An ecological risk assessment framework for contaminants in soil

Science Report – SC070009/SR1

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This report is the result of research commissioned and funded by the Environment Agency's Science Programme.

Published by:
Environment Agency, Rio House, Waterside Drive,
Aztec West, Almondsbury, Bristol, BS32 4UD
Tel: 01454 624400 Fax: 01454 624409
www.environment-agency.gov.uk

Front cover image: RSPB images, taken by Nigel Blake

ISBN: 978-1-84432-939-7

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Dissemination Status:
Released to all regions
Publicly available

Keywords:
Contaminated Land, Ecological Risk Assessment, ERA, Soil, Contamination, Part 2A, Environmental Protection Act, Framework.

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Science Project Number:
SC070009/SR1

Product Code:
SCHO0908BOOZ-E-P

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Steve Killeen

Head of Science

Executive summary

The Ecological Risk Assessment (ERA) Framework for contaminated soils has been developed by the Environment Agency in collaboration with DEFRA, Natural England, the Countryside Council for Wales, local authorities and industry. It aims to provide a structured approach for assessing the risks to ecology from chemical contamination in soils that is requirement under Part 2A (Contaminated Land) of the Environmental Protection Act 1990.

This document sets out the three-tiered risk assessment process that has been designed to:

- establish whether pollutant linkages between the contamination and the designated ecological receptors are likely to exist;
- gather sufficient information for making decisions regarding whether harm to those receptors is, or could, occur.

The risk assessment is preceded by a desk study that reviews information about the site and nature of the contamination to assess whether pollutant linkages are feasible.

Tier 1 of the risk assessment is a screening step based on a comparison of chemical analyses of site soils with a soil screening value (SSV) for the contaminant of concern.

Tier 2 uses a choice of tools (ecological surveys and biological testing) to provide evidence for harm to the receptors.

Tier 3 seeks to attribute the harm to the chemical contamination.

The ERA framework is supported by further guidance documents – both for the desk study (how to develop a Conceptual Site Model) and at each tier. The series includes guidance on:

- the use of soil screening values;
- how and when to perform ecological surveys and biological tests;
- Standard Operating Procedures for bioassays;
- how to consider cause–effect attribution.

The ERA framework and guidance documents make reference to the Statutory Guidance as necessary.

The ERA framework is intended to structure decision-making and, as such, does not seek to provide criteria on which determinations of contaminated land can be made. These decisions remain with the relevant regulator. However, the ERA framework can also be used in contexts other than Part 2A (Contaminated Land) such as within conservation regulations, and planning and pollution control.

Acknowledgements

The Environment Agency would like to acknowledge and thank all of the organisations below for their collaboration in or contribution to the development of this Ecological Risk Assessment Framework for contaminants in soils.

Atomic Weapons Establishment

BAE Systems

British Petroleum

Buildings Research Establishment

Bury Metropolitan Borough Council

Capita Symonds

Central Science Laboratory

Centre for Ecology and Hydrology Monks Wood

Corus

Countryside Council for Wales

Defence Logistics Organisation

Department for Environment, Food and Rural Affairs

Energy Institute

EURAS

Hull City Council

Institute for Environment & Health

Natural England

Scottish Environmental Protection Agency

Scottish Natural Heritage

Secondsite Property Holdings

Shell Global Solutions

University of Reading

Watts & Crane Associates

Welsh Assembly Government

WRc plc

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1 Introduction

1.1 The purpose of this document

This document introduces the Environment Agency's Ecological Risk Assessment (ERA) framework for contaminants in soil. The document:

- provides information on the purpose of the framework;
- contains flow diagrams to aid decision-making;
- presents four illustrative examples to reflect how the ERA framework might be used in practice.

1.2 How this document fits into the ecological risk assessment framework

This document is the overarching guidance document for the Ecological Risk Assessment framework. It should be the starting point for any risk assessor (e.g. consultant, regulator or land owner) who is assessing risks to ecological receptors from contaminants in soil.

The ERA framework adopts a tiered approach and is supported by six separate guidance documents covering the activities that can be employed at each of the tiers. The relationship between the tiers of the ERA Framework given in this document and the supporting guidance is illustrated in the flow chart shown in Figure 1.1, where the position of this document is shown in red.

This report and the guidance documents in the series refer to each other in the following manner (full details can also be found in the reference list):

- This report is referred to as ERA 1 (Framework document).
- The Guidance on desk studies and Conceptual Site Models in Ecological Risk Assessment is referred to as ERA 2a (Guidance on desk studies and CSM).
- The Guidance on the use of Soil Screening Values in Ecological Risk Assessment is referred to as ERA 2b (Guidance on the use of SSV).
- The Guidance on the use of Bioassays in Ecological Risk Assessment is referred to as ERA 2c (Guidance on the use of bioassays).
- The Guidance on the use of Ecological Surveys in Ecological Risk Assessment is referred to as ERA 2d (Guidance on the use of ecological surveys).
- The Guidance on the Attribution of Cause and Effect in Ecological Risk Assessment is referred to as ERA 2e (Guidance on the attribution of cause and effect).
- The Standard Operating Procedures for Bioassays is referred to as ERA 3 (SOPs for bioassays).

