succession Collection of samples Depth to the water table Use of *in-situ* tests	Assessment of soil and sediment stratigraphy Recovery of samples
Hand or power auger coring	Drilling and sampling using hand-held equipment, usually to a depth of 1-5m Different methods available for various soil types	Visual inspection of the soil profile and geological succession Collection of samples Depth to the water table Use of *in-situ* tests	Assessment of soil and sediment stratigraphy Recovery of samples
Flight auger, or other boring techniques	Drilling and sampling using powered drilling rig usually to a depth exceeding 5m	Visual inspection of the soil profile and geological succession Collection of samples Depth to the water table	Assessment of soil and sediment stratigraphy, particularly in deep alluvial sediments Recovery of samples
Window sampling	Percussive method for creating small diameter holes using handheld equipment or a small drilling rig	Visual inspection of the soil profile and geological succession Collection of samples Depth to the water table	Assessment of soil and sediment stratigraphy Recovery of samples

Table 6.2 Examples of non-intrusive site investigation techniques

Technique	Brief description of technique	Potential information obtained for the land contamination assessment	Potential information obtained for the archaeological assessment
Geophysical survey: Radar (Ground Penetrating Radar)	Reflection of a radar signal transmitted into the ground reveals variations in subsurface materials	Utility mapping, detection of voids and chambers, bedrock location and structure and mapping of Made Ground and landfill thickness	Particularly effective for detecting buried structures such as walls and for location of voids such as culverts or crypts
Geophysical Survey: Topsoil magnetic susceptibility	Measurement of magnetization of topsoil using field coil or by lab analysis	Not commonly used	Enhanced magnetization may indicate past activity, identifying features and buried objects
Geophysical Survey: Gradiometer or magnetometer	Measurement of slight variations in earth's magnetic field caused by buried material.	Detection of buried structures and underground pipes. Characterisation of landfill depth and extent. Detection of certain geological formations and discontinuities.	Sub-soil cut features may be identified by difference in magnetic properties of their fill. Strongly heated features such as hearth and kilns produce strong, readily detected signatures.
Geophysical Survey: Soil conductivity	Electro-magnetic measurement of subsurface ground conductivity	Detection of buried structures, voids, former landfill sites, contaminated ground and leachate plumes.	Rapid investigation of sub-surface character.
Geophysical Survey: Soil resistivity	Measurements of the varying ability of soils to conduct an introduced electric charge	Detection of structures and voids, disturbed ground, contaminant spills and leachate plumes	Structures or features that differ strongly in resistance to subsoil such as walls and ditches are readily detected.
Geophysical Survey: Resistivity Tomography	Generation of sub-surface pseudo-sections by measuring variations in ground resistance	Location of foundations, infilled ditches and ponds. Landfill character.	Profiling buried features with strong resistance contrast to subsoil such as wall, pits or ditches
Microgravity Surveys (gravity surveying)	Measurement of distribution of gravity anomalies	Detection of buried voids or tanks	Detection of buried structures or features such as walls
Topographical Survey	Use of a range of techniques to build up a base plan of a site	Characterisation of the site, identification of uses and structures over time.	Characterisation of the site. Mapping of structures and earthworks, areas of past disturbance and intrusive damage to archaeological deposits
Soil Chemical Survey	Systematic surface sample collection and analysis for a variety of chemical indicators	Surface soil sample collection	Identification of past occupation or activity areas, industrial practices, etc.

6.3 Other Potential Issues of Concern

In addition to the consideration of the impact of the site investigation method(s) on the archaeological resource, it is also important to mitigate the potential impact of ancillary activities such as vehicle and plant movement. For example, the weight of earth moving equipment and heavy plant or other imposed loads may cause soil failure through shearing or compaction resulting in the displacement of and physical damage to archaeological remains. This can be limited by careful planning, which can only be achieved if early consultation has taken place between all parties involved. Temporary roadways, comprising road plates laid on existing surfaces, can be used to protect underlying deposits from vehicle damage and limit the need for excavation to construct site access and compounds. Other potentially intrusive activities, such as temporary services and fencing, can be located above less archaeologically sensitive areas (Davis *et al* 1998).