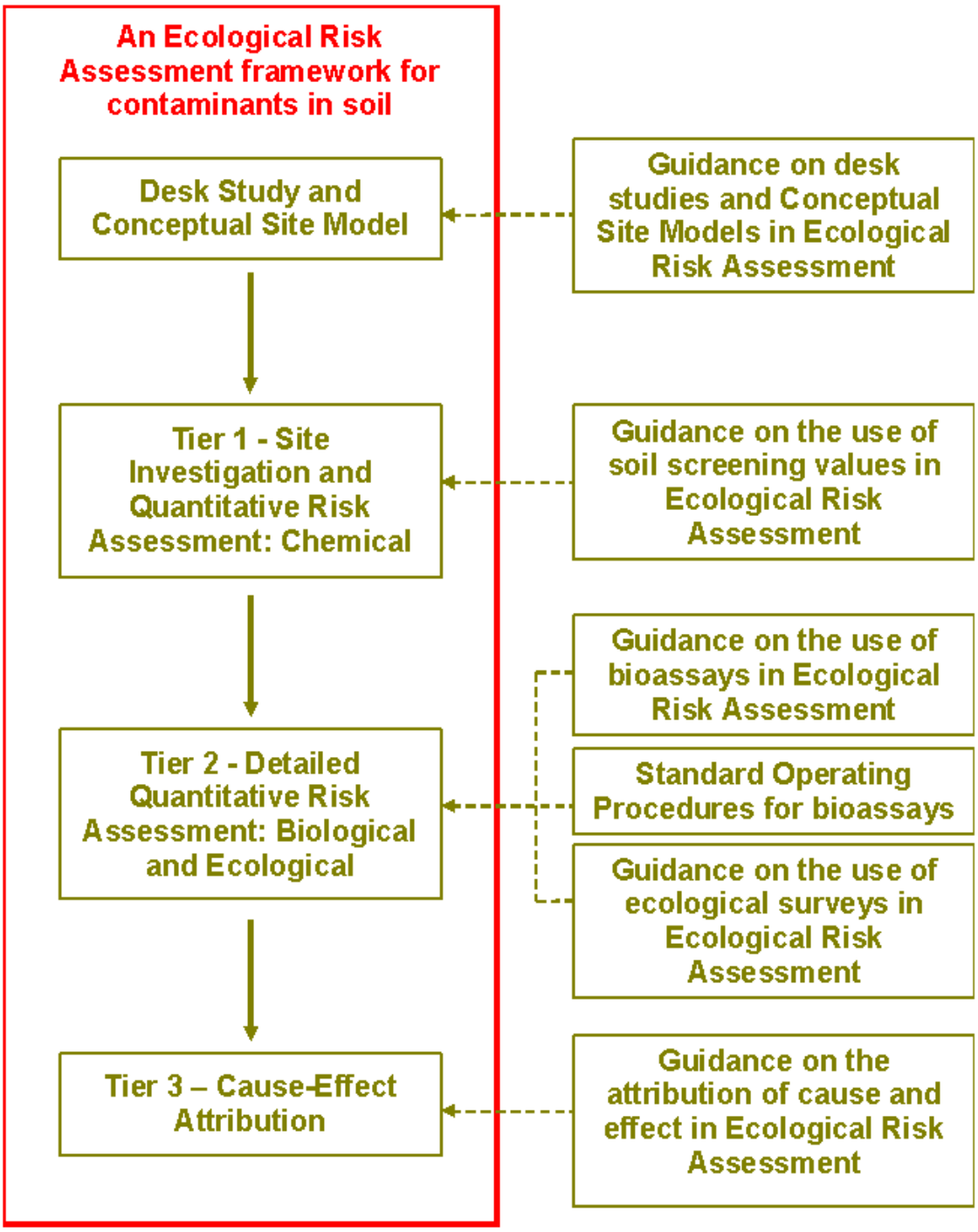


Figure 1.1 Position of this document within the overall ERA framework

1.3 Potential regulatory drivers for ecological risk assessment

The primary driver is Part 2A of the Environmental Protection Act 1990. Other potential regulatory drivers include the Habitats Directive and the planning regime.

1.3.1 Part 2A of the environmental protection act

Section 57 of Part 2A of the Environmental Protection Act 1990 (EPA 1990) introduced a new statutory regime for the identification and control of contaminated land in England and Wales (DEFRA 2006). The Act states that:

> *'Contaminated land' is any land which appears to the local authority in whose area it is situated to be in such a condition, by reason of substances in, on or under the land, that –*
>
> *significant harm is being caused or there is a significant possibility of such harm being caused; or pollution of controlled waters is being, or is likely to be, caused…*

where 'harm' is defined as:

> *harm to the health of living organisms or other interference with the ecological systems of which they form a part, and in the case of man includes harm to his property.*

'Ecological harm' within Part 2A is confined to specified receptors as set out in Table A of the Statutory Guidance (DEFRA 2006). In summary, these are:

- any ecological system, or living organism forming part of such a system, within a location which is:
  - a site of special scientific interest (SSSI) notified under section 28 of the Wildlife and Countryside Act 1981;
  - a national nature reserve (declared under section 35 of the above act);
  - a marine nature reserve (designated under section 36 of the above act);
  - an area of special protection for birds (under section 3 of the above act);
  - any habitat or site afforded policy protection under paragraph 6 of Planning Policy Statement (PPS 9) on nature conservation;
  - any nature reserve established under section 21 of the National Parks and Access to the Countryside Act 1949;
  - any European site within the meaning of regulation 10 of the Conservation (Natural habitats etc) Regulations 1994;
  - any candidate Special Areas of Conservation or potential Special Areas of Conservation given equivalent protection.

1.3.2 Habitats directive

Regulation 3 of the Conservation Regulations 1994 (commonly known as the Habitats Regulations) implements the requirements of the European Habitats Directive 92/43/EEC in Great Britain. It also secures the protection of areas classified under the Wild Birds Directive 79/409/EEC.

The Environment Agency is the competent authority (in England and Wales) for these regulations. As such, it applies the regulations when considering all applications for authorisations, permissions, permits, consents and environmental licences and for all relevant Environment Agency policy and operational activities.

A risk assessment process is initiated in situations where an application under the UK system of land use planning or a review of permits, licences, etc. is likely to impact on sites protected under the regulations. There are four stages to the risk assessment:

- identifying relevance;
- likely significant effect;
- identifying adverse impacts;
- implementing any changes.

The ERA framework will be a useful aid in this process.

1.3.3 Planning

Planning Policy Statement (PPS) 23: *Planning and Pollution Control* states that:

> *Land contamination, or the possibility of it, is a material planning consideration in the preparation of development plan documents and in taking decisions on individual planning applications* (ODPM 2004).

The remediation of contaminated land through the planning process should secure the removal of unacceptable risk and make the site suitable for its new use. Following redevelopment, the land should not be capable, as a minimum, of being determined as contaminated land under Part 2A of the Environmental Protection Act 1990.

Development plans and decisions on individual planning applications should take into account the potential sensitivity of the area to adverse effects from pollution, including nature conservation interests such as:

- SSSIs;
- National Parks;
- Areas of Outstanding Natural Beauty (AONBs);
- Special Areas of Conservation (SACs);
- Special Protection Areas (SPAs);
- wetlands of international importance (RAMSAR sites).

Where appropriate, soil screening values and the wider ERA framework can be used to assess the possible risks to nature conservation interests when potentially polluting activities are proposed. Where necessary, they can also be applied to the assessment and remediation of historic contamination.

1.4 Report structure

Section 2 explains the role of the ERA framework in aiding decision-making about whether or not land is deemed ‘contaminated’ based on risks to ecological systems.

Section 3 presents four flow diagrams depicting the tiers of the framework. Each diagram has a number of key points. The commentary on these key points highlights the guidance available to risk assessors and others using the ERA framework.

Section 4 contains four illustrative examples showing the use of the ERA framework in practice. These conclude at the four different stages of the framework (i.e. desk study only, Tier 1, Tier 2, Tier 3).

2 The framework for ecological risk assessment

Decisions on whether or not land should be determined as contaminated land based on risks to ecological systems may have far-reaching consequences both for the quality and health of ecosystems and for the public/private purse. It is therefore essential that decisions are based on relevant and comprehensive information which is treated in an appropriate manner so as to draw out the nature and extent of any harm that may be occurring in these ecosystems.

The Ecological Risk Assessment (ERA) framework presented here is intended as an aid to making these decisions regarding the potential risk to ecological systems from contaminants in soil. It is a tiered approach designed to be efficient in excluding sites with no potential to cause harm to ecosystems while also gathering sufficient evidence for harm or the possibility of harm at sites where risk management may be required either voluntarily or through enforcement action.

The preliminary activity in the ERA framework is a desk-based study and the development of a Conceptual Site Model (CSM). This will usually be undertaken by a stakeholder in the site – either the regulator (local authority officer) or the site owner. The purpose of this stage is to document the chain of reasoning as to whether pollutant linkages are likely, i.e. whether ecological receptors are able to be exposed to the contaminants given their fate, behaviour and proximity. If this is clearly not the case, then the site need not progress further in the risk assessment.