Likewise the potential impact of any intrusive method utilised in the archaeological assessment needs to be considered in the context of the land contamination. The most likely scenario is for an intrusive technique in a poorly designed investigation to create a pathway for the transfer of contamination to another receptor, or to cause radial stresses that can damage archaeological resources. For example, the use of auger boring to assess the soil stratigraphy could create a pathway for the transfer of mobile contaminants to an underlying aquifer. The potential for the creation of pathways will depend on the site conditions including the geology, the intrusive methods utilised and the contaminant physical and chemical properties, all of which can be accommodated in a well planned investigation.

Where sensitive *in-situ* archaeological resources are present it will be necessary to ensure that the soil structure and strength are not impacted. It may be necessary to employ measures to mitigate the impact of heavy equipment including the use of loading plates, low pressure tyres on earth moving equipment or geotextile mats. Other issues may include not undertaking the investigation in wet weather when soil strength is lower leaving any archaeological deposits more vulnerable (Davis *et a.l* 1998).

6.4 Health and Safety Issues

In both the land contamination and archaeological disciplines it is always necessary to undertake a site-specific assessment of the potential risk to the health and safety of site personnel before any site work is undertaken.

It is not the purpose of this document to provide detailed guidance on assessing risks to occupational health and safety. This section seeks merely to identify some of the issues that may need to be considered where both contamination and archaeology are present, or suspected. The legislative framework for health and safety may vary depending on the nature of the site but is likely to include the Health and Safety at Work Act 1974, Control of Substances Hazardous to Health (COSHH) Regulations 2002, Construction Design and Management (CDM) Regulations 1994, Management of Health and Safety at Work Regulations (1999) and the Personal Protective Equipment at Work Regulations (2002). There is a wide range of guidance available to assist the preparation of health and safety plans including generic Health and Safety Executive (HSE) on undertaking risk assessments and more specific guidance for land contamination and archaeology applications. These include CIRIA (1996) *A Guide for Safe Working on Contaminated Sites*, AGS (2002) *Manual on Safe Working Practices*, Allen and Holt (1997) *Health and Safety in Field Archaeology* and the IFA (2000) *Code of Conduct.*

The work practices for each of the parties e.g. engineer, drilling contractor, geologist, archaeologist on the site will vary and this needs to be reflected in specific health and safety plans.

The work undertaken by the archaeologist will normally involve direct physical contact with (potentially contaminated) materials and this must be reflected in the health and safety plan. It may be that the nature of the contamination on a site will place limitations on the archaeological activities that can be undertaken. For example

- Hazards may be physical (risk of injury from plant and machinery), biological (leptospirosis in stagnant waters) or chemical (inhalation of harmful vapours);

- Depending on the nature of the contamination any of the following properties may, for example, need to be considered: corrosive, toxic, asphyxiant, carcinogenic, mutagenic, teratogenic, pathogenic, radiological, physical, asbestos, explosive/flammable;

- Effects may be immediate, short term, long term;

- The nature of the hazard will depend on the site and working conditions, for example, the archaeological resource may be some distance from the contamination source but the geology of the site may facilitate migration of vapours/gases. Confined spaces, such as the bottom of a deep excavation trench, may pose particular hazards to the archaeologist due to the build up and lack of dispersion of harmful fumes;

- Risk management: a risk assessment is necessary detailed health and safety plans and procedures with reporting and record keeping, health and safety training, good communication, on some sites the nature of the hazard may be such that close contact with the material is not possible, provision of personal protective equipment, good hygiene practices, health surveillance, contingency plans, decontamination (CIRIA 1996) ;

- To undertake site investigation work in a potentially hazardous environment a safe system of work will be required. This may involve, for example, the removal of hazardous material prior to the start of the work or the use of appropriate personal protective equipment and constant monitoring of the hazard (cf Case Study 4 – Forth Banks Infirmary).

7 REMEDIAL OPTIONS

7.1 Introduction

In a land contamination assessment, the data collected during the site investigation is used to refine the conceptual site model. A well planned and focussed investigation will enable the further characterisation of the site in terms of the nature and extent of contamination, the ground conditions and the plausibility of the potential pathways for the transfer of contamination to the receptor(s). A decision can then be made as to the acceptability of the potential risk from each of the pollutant linkages taking account of the uncertainty associated with the site. If the level of risk is not unacceptable there is no need to undertake risk reduction measures.