If pollutant linkages are considered likely, then it is likely to become necessary to employ an experienced ecological risk assessor to move through the three tiers of the ERA framework. Tier 1 is based on an initial intrusive site investigation including a site walkover and sampling the soils for chemical analysis. Sampling should be performed in the area that supports the ecological receptors; this area may or may not be coincident with the source of the contamination.

The purpose of Tier 1 is to establish whether the contamination is present in sufficient concentrations to pose a risk to the ecological receptors. Soil screening values (SSVs) for a range of contaminants have been proposed as an aid in making this decision. The SSVs have been derived from the results of a suite of ecotoxicological tests using soil organisms and comparison with them can indicate where the measured levels of contaminant(s) have the potential to cause harm.

Where the measured levels exceed the SSV or where no SSV or equivalent value is available, the risk assessor should proceed to Tier 2. The purpose of Tier 2 is to judge whether the ecological receptors are subject to significant harm or the significant possibility of significant harm. This judgement is based on the weight of the evidence available and two techniques are offered to address the collection of evidence – ecological surveys and biological testing (bioassays).

Either or both of these tools can be applied according to the circumstances of the assessment. The selection of tools and the order in which they are prioritised and deployed will be a matter for discussion amongst all the stakeholders, given the site conditions and objectives of the risk assessment in terms of the contaminants, pathways and ecological receptors identified. Both approaches can have equivocal outcomes and therefore where one tool is initially deployed, the other may then be needed to aid in the interpretation. Care should be taken in selecting the most appropriate tools for each site in order to maximise the evidence gathered in the most resource-effective way.

If it is considered that harm is occurring or may occur, then it is necessary to link the observed effect to the source of contamination. This is the purpose of Tier 3, the final tier. This should not be a costly process, and involves reviewing and re-analysing the data to assess the strength of the association between cause and effect. It will help in any legal processes that may arise and in ensuring that any remediation steps taken are cost-effective.

A flow diagram of each tier with key points to assist the risk assessor in the progression of the ERA is provided in this document (see Section 3). Six further guidance documents explain the use and application of the tools and techniques that can be applied at each tier. The tier of the ERA framework for which each guidance document is intended is shown in Figure 1.1.

The provision of this primary guidance does not preclude the risk assessor using other sources of guidance and indeed other sources are indicated in the suite of guidance documents. However, it is imperative to the ERA process that all sources used and all decisions made are agreed between all the stakeholders and are documented.

A series of examples of progression through the ERA framework is given in Section 4. These illustrate the judgements that can be required to exit from the process at each tier. Although anonymous, they are based on real data wherever possible.

The Environment Agency has developed this ERA framework in close collaboration with:

- Department for Environment, Food and Rural Affairs (DEFRA);
- other regulators (local authorities);
- industrial partners;
- conservation bodies.

The contribution of these parties has been most valuable, with the regulators advising on the applicability of the process, the industrial partners testing the tools and providing data and feedback on practicality, and the conservation bodies outlining their responsibilities for the designated conservation areas that constitute ecological receptors.

Natural England, the Countryside Council for Wales and Scottish Natural Heritage have all agreed to continue to provide advice to risk assessors on sites for which they are responsible; as much information as possible should be sought from their websites initially. For other conservation areas, it will be necessary to approach the management trust or site owners for advice on appropriate conservation objectives.

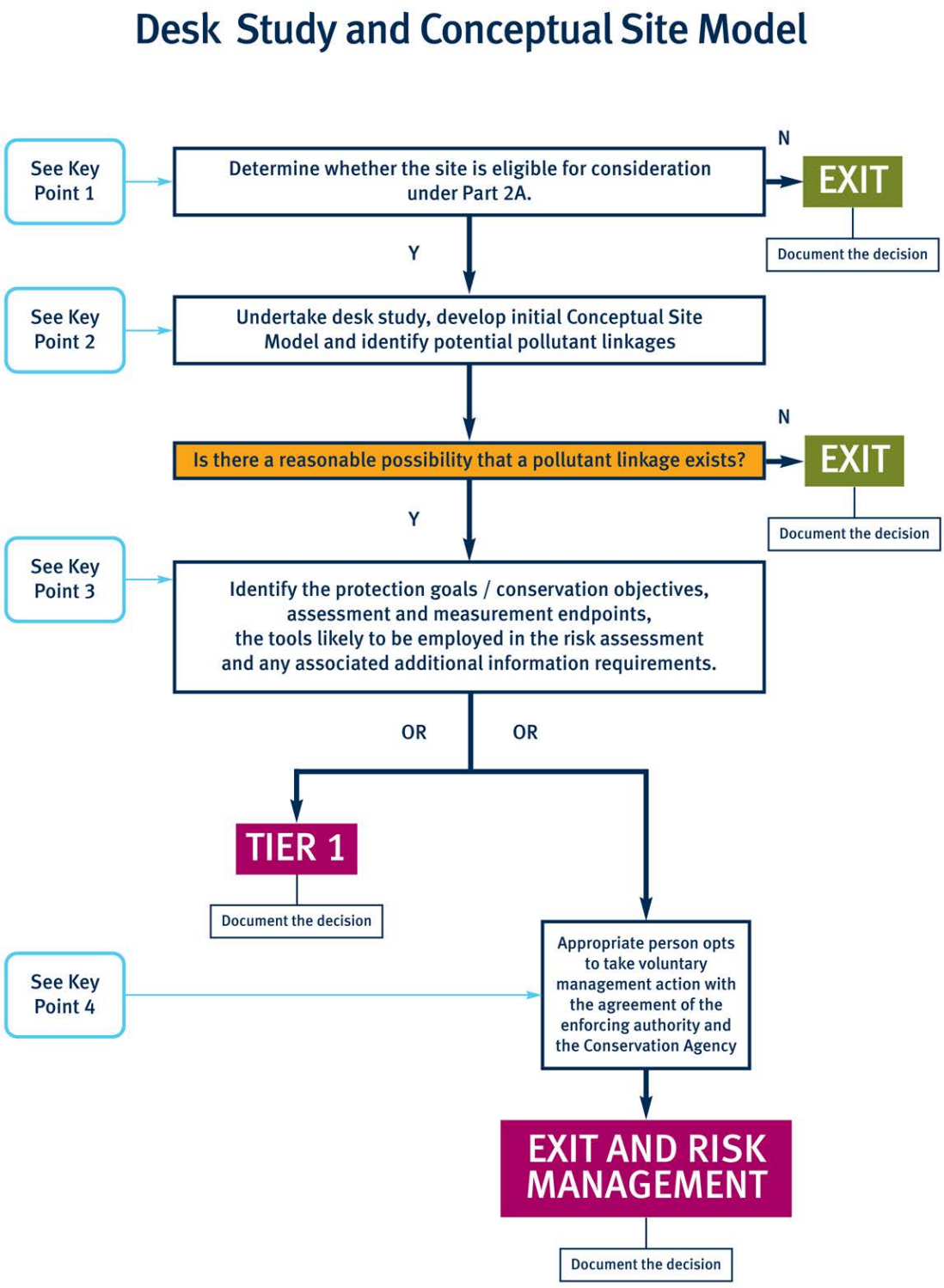
All parties that use the ERA framework should be aware that it is a process designed to gather and interpret information in a logical manner so that evidence can be assessed and sound decisions made as to the degree of risk to ecological receptors posed by contamination. No part of the structure has legal implications in its own right; rather it is intended to support the development of clear and auditable judgements when considering a determination of contaminated land.