Where an unacceptable risk is found to exist it is necessary to reduce the risk to an acceptable level. This may involve

(a) returning to the initial stages of the risk assessment process collating further information and data reducing the uncertainty and reassessing the potential risk from the pollutant linkage; or
(b) instigating risk management options to mitigate the risk (i.e. breaking the pollutant linkage). This may involve source reduction, pathway management or protecting or reducing the exposure of the receptor. Risk management options need not necessarily involve technical remedial measures and in some instances management or institutional controls can be used to effectively manage the risk to the defined receptor (e.g. changing the proposed use).

Where remedial measures are required and archaeological remains are present (whether or not as part of the pollutant linkage), an interdisciplinary approach is necessary to ensure that the remediation does not impact unnecessarily on the archaeological resource, for example by careful zoning of the development site to avoid impact on vulnerable remains.

The selection of appropriate remedial measures on a site must be made on a site-specific basis and will be dependant on a range of factors including:

- the nature of the pollutant linkages present
- the contaminant(s) present
- the receptor (e.g. human health, water environment, archaeology, ecology)
- the nature of the pathway linking the contaminant and the receptor
- time implications
- costs
- local issues (e.g. noise, dust, lorry movements etc.)
- regulatory controls (Why is the work being undertaken? Remediation requirements under Part IIA must be reasonable (DETR 2000a))
- the remedial technology including the track record, requirement for regulatory control of the technology (e.g. some remedial technologies require planning permission, discharge consents, waste management controls, or Scheduled Monument Consent)
- aftercare and monitoring requirements.

Given the complexities of many land contamination sites, including the presence of more than one pollutant linkage, variations in the ground conditions and contaminant properties, an effective remedial strategy will often involve more than one remedial measure.

In the development context, it may also be the case that the project may not be undertaken due to the prohibitive costs of addressing the risks from the contamination on the site or the risks to the archaeological resources (or indeed both).

7.2 Developing a Remediation Strategy

The development of an effective remedial strategy for a site can be a complex process in terms of achieving required standards and cost efficiency and minimising the potential impact on the environment within the time frame allocated. Where archaeological resources are a consideration, early consultation between the parties involved is essential to help mitigate the potential negative impact of the remedial measures.

There is a vast amount of technical literature available on remediation techniques. The Environment Agency is currently producing a series of remedial treatment data sheets for a range of techniques that it considers applicable to remediation of land contamination in England and Wales (Environment Agency 2002b). The data sheets are intended to assist the user in identifying the best practicable technique for a remediation action in the context of the Part IIA regime. The criteria for determining the best practicable technique for remediation include effectiveness, reasonableness (costs and benefits), practicability and durability.

Much of the importance of an archaeological site lies in the form, composition and sequence of its ‘soft’ deposits. Remediation techniques that involve bulk disturbance to these deposits will therefore be extremely destructive to the archaeological value of the site. Remediation techniques that involve localised disturbance to the deposits will also be destructive, but there will often be scope for designing the interventions in order to minimise this destruction. Techniques that do not involve physical disturbance to the archaeological deposits will in general be less destructive, but may involve degradation of specific aspects of the archaeological record (such as waterlogged material, or specific classes of artefacts). Remediation techniques may also cause indirect damage to archaeological deposits due to changes in the physical or chemical environment (for example, vibration, degradation of waterlogged deposits due to lowering of the water table or oxygenation of the groundwater), and these effects may extend well beyond the target area of the treatment.

7.3 Remediation Treatments and Technologies

Table 7.1 below sets out categories of the remedial options used in the UK (after Nathanail *et al* 2002).

Table 7.1 Classification of remedial options

Remedial Option	Breaks pollutant linkage by	Classification	
Landfill	Removing source	Off-site	Ex-situ
Containment	Breaking pathway	On-site	In-situ
Treatment technologies • physical • chemical • biological • thermal • solidification/stabilisation A number of treatment technologies may fall into one or more categories.	Removing or reducing source and/or breaking pathway	Can be off-site or on-site	Can be ex-situ or in-situ

Off-site: Contaminated material is removed from the site for treatment or disposal e.g. landfill.

On-site: Remedial treatment takes place on the site, may be *ex-situ* or *in-situ*.

Ex-situ: Treatment process applied to excavated soils or abstracted groundwater. The material may then be returned to its original position, used elsewhere on the site or removed off site for disposal or reuse.

In-situ: Treatment process applied to unexcavated soils or unabstracted groundwater.