It is not necessary therefore to follow the process absolutely, instead the local authority is at liberty to make a determination of contaminated land at any stage should they feel the evidence is sufficient or the degree of harm is such that urgent works should be undertaken.

The overall aim of the ERA Framework is to help regulators and land owners meet the statutory requirements of Part 2A (Contaminated Land) of the Environmental Protection Act 1990.

3 Flow diagrams for decision-making

This section presents a series of four flow diagrams showing the questions posed by and the activities required by the three tiers of the ERA Framework and the preliminary desk study, together with commentary on the key points of understanding.



3.1 3.1 Desk study and conceptual site model key points

Key Point 1

Consult the Statutory Guidance to determine whether an ecological receptor falls under Part 2A. The Statutory Guidance for England, Scotland and Wales is as follows:

- **England**:
  Environmental Protection Act 1990: Part 2A. Contaminated Land. DEFRA Circular 01/2006 (DEFRA 2006).
- **Wales**:
  Welsh Assembly Government Guidance on the Remediation of Contaminated Land (Welsh Assembly Government 2006).
- **Scotland**:
  Environmental Protection Act 1990: Part 2A Contaminated Land Statutory Guidance: Edition 2. Scottish Executive Paper SE/2006/44 (Scottish Executive 2006).

This ERA framework may also be of use under other regulatory regimes including town and country planning, the Habitats Directive or the Environmental Liabilities Directive.

If it is necessary to clarify the status of the site, consult the enforcing authority or the relevant conservation organisation. This can be either the national conservation agency, a wildlife trust, another nature reserve management group or even the site owner as appropriate. Such information can often be obtained from their websites.

Key Point 2

At this stage, take account of:

- *Guidance on desk studies and Conceptual Site Models in Ecological Risk Assessment* (ERA 2a);
- Contaminated Land Report (CLR) 11 *Model procedures for the management of land contamination* (Environment Agency 2004);
- general good practice guidance.

The aim of this activity is to gather information on potential sources, pathways and ecological receptors in order to establish potential pollutant linkages. This will generally involve desk-based research but, at some sites, the risk assessor may wish to gather a larger degree of ecological information through field work. In such circumstances, the risk assessor should also consider:

- *Guidance on the use of ecological surveys in Ecological Risk Assessment* (ERA 2d).

The level of information and detail incorporated into the risk assessment at this stage of the framework will be site-specific.

In some circumstances, this activity will be sufficient to screen out sites where there is clearly no reasonable possibility of pollutant linkages to ecological receptors.

In other circumstances, a large amount of information (e.g. on sources of contamination and species of special interest) may already be available that suggests there is a reasonable possibility that pollutant linkage(s) to ecological receptors exist. Where this is the case, the desk study and Conceptual Site Model may be much more detailed, incorporating information on specific contaminants, receptors of potential concern and likely pathways.

Consulting the enforcing authority and the relevant conservation organisation will help to ensure all potential sources, pathways and receptors are identified.

Where a site exits from the ERA framework because it is deemed there is no reasonable possibility that a pollutant linkage exists, the enforcing authority and the conservation agency should be provided with a copy of the documented decision.

Key Point 3

At this stage either progression to Tier 1 or voluntary action will be required. The risk assessor will need to consider what further information may be required to help ensure any site investigation is designed appropriately and provides information relevant to decision-making. The following should be considered:

- conservation objectives for the site;
- assessment and measurement endpoints;
- tools for assessing harm that are likely to be used at Tier 2 (e.g. type of ecosurveys / bioassays);
- potential influence of non-chemical hazards (e.g. human disturbance) at the site.

Do this in consultation with, and the agreement of, the enforcing authority and the relevant conservation organisation and consult the following guidance documents:

- *Guidance on desk studies and conceptual site models in Ecological Risk Assessment* (ERA 2a);
- *Guidance on the use of ecological surveys in Ecological Risk Assessment* (ERA 2d);
- *Guidance on the use of bioassays in Ecological Risk Assessment* (ERA 2c);
- *Standard Operating Procedures for bioassays* (ERA 3).

Where the ecological receptor site is an SSSI, the favourable condition tables may also be useful. These can be obtained from the websites of the relevant nature conservation agencies.

Key Point 4

It is important to remember that:

- any relationships between contaminants and ecological receptors will not necessarily be straightforward;
- some contamination may be beneficial to certain ecological assemblages or species of special interest.

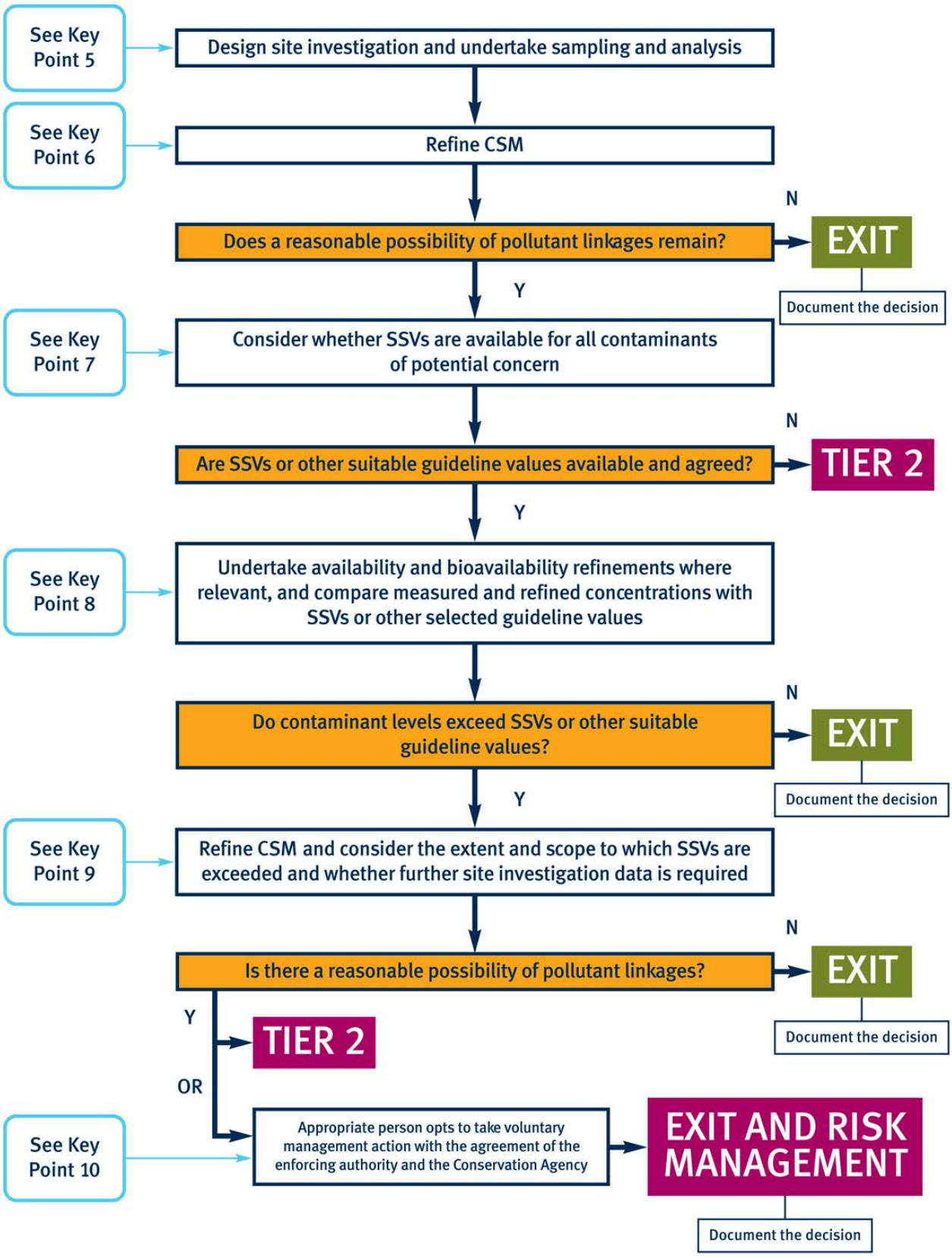
If ill-conceived remedial works are undertaken, it is possible they could do more ecological harm than good. Where remediation is planned, it is essential to understand the impacts of the work and, where necessary, to mitigate against adverse effects.

Further guidance on this issue is given in:

- *Guidance on the use of ecological surveys in Ecological Risk Assessment* (ERA 2d).

Before planning any remedial work, consult the relevant enforcing authority and nature conservation bodies (including appropriate non-statutory organisations).

Tier 1 – Site Investigation and Quantitative Risk Assessment: Chemical



3.2 3.2 Tier 1 key points

Key Point 5

The site investigation must be based upon the CSM and designed so that it provides relevant information for decision-making.

Some of the factors to ensure are that:

- an appropriate suite of analysis is specified based upon the contaminants of potential concern;
- potential pathways and receptors are agreed;
- assessment and measurement endpoints are agreed;
- appropriate limits of quantification are set for each determinand;
- appropriate sampling locations, depths and methods of sample retrieval and storage are established;
- other relevant measurements will be taken (e.g. organic carbon, cation exchange capacity and clay content) to allow site-specific refinements.

At this stage consider the following guidance documents:

- *Secondary model procedures for the development of appropriate soil sampling strategies for land contamination* (Environment Agency 2000);
- *Guidance on the use of soil screening values in Ecological Risk Assessment* (ERA 2b);
- *BS10175: 2001 Investigation of potentially contaminated sites: code of practice* (BSI 2001).

In some circumstances, bioassays such Microtox ® may be utilised at Tier 1 to provide initial estimates of contaminant impacts. If considering such tests, refer to the following guidance documents:

- *Guidance on the use of bioassays in Ecological Risk Assessment* (ERA 2c);
- *Standard Operating Procedures for bioassays* (ERA 3).

This activity should be undertaken in consultation with the enforcing authority and the relevant conservation organisation.

Key Point 6

Refining the CSM at this point allows the findings from the site investigation to be incorporated, e.g. the observed absence of proposed pathways due to the presence of physical barriers. The potential significance of any observations or measurements supporting the presence of potential pathways can also be recorded before chemical analysis of the soil samples begins.

This information may rule out some of the potential pollutant linkages from the CSM or introduce new ones. It may also become apparent that:

- there are important data gaps;

- further site investigations may be required at Tier 1.

Key Point 7

If considering the use of generic guideline values other than the soil screening values (SSVs) published as part of the ERA framework, it is vital the approach taken to derive the other guideline values is well understood. The underlying data used to derive the values being proposed for use should be compared with those used to derive SSVs, and the drawbacks associated with any reduction in data quality understood and documented.

The use of screening values from outside the ERA framework must be appropriate to the CSM and justified to the enforcing authority and relevant conservation organisation. Such values should only be used with their agreement.

Further guidance is provided in:

- *Guidance on the use of soil screening values in Ecological Risk Assessment* (ERA 2b).

Key Point 8

Site-specific refinements to take account of availability and bioavailability are available for use with the SSVs. These modifications can be made with the SSV Decision Tool – a spreadsheet tool available on the Environment Agency website. Further information is available in:

- *Guidance on the use of soil screening values in Ecological Risk Assessment* (ERA 2b).

The bioavailability refinements should only be applied to the SSVs published as part of the ERA framework. They are not applicable for use with other generic screening values.

Key Point 9

At this point it may be beneficial to:

- refine the CSM;
- consult the enforcing authority and the relevant conservation organisation regarding the significance of the extent to which the SSVs have been exceeded.

At this stage it may be possible to incorporate known background levels from uncontaminated localities. This should allow any site-specific factors (e.g. any beneficial relationships between contaminants and ecological receptors) to be considered.

Consulting the enforcing authority and the relevant conservation organisation will also help to determine:

- whether the risk assessment should progress to Tier 2; or

- whether further information should be gathered to aid decision-making at Tier 1.

Where further information is to be gathered at Tier 1, the scope of the work should be agreed by the risk assessor, the enforcing authority and the relevant conservation organisation.

Examples of such information might include:

- further data on the extent or form of a particular contaminant of potential concern;
- information on the characteristics of the site soils.

Key Point 10

It is important to remember that:

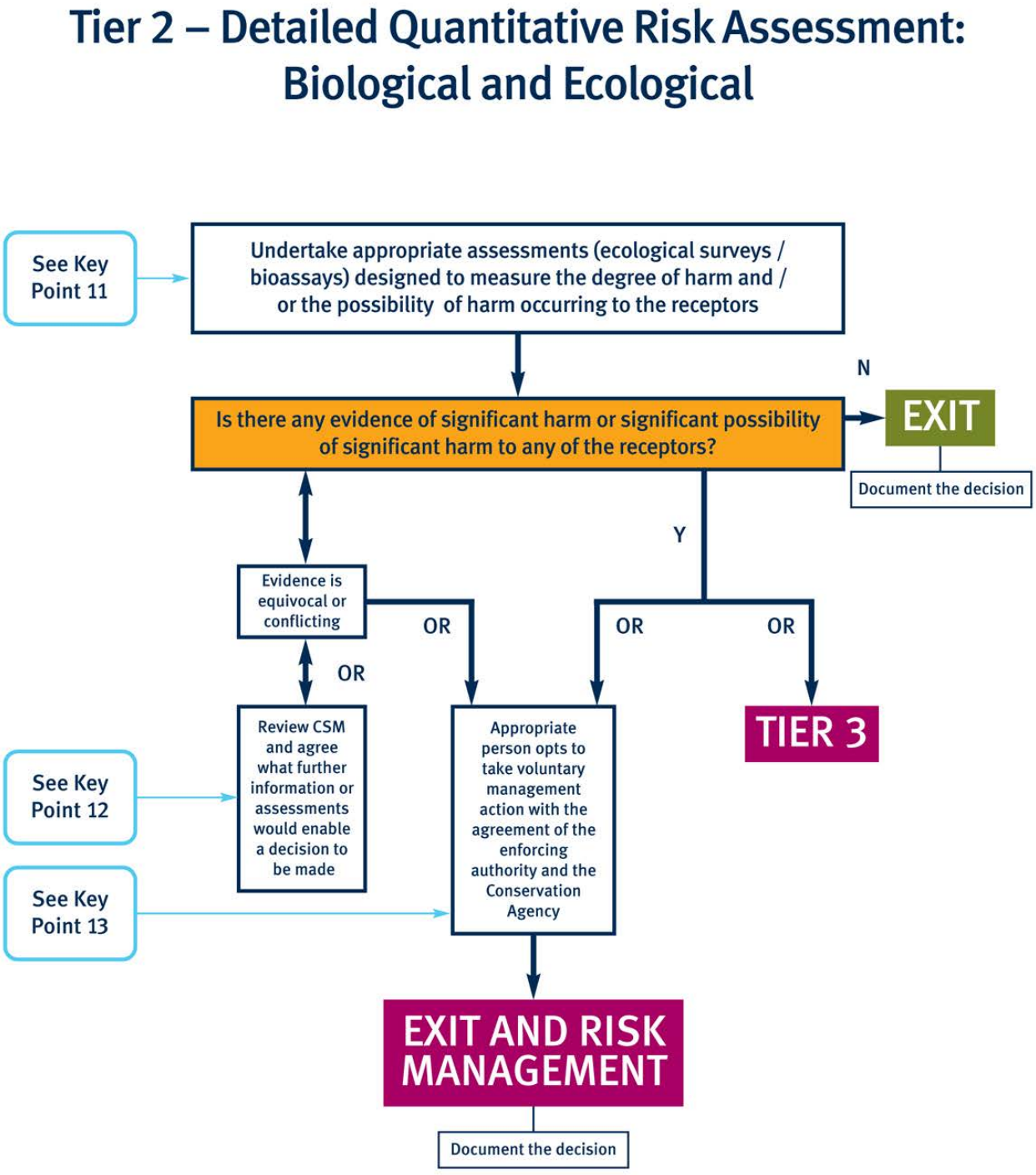
- any relationships between contaminants and ecological receptors will not necessarily be straightforward;
- some contamination may be beneficial to certain ecological assemblages or species of special interest.