7.3.1 Excavation and disposal or recovery

The excavation of contaminated material and its disposal in suitably licenced waste disposal facilities ('dig and dump') is one of the more common remedial options currently in use in the UK. In the context of the pollutant linkage excavation and disposal removes the source of contamination. It is widely favoured because of the potential to remove virtually all contaminated materials (thus removing any residual liabilities associated with contamination at the site), it is relatively quick and there is no need for a waste management licence or PPC permit. There are practical limitations in that it is not possible to excavate beneath existing structures and excavation of soils may impact on the geotechnical stability of the site, it is also necessary to backfill the void. In considering landfill as an option there are many issues for debate including sustainability (depositing the problem somewhere else and not dealing with it) and the impact on the local environment (including increased traffic, potential for mobilisation of contamination during excavation).

In the context of archaeological resource management the excavation of contaminated material has the potential for severe or total destruction of archaeological evidence. Although not directly impacted by the excavation archaeological evidence in the locality of the treatment zone may be damaged due to dewatering (which is required if materials below the water table are to be excavated) or by ancillary activities such as the mobilisation of heavy plant equipment. Where excavation whether to landfill or for treatment is the selected remedial option it is of vital importance that time is set aside for any archaeological evidence to be properly recorded.

7.3.2 Containment

Approaches such as low permeability barriers and capping are termed as containment. These are designed to prevent or limit the migration of contaminants into the wider environment and generally require some degree of long term monitoring.

Measures taken to 'contain' the contamination may result in changes in the soil conditions which in turn may have an impact on the stability of archaeological remains. For example an engineered cover system laid over contaminated ground may form an effective barrier between the contamination and the human receptor but in doing so reduce the water infiltration rate to the soil thereby affecting the archaeological remains. In engineering containment systems it is important that due regard is given to the load bearing capacity of the soils as the weight of the cover and any structures built on top may damage vulnerable archaeological evidence. Likewise the installation of vertical containment may cause direct physical damage to the archaeological resource and indirectly impact on the burial environment by altering the soil chemistry and water levels (Nixon 1998, Shilston and Fletcher 1998).

7.3.3 Treatment Technologies

A brief overview of several categories of process-based treatment technologies is provided with selected examples within each category. The overview is not intended to be exhaustive, but an introduction, and as such the reader is directed to the extensive literature available for this field.

In the development context, treatment technologies are often viewed as unfeasible due to time implications (treatability studies or pretreatment of soils may be required), the requirement for regulatory permits or consents, space restrictions (for *ex-situ* treatments) and the need for monitoring and aftercare. However these considerations should be balanced against the imperative to ensure the preservation of archaeological remains *in-situ* and the potential cost savings achieved by removing the necessity for archaeological excavation and recording. The actual time required to achieve effective remediation will depend on a range of factors including the contaminant (type and extent), the volume of material, the type of soil, the space available on site and the standard to be achieved. The timescales identified in the tables below are indicative only.

The remediation of land contamination normally requires compliance with requirements under one or more regulatory regimes, for example Waste Management Licensing Regulations 1994. It is therefore recommended that consultation with the Environment Agency is carried out at an early stage in the design of any remediation scheme.

Physical Methods

Physical remediation processes rely upon the exploitation of physical differences between the soil and the contaminant or the contaminated soil particles and the uncontaminated soil particles. Physical methods do not reduce the mass of contaminant present within a soil, but rather concentrate it within a smaller proportion of soil residue which will still require further treatment or disposal for example at landfill. Physical methods include but are by no means restricted to:

Table 7.2 Examples of physical remedial methods

Treatment	Ex-situ/In-situ	Brief Description	Impact
Soil washing	Ex-situ Timescale: depends on volume of soil	Exploitation of the differences in, for example, density, surface chemistry and size between contaminants, contaminated soil particles and uncontaminated particles Used for heavy metal contamination	Soil disturbance Destruction of archaeological deposits and structures
Soil Vapour Extraction (SVE)	In-situ Timescale: 6-18 months	Air is injected or extracted in/out of the ground to volatilise contaminants n the vadose zone	Some degree of soil disturbance for installation of wells or trenches *Changes to the burial environment adversely affecting archaeological remains
Air sparging	In-situ Timescale: 6-18 months	Compressed air is injected into the ground below the water table resulting in volatilisation, biodegradation and diffusion of contamination	Some degree of soil disturbance for installation of wells or trenches Can be used to treat beneath structures * Changes to the burial environment adversely affecting archaeological remains
Electro-remediation	In-situ/ex-situ	Mobilisation of ionic contaminants or soil particles in an artificially induced electric field. Used in treatment of contaminated sediments/sludges.	Mobilisation and disturbance of soils. * Changes to the burial environment adversely affecting archaeological remains

* Changes to the burial environment might include changes in hydrology, changes in chemistry, particularly oxygenation, redox and pH, and changes in microbiology leading to degradation of artefacts and ecofacts.