If ill-conceived remedial works are undertaken, it is possible they could do more ecological harm than good. Where remediation is planned, it is essential to understand the impacts of the work and, where necessary, to mitigate against adverse effects.

Further guidance is given in:

- *Guidance on the use of ecological surveys in Ecological Risk Assessment* (ERA 2d).

Before planning any remedial work, consult the relevant enforcing authority and nature conservation bodies (including appropriate non-statutory organisations).



3.3 3.3 Tier 2 key points

Key Point 11

This activity involves the design of ecological surveys / bioassays and the interpretation of the results. It should be undertaken in consultation with the enforcing authority and the relevant conservation organisation.

At this stage consider the following guidance documents:

- *Guidance on the use of ecological surveys in Ecological Risk Assessment* (ERA 2d);
- *Guidance on the use of bioassays in Ecological Risk Assessment* (ERA 2c);
- *Standard Operating Procedures for bioassays* (ERA 3).

One or more of these tools can be used to make the assessments as appropriate.

It will often be necessary to employ expert advice in the collation and interpretation of the results.

Where the results show evidence of significant harm or significant possibility of significant harm to receptors, the risk assessment may progress to Tier 3. In some instances the enforcing authority may consider it has sufficient information to take regulatory action before progression to Tier 3, but this is a site-specific decision to be taken by the local authority.

Key Point 12

In some cases, the results of the assessments completed at Tier 2 will be equivocal or conflicting. In such circumstances further assessments or site investigations may be necessary to aid the decision-making process.

The aim of any such assessments or investigations should be to fill data gaps and enable a decision to be made on whether significant harm or the significant possibility of significant harm is occurring to the ecological receptor, and therefore whether to proceed to the next tier of risk assessment or exit the ERA framework.

The scope of any work should be agreed by the risk assessor, the enforcing authority and the relevant conservation organisation.

Key Point 13

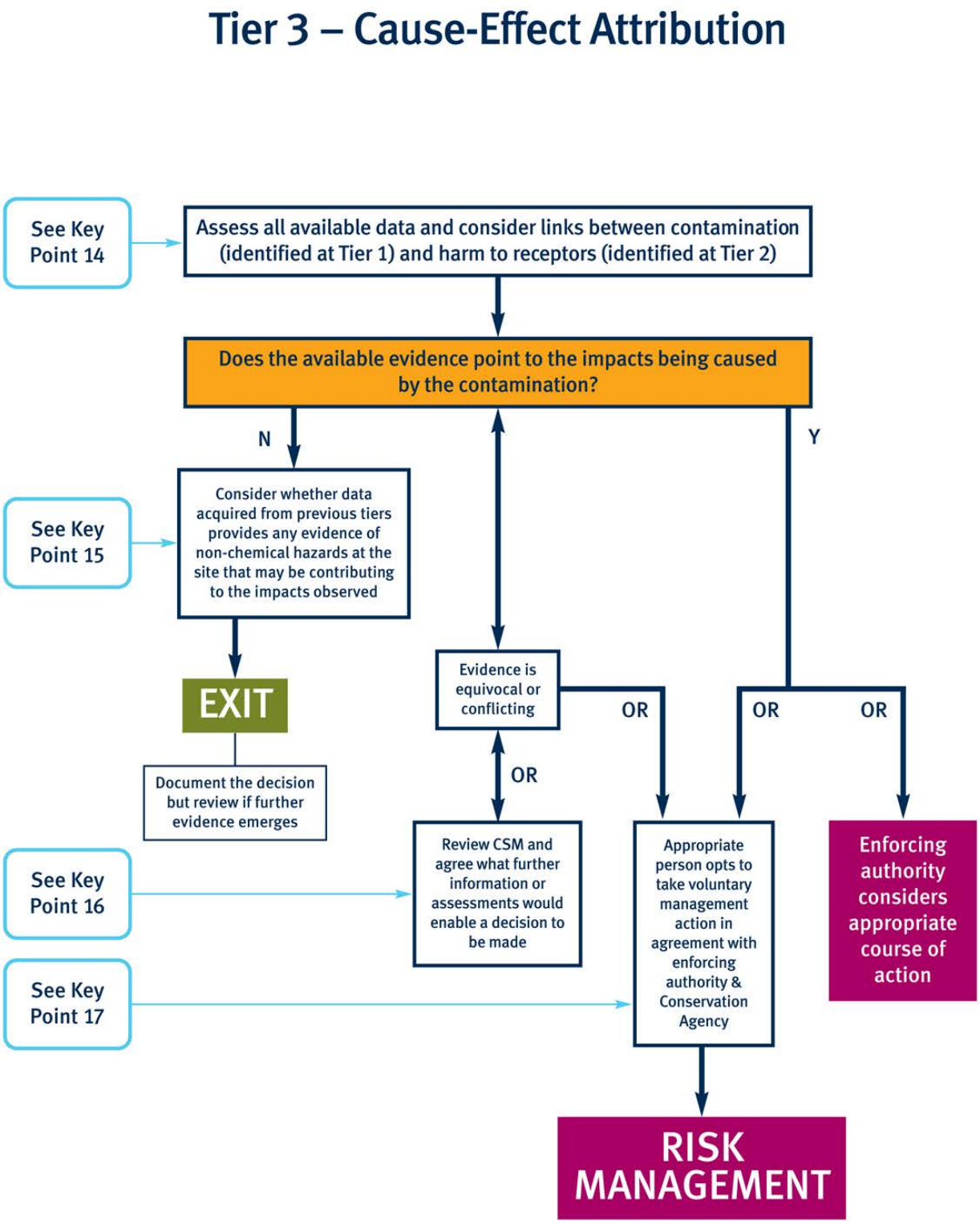
It is important to remember that:

- any relationships between contaminants and ecological receptors will not necessarily be straightforward;
- some contamination may be beneficial to certain ecological assemblages or species of special interest.