Chemical Methods
Chemical remediation processes aim to reduce contaminant mass by the transformation or destruction of contaminants or to concentrate them for disposal. It requires the addition or use of chemical reagents. Often combined with physical methods to enhance their effectiveness.

Table 7.3 Examples of chemical remedial methods

Treatment	Ex-situ/In-situ	Brief Description	Impact
Permeable Reactive Barriers (oxidation/reduction) (may also be classified as biological)	In-situ Timescale: 6-36 months to build, but operate for many years	Used to clean up groundwater. Reactive containment which treats the groundwater as it passes through. May be contained by an engineered structure . Reactive cell contains reagent applicable to contaminant present, such as iron filings or activated carbon. Often relying on inducing oxidation or reduction processes.	Soil disturbance Changes in ground water, pH and redox Localised destruction of archaeological deposits. Potential geochemical changes in the burial environment
Pump and Treat	Ex-situ Timescale: typically 2+ years	Groundwater abstracted, treated above ground and discharged to surface water, sewerage or the aquifer.	Changes in ground water affecting the burial environment. Aeration increasing oxidisation and microbial activity
Air stripping	In-situ	The removal of volatile compounds from an aqueous solution by bubbling air through it. The resultant off-gas generally requires treatment.	Changes in ground water affecting the burial environment. Aeration increasing oxidisation and microbial activity.

Biological methods

Biological remediation processes are reliant upon the ability of micro-organisms to degrade, transform, sorb or accumulate contaminants either by the organisms themselves or due to the activity of the organisms. The principal process used in the UK is biodegradation.

Table 7.4 Examples of biological remedial methods

Treatment	Ex-situ/In-situ	Brief Description	Impact
Land farming	Ex-situ/in-situ (if contamination is close to surface) Timescale 3-24 months.	Excavated soil is placed in thin layers on the ground and biodegradation via microbial activity is optimised via the introduction of minerals, nutrients and moisture. Layers may be tilled periodically. Used for organic contamination	Soil disturbance. If ex-situ - destruction of archaeological deposits and structures. May involve the addition of organisms increasing microbial activity, changes in pH and redox.
Bioventing	Ex-situ/in-situ Timescale 3-24 months.	Biodegradation is optimised by the addition of oxygen and nutrients to the contaminated soils by air injection wells possibly combined with vacuum extraction wells to ensure an air flow gradient across the contaminated area.	Soil disturbance. If ex-situ - destruction of archaeological deposits and structures. Shallow soil disturbance where increased aeration of soils is required. Drilling of wells may disturb/destroy archaeological structures/deposits. Increased microbial activity with changes in pH and redox.
Biopiles	Ex-situ Timescale 3-12 months.	Excavated soils placed in static biopiles above ground in a bunded area. Oxygen transfer by air injection or vacuum extraction used to promote aerobic microbial activity. Used for organic contamination	Soil disturbance. Destruction of archaeological deposits and structures
Windrow Turning	Ex-situ Timescale 3-12 months.	Excavated contaminated soils are mixed with composting materials (e.g. straw, wood) and placed in windrows. These windrows are then turned and aerated optimising the transfer of oxygen to the contamination. Suitable for organic contamination	Soil disturbance. Destruction of archaeological deposits and structures
Monitored Natural Attenuation	In-situ Timescale over 5 years	Monitoring of groundwater to confirm whether naturally occurring physical, chemical and biological processes are acting at a sufficient rate to reduce the contaminant, load, concentration, flux or toxicity. It does not incorporate dilution.	Soil disturbance limited to locations where the groundwater monitoring network is installed.

Thermal Methods

Thermal methods seek to reduce contaminant concentrations in soils by destroying or concentrating the contaminants by applying elevated temperatures in direct or indirect contact with the contaminated soil.