If ill-conceived remedial works are undertaken, it is possible they could do more ecological harm than good. Where remediation is planned, it is essential to understand the impacts of the work and, where necessary, to mitigate against adverse effects. Further guidance is provided in:

- *Guidance on the use of ecological surveys in Ecological Risk Assessment* (ERA 2d).

Before planning any remedial work, consult the enforcing authority and relevant nature conservation bodies (including appropriate non-statutory organisations).



3.4 3.4 Tier 3 key points

Key Point 14

This activity aims to determine whether the observed impact can be attributed to the chemical contaminant(s) by means of significant correlations and/or gradients of measured chemicals, or other patterns indicative of this relationship.

The review of data should be undertaken in consultation with the enforcing authority and the relevant conservation organisation.

At this stage consider the following guidance document:

- *Guidance on the attribution of cause and effect in Ecological Risk Assessment* (ERA 2e).

Key Point 15

At this point it is appropriate to re-examine the extent to which any non-chemical hazards may be responsible for any observed harm to receptors. Examples may include:

- disease;
- human disturbance;
- competition from invasive species;
- longer term environmental variables (e.g. changes in precipitation and/or temperature).

The risk assessor should undertake this activity in close consultation with the enforcing authority and the relevant conservation organisation. It may also be helpful to include the land owner/tenant and local interest groups as they will have a good local knowledge of the area.

If harm to ecological receptors is attributable to a non-chemical hazard, it may be necessary to consider other regulatory regimes (e.g. statutory nuisance, environmental liabilities, etc.).

Key Point 16

Where there is uncertainty regarding the extent to which chemical contamination is responsible for harm to ecological receptors, it may be appropriate to carry out further work.

The aim of any further work should be to fill data gaps in order to aid decision-making. Such work might include:

- further ecological surveying or monitoring over longer time periods;
- further chemical analysis;
- wider consultation.

The scope of any further work should be agreed by the risk assessor, the enforcing authority and the relevant conservation organisation.

Key Point 17

It is important to remember that:

- any relationships between contaminants and ecological receptors will not necessarily be straightforward;
- some contamination may be beneficial to certain ecological assemblages or species of special interest.

If ill-conceived remedial works are undertaken, it is possible they could do more ecological harm than good. Where remediation is planned, it is essential to understand the impacts of the work and, where necessary, to mitigate against adverse effects.

Further guidance is provided in:

- *Guidance on the use of ecological surveys in Ecological Risk Assessment* (ERA 2d).

Before planning any remedial work, consult the enforcing authority and relevant nature conservation bodies (including appropriate non-statutory organisations).

4 Illustrative examples

This section provides four examples to illustrate exits form the framework after a desk study, and at Tiers 1, 2 and 3. Although the examples use real data in parts, they are not based on actual case studies and as such should be used for illustrative purposes only. In 'live' situations, advice should be sought from the relevant conservation bodies on the most appropriate route through the ERA Framework at each stage.

4.1 4.1 Illustrative example A

4.1.1 4.1.1 A risk assessment concluded by desk study only

A local authority in the west of England identified the site of a former oil distribution depot as a potential source of contamination. A desk study was undertaken to gather information to assess the likelihood of pollutant linkages to any ecological receptors.

The study identified that the oil distribution depot ceased operation in the late 1990s after almost 50 years of operation. During the site's operational life, refined petroleum products such as petrol, diesel and heating oil were stored in aboveground storage tanks prior to distribution by road tanker to retailers and end users.

The depot site covers approximately one hectare, is surrounded by a mixture of residential and light industrial properties, and stands around 90 metres above ordnance datum. There is a river about 300 metres to the west; consultation with the Environment Agency confirmed that the groundwater gradient in the area is likely to be towards this river. The site and surrounding area is situated on sandstone overlain by sands, silts and clays.

The Contaminants of Potential Concern associated with the depot were identified to be:

- oil/fuel hydrocarbons and associated substances (e.g. MTBE,[1] BTEX[2]);
- lead.

Based on the known fate and transport behaviour of these substances, the local authority considered the hydrocarbons and MTBE could be contained within soil at the depot site, volatilising to air, or may be migrating as free phase or dissolved phase in groundwater. The lead could be contained within soils, with potential leaching to groundwater.

The desk study included a search for protected locations.[3] This search found that the former depot itself was not within a protected location, but that a Site of Special Scientific Interest (SSSI) is located 1 km to the north east. The SSSI is an area of acid heathland covering approximately 20 hectares which, at 120 metres above ordnance datum, lay topographically upgradient of the depot site. Information published on the Natural England website stated that the site was designated because of:

- the importance of heath and mire plant communities within it;

[1] methyl tert-butyl ether
[2] benzene, toluene, ethylbenzene and xylenes
[3] Designated conservation areas listed in Table A of the Statutory Guidance on contaminated land, Defra Circular 01/2006 (Defra 2006).

- the presence of rare and scarce species – notably bog orchids and mosses, dragonfly species, sand lizards and smooth snakes.

Discussion with Natural England identified the function of these habitats and the species of special interest as ecological Receptors of Potential Concern in accordance with the Statutory Guidance.

The potential generic pathways between the source and these receptors were considered to be:

- migration of hydrocarbons through groundwater and subsequent uptake by plant roots;
- direct contact between ecological receptors and contaminated surface water;
- direct contact between ecological receptors and contaminated soils;
- ingestion of contaminated soils/surface waters by ecological receptors;
- Inhalation of vapours or wind-blown dust by ecological receptors

The local authority constructed a Conceptual Site Model to assess the likelihood of potential pollutant linkages occurring between the possible source of contamination at the former depot and ecological receptors associated with the protected location.

The CSM illustrated that such pollutant linkages were not reasonably possible because:

- any contamination in groundwater or surface water would be likely to be migrating away from the depot and towards the river (west) and, in any case would not be capable of reaching the protected location which is 1km from the former depot;
- the ecological receptors associated with the protected location are relatively sessile and are therefore unlikely to come into contact with contaminated soils at the depot, especially as any contaminated soils would largely be located beneath hardstanding;
- wind-blown contaminants and vapours were unlikely to travel far enough to reach ecological receptors associated with the protected location.

Consequently, the local authority concluded that progression to tier 1 of the ERA framework was not warranted and the site exited the process at this point. The decision was documented and forwarded to Natural England for its records.

4.2 4.2 Illustrative example B

4.2.1 4.2.1 A risk assessment concluded at tier 1

A local authority identified a site it believed had been used for the storage and processing of scrap metals for a period of time during and after the Second World War.

A desk study established that the site covers an area of 1 hectare, contains a disused building, and is bordered by a 1970s housing estate to the east and a main road to the south. It is situated on limestone and the soils are neutral-to-alkaline and loamy. The nearest surface water is 500 metres to the south.