Table 7.5 Examples of thermal remedial methods

Treatment	Ex-situ/In-situ	Brief Description	Impact
Incineration	Ex-situ	Destruction of contaminants at high temperatures Used for organic contamination. Slag or ash treatment residue results.	Soil disturbance. Destruction of archaeological deposits and structures, artefacts and ecofacts
Thermal Desorption	In-situ/ex-situ	Volatilisation of organic contaminants from soil by heating (typically at 600^{o}C) and secondary combustion producing a soil-like residue	Destruction of archaeological deposits and structures, artefacts and ecofacts

Solidification and Stabilisation

Solidification methods comprise the encapsulation or fixing of contaminated soils in a lower permeability mass. Stabilisation methods comprise the conversion of soil contaminants to less toxic/more stable forms by the addition of chemical agents.

Table 7.6 Examples of solidification and stabilisation methods

Treatment	Ex-situ/In-situ	Brief Description	Impact
Direct mixing with cement	Ex-situ/in-situ	Excavation of contaminated material, mixing with cementitious material to produce more chemically stable constituents.	Soil disturbance. Destruction of archaeological deposits and structures.
Direct mixing with lime & pozzolans.	Ex-situ/in-situ	Combining lime and pozzolanic substances such as some fly ash will induce exothermic reactions and result in the encapsulation of contaminants such as oils and other organic pollutants.	Large degree of soil disturbance for both in-situ and ex-situ applications. Destruction of archaeological deposits and structures

7.4 Potential impact of remediation techniques on archaeological resources

Most forms of remediation have the potential for some adverse archaeological impact. This may be either a direct physical impact or an indirect impact for example on the burial environment (as indicated in Tables 7.2-7.6). Methods that involve physical disturbance or removal of archaeological deposits will normally be totally destructive. Where important archaeological deposits exist, the need for physically intrusive remediation must be very clearly demonstrated. *In-situ* remediation almost always involves a level of physical disturbance and will have a varied impact on the burial environment. These impacts and their effects are summarised in Table 7.7.

Table 7.7 Summary of potential impacts of remediation

Impact	Potential effect on archaeological resources
Soil disturbance	Will destroy features and context, may destroy artefacts.
pH	Any changes in pH may affect the corrosion of archaeological metals (e.g. iron and copper) Other potential impacts may be on • Organic artefacts e.g. leather, wood, textiles, bone • Carbonate (e.g. shells) may degrade with acids • Glass may be affected by a rise in pH • Iron corrosion enhanced at high pH • DNA preservation in organic remains is best at neutral pH
Addition of organisms	May affect degradation of organic artefacts and could affect the redox and pH of the burial environment May promote corrosion of metals e.g. sulphate reducing bacteria May promote the degradation of organic materials Effects on scientific analysis: organic chemicals, bacteria and fungi may affect results of radio carbon dating, carbon / nitrogen ratios and DNA analysis
Redox	Change in redox may affect metal artefacts and organic materials • aeration causing shift in redox from anaerobic to aerobic conditions
Addition of substances or transformation	May react with • Archaeological metals e.g. iron and copper • Organic artefacts e.g. leather, wood, textiles e.g. with the addition of S^{2-} Effects on scientific analysis: organic chemicals, bacteria and fungi may affect results of radio carbon dating, carbon / nitrogen rations and DNA analysis
Changes in groundwater level	May affect • Archaeological metals e.g. iron and copper • Organic artefacts e.g. leather, wood, textiles, bone • Fluctuations may affect stone surfaces

7.5 Other considerations

As with site investigation works it is not only the direct impact of the remedial option that may have an impact on the archaeological resource either on site or under adjacent land. Ancillary activities including plant and vehicle movement across the site can also damage vulnerable archaeological evidence (Davis *et al* 1998).

At development sites, 'ground improvement' measures may be required to provide stable and geotechnically suitable ground for construction. Ground improvement techniques, such as vibro-compaction and surcharging, can affect the survival of archaeological resources, for example vibration leading to physical damage.

7.6 Measures to Mitigate the Impact of the Remedial Option

An appropriate remediation strategy for a site should take account of the archaeological resource in addition to the requirement to break any pollutant linkage, whether or not the archaeology is part of the linkage.

The most effective strategy may be achieved by sympathetic consideration of the archaeological remains across the site. For example, zoning the site to put a less sensitive end use on the contaminated area with archaeological remains may remove the need for remediation. In such a situation it may be necessary to seal the archaeological remains beneath an appropriately constructed barrier (containment).

In the selection of *in-situ* techniques any additional cost of the remediation may be off set by cost saving in terms of reduced archaeological intervention. Where an *in-situ* remedial technique is selected an effective barrier may need to be constructed to protect vulnerable archaeological remains on an adjacent part of the site.

Remediation techniques that are more intrusive on archaeological remains may be mitigated by an appropriate programme of recording the remains (preservation by record).

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9 ACRONYMS AND GLOSSARY

CDM	Construction Design and Management Regulations 1994
DEFRA	Department for Environment, Food and Rural Affairs
DETR	Department for Environment, Transport and Regions
DoE	Department of the Environment
DTLR	Department for Transport, Local Government and the Regions
EIA	Environmental Impact Assessment
IPPC	Integrated Pollution Prevention and Control
LPA	Local Planning Authority
MPP	Monuments Protection Programme
ODPM	Office of the Deputy Prime Minister
RCHME	Royal Commission on the Historical Monuments of England
SAM	Scheduled Ancient Monument
SMR	Sites and Monuments Record

Archaeological Assessment	Collation of existing information to assess the potential archaeological resource within a specified site or area
Archaeological Evaluation	Site investigation work carried out to enhance knowledge of the archaeological resource within a specific site or area
Artefact	Object or item of human manufacture in an archaeological context
Biological processes	Reliance on the ability of micro-organisms to degrade, transform, sorb or accumulate contaminants
Brief	Document prepared by an LPA archaeologist to set the terms of reference for an archaeological assessment or evaluation

Brownfield	Any land that has been previously developed
Chemical processes	Destroy, fix or concentrate toxic compounds by using one or more types of chemical reaction.
Conceptual model	A textual or graphical representation of the relationship(s) between source(s), pathway(s) and receptor(s) developed on the basis of Phase 1a Risk Assessment findings, and refined during subsequent phases of assessment.
Ecofact	Naturally occurring evidence in an archaeological context e.g. pollen, plant or animal remains
Hazard Assessment	The stage of risk assessment concerned with assessing the degree of hazard associated with a site or group of sites.
Hazard Identification	The stage of risk assessment concerned with identifying and characterising the hazards that may be associated with a particular site or group of sites.
Pathway	A route along which a substance or contaminant moves through the environment and comes into contact or otherwise affects a receptor
Physical processes	Separate contaminants from the soil matrix by exploiting physical differences between the soil and contaminant (e.g. volatility, behaviour in electric fields) or between contaminated and uncontaminated soil particles (e.g. density).
Pollutant linkage	The relationship between a contaminant (the source), a pathway and a receptor
Preservation by record	The act of permanently documenting an archaeological resource through its systematic excavation and recording. This by necessity leads to the destruction of the remains so documented
Preservation *in-situ*	Securing the survival of archaeological remains in their present location often requiring active intervention to ensure the physical protection of the remains and the integrity of the burial environment
Receptor	An entity (human, animal, building, controlled water, plants, air) which is vulnerable to the adverse effects of a hazardous substance or agent.
Risk Assessment	The process of assessing the hazards and risks associated with a particular site or group of sites.

Risk Estimation	The stage of risk assessment concerned with estimating the likelihood that receptors will suffer adverse effects if they come into contact with, or are otherwise affected by, a hazardous substance or agent under defined conditions.
Risk Evaluation	The stage of risk assessment concerned with evaluating the acceptability of estimated risks, taking into account the nature and scale of risk estimates, any uncertainties associated with the assessment and the broad costs and benefits of taking action to mitigate risks.
Risk Management	The process whereby decisions are made to accept a known or assessed risk and/or the implementation of action to reduce the consequences or probabilities of occurrence.
Solidification	Solidification reduces the physical accessibility of contaminants by encapsulating them in a monolithic solid of high structural integrity.
Source	A natural or manmade hazardous substance or agent that is capable of causing harm
Stabilisation	Stabilisation reduces the chemical availability contaminants. In practice, stabilisation is often accompanied by solidification and vice versa, but this is not always the case, particularly in the case of organic contaminants.
Watching Brief	Monitoring and where appropriate intervention by archaeological staff during the development process. Typically a watching-brief will be maintained on areas where there is a low expectation that archaeological resources exist with the aim of facilitating the production of a rapid record should they be encountered.
Weil's Disease (also known as leptospirosis)	A bacterial disease transmitted in water contaminated with the urine of infected animals.

APPENDIX ONE

A1 Assessing the Potential Risk to Other Receptors

As indicated in Section 1.1 of the main report when dealing with land contamination archaeological resources may be only one of a number of receptors present. Other receptors may include for example human health, the water environment, ecological systems and buildings. The following table provides details of some of the guidance available for assessing the potential risk to these receptors. This is not intended as an exhaustive list of guidance.

The overall framework for environmental risk assessment and management is contained in DETR (2000) *Guidelines for Environmental Risk Assessment and Management* The Stationery Office, London. Available at
http://www.environment.defra.gov.uk/eramguide/02.htm
with CLR 11 providing the specific framework for the investigation, assessment and management of land contamination (DEFRA and Environment Agency (2003 in preparation) *Model Procedures for the Management of Contaminated Land*).

Receptor	Summary of Guidance Documents
Human Health	CLR7-10 series published by DEFRA and the Environment Agency in 2002 CLR 7 Assessment of Risks to Human Health from Land Contamination: An Overview of the Development of Soil Guideline Values and Related Research CLR 8 Potential Contaminants for the Assessment of Land CLR 9 Contaminants in Soil: Collation of Toxicological Data and Intake Values for Humans and associated TOX reports CLR 10 The Contaminated Land Exposure Assessment Model (CLEA): Technical Basis and Algorithms and associated Soil Guideline Value (SGV) Reports All available from Environment Agency regional libraries or www.eareports.com and for download at www.defra.gov.uk/environment/landliability/pubs.htm#new
Ecological Systems	Review of Ecotoxicological and Biological Test Methods for the Assessment of Contaminated Land. Report TR P300 published in 2002 by the Environment Agency Assessing Risks to Ecosystems from Land Contamination. Report TR P299 published in 2002 by the Environment Agency Available from Environment Agency regional libraries or www.eareports.com
Water Environment	Methodology for the Derivation of Remedial Targets for Soil and Groundwater to Protect Water Resources. R&D 20 published by the Environment Agency in 1999

	Available from Environment Agency regional libraries or www.eareports.com
Buildings	Assessment and Management of Risks to Buildings, Building Materials and Services from Land Contamination Report P5-035/TR/01 published in 2001 by the Environment Agency Risks of Contaminated Land to Buildings, Building Materials and Services: A Literature Review Report P331 published in 2000 by the Environment Agency Available from Environment Agency regional libraries or www.eareports.com

A2 Further Information

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APPENDIX TWO: USEFUL ADDRESSES

AIGAO	Association of Local Government Archaeological Officers General and specific enquiries to the Association should be directed in the first instance to the administrative assistant, Caroline Ingle at : e-mail: algao.cji@ntlworld.com Tel: 01287 205863 www.algao.org.uk
CADW – Welsh Historic Monuments	National Assembly for Wales Cathay Park Cardiff CF10 3NQ Tel: 029 2050 0200 Fax: 029 2082 6375 www.cadw.wales.gov.uk
CBA	Council for British Archaeology The Council has a small permanent secretariat, based in York at Bowes Morrell House, 111 Walmgate, York YO1 9WA, UK, telephone 01904 671417, fax 01904 671384. www.britarch.ac.uk
CIEH	Chartered Institute of Environmental Health, Chadwick Court 15 Hatfields, London SE1 8DJ United Kingdom Telephone: 020 7928 6006 Fax: 020 7827 5866 www.cieh.org.uk email: info@cieh.org
EA	Environment Agency Rio House, Waterside Drive, Aztec West, Almondsbury, Bristol BS32 4UD Tel: 01454 624400 Fax: 01454 624409 www.environment-agency.gov.uk
EH	English Heritage Customer Services Department PO Box 569 Swindon SN2 2YP England Email: Customer Services Telephone: +44 (0) 870 333 1181 Fax: +44 (0) 1793 414926 www.english-heritage.org.uk

IFA	Institute of Field Archaeologists Contact: IFA University of Reading 2 Earley Gate PO Box 239 Reading RG6 6AU Tel: 0118 931 6446 Fax: 0118 931 6448 www.archaeologists.net E-mail: administrator@archaeologists.net
LGA	Local Government Association Local Government House Smith Square London SW1P 3HZ. Tel: 020 7664 3000 Fax: 020 7664 3030 www.lga.gov.uk
RTPI	The Royal Town Planning Institute 41 Botolph Lane London EC3R 8DL. Tel +44 20 7929 9494, Fax +44 20 7929 9490 www.rtpi.org.uk