The Contaminants of Potential Concern associated with the site were identified to be:

- copper;
- nickel.

Consideration of their fate and transport suggested that they would be present in soils, with possible leaching to groundwater.

The desk study revealed that the site is part of a seven-hectare plot designated as a Local Nature Reserve (LNR) under Section 21 of the National Parks and Access to the Countryside Act 1949. It was designated because of the unimproved chalk grassland habitat containing two locally rare orchids and an endangered butterfly species. Consultation with the appropriate conservation organisations identified that these should be considered as the ecological Receptors of Potential Concern.

A Conceptual Site Model was constructed and the possible exposure pathways of the metal contaminants to the identified ecological receptors were initially considered to be:

- direct uptake of contaminants by grassland plants via roots;
- direct uptake of contaminants by orchids via roots;
- ingestion of contaminants contained in plant matter by butterfly larval stage;
- indirect exposure of butterfly larval stage to effects of contamination via loss of food plants;
- indirect exposure of butterflies to effects of contamination through loss of plant species on which it lays eggs.

Because it was reasonably possible that pollutant linkages existed at the site, the local authority decided that the ERA should progress to Tier 1.

The assessment and measurement endpoints were agreed in consultation with the conservation organisations and other stakeholders[4]. The assessment endpoints were based upon the Receptors of Potential Concern and it was agreed that measurement endpoints could include:

- ecological surveys to assess the extent and quality of grassland plant communities, with particular reference to counting or estimating the number of individual orchid plants and butterflies;

[4] Where a risk assessment is proceeding to tier 1 it is necessary to think ahead and agree the possible assessment and measurement endpoints as a part of the CSM. This will help to ensure that any site investigation and sampling at tier 1 is appropriately focussed and provides information relevant for risk assessment. Guidance on selecting assessment and measurement endpoints is provided in ERA 2a (Guidance on desk studies and CSM).

- plant toxicity bioassays using:
  - wheat to represent the chalk grasses;
  - Chinese cabbage to assess impact on a foliate dicotyledon representing the food source of the endangered butterfly larvae.

The local authority established that the Environment Agency had proposed soil screening values (SSVs) for both of the identified Contaminants of Potential Concern.

At Tier 1, the local authority commissioned a site investigation which included the collection and analysis of soil samples from the area of potential contamination and from elsewhere on the LNR for comparison.

The samples were analysed for metal concentrations and the parameters needed to make availability and bioavailability adjustments, i.e. pH, percentage organic matter (%OM) and percentage clay content. The results are given in Table 4.1.

The results were entered into the SSV Decision Tool provided on the Environment Agency website. This adjusted the values for availability and bioavailability according to the physico-chemical characteristics of the site soil. The adjusted values were then compared with the measured metal concentrations to derive risk quotients (RQs). These outcomes are also shown in Table 4.1.

Table 4.1 Output from the SSV decision tool (all values in mg/kg)

Sample	Measured concentration	Generic aged SSV	pH	% OM	% Clay	Adjusted SSV	RQ
Site 1 Cu	95	57.8	7.04	3.9	28	114.9	0.83
Site 1 Ni	19	21.0	7.04	3.9	28	63.3	0.30
Site 2 Cu	87	57.8	6.99	4.2	28	117.8	0.74
Site 2 Ni	10	21.0	6.99	4.2	28	64.5	0.15
Site 3 Cu	101	57.8	7.12	3.9	30	117.3	0.86
Site 3 Ni	12	21.0	7.12	3.9	30	67.6	0.18
Site 4 Cu	122	57.8	7.06	4.0	29	117.5	1.04
Site 4 Ni	25	21.0	7.06	4.0	29	65.8	0.38
Site 5 Cu	97	57.8	7.09	4.05	30	119.5	0.81
Site 5 Ni	7	21.0	7.09	4.05	30	68.2	0.10
Off- Cu	88	57.8	7.11	3.9	30	118.0	0.75
Site 1 Ni	16	21.0	7.11	3.9	30	67.5	0.29
Off- Cu	125	57.8	6.98	4.1	31	122.7	1.02
Site 2 Ni	20	21.0	6.98	4.1	31	69.4	0.48

The risk quotients were <1 in all cases except for copper in one sample. Given the spread of the data population, the small degree of the exceedance and the similarity to samples taken elsewhere on the reserve, the risk assessor decided the contaminants were in general not likely to be causing a substantial adverse impact on the ecological receptors at the site.

Because the contaminants were not present in sufficient concentrations to cause concern, there was no potential for pollutant linkages to occur.

Consequently the local authority concluded that progression to Tier 2 of the ERA framework was not warranted. Agreement on this decision was sought from the appropriate conservation organisations and the site exited the process at this point.

4.3 4.3 Illustrative example C

4.3.1 4.3.1 A risk assessment concluded at Tier 2

A land owner undertook a voluntary inspection of one of their sites in Wales to assess whether there where any significant pollutant linkages. The site is an active fuel storage, repackaging and distribution depot and it is suspected that long-term use of the site is likely to have resulted in soil contamination.

A desk study established that a large portion of the site falls within a Site of Special Scientific Interest (SSSI). The site is on sandstone with superficial deposits of sand and gravel.

Based on the substances known to have been handled on the site, the Contaminants of Potential Concern were identified as:

- hydrocarbons (diesel and petrol range);
- BTEX[5];
- chlorinated solvents;
- polycyclic aromatic hydrocarbons (PAHs);
- metals (chromium, copper, lead and zinc).

Consultation with Countryside Council for Wales (CCW) established that the SSSI covers 766 hectares and was designated because it consists of wet and dry heathland lying on acidic sands that are now rare remnants of a once extensive habitat. Although the SSSI contains a number of important species, the species of special interest in the vicinity of the area of the contamination were identified as:

- green-winged orchid;
- large marsh grasshopper;
- silver studded blue butterfly;
- woodlark;
- stonechat.

These species, along with the functioning of the wet and dry heathland ecosystem itself, were considered the ecological Receptors of Potential Concern.

The risk assessor developed a Conceptual Site Model to better understand the potential pollutant linkages at the site. Some of the main pathways of concern were identified as:

- direct uptake of contaminants by heathland plants and orchids via their roots;
- direct contact and ingestion of contaminants by grasshoppers, butterflies and birds;
- ingestion of contaminants contained in plant matter by grasshopper and butterfly larval stage;

[5] benzene, toluene, ethylbenzene and xylenes

- indirect exposure of grasshoppers and butterfly larval stage to effects of contamination via loss of food plants;
- indirect exposure of butterflies to effects of contamination through loss of plant species on which it lays eggs;
- ingestion of contaminants contained in invertebrates by birds;
- indirect exposure of birds to effects of contamination via loss of invertebrate food populations.

On this basis it was decided that pollutant linkages to ecological receptors were reasonably possible and that the ERA should progress to Tier 1.

The assessment and measurement endpoints were agreed by the risk assessor, the site owner, the local authority and CCW. The assessment endpoints were based upon the Receptors of Potential Concern and it was agreed that measurement endpoints should include:

- surveys to assess the extent and quality of heathland plant communities, with particular reference to counting or estimating the number of individual orchid plants;
- surveys to assess the size and diversity of invertebrate populations, with particular reference to counting or estimating the number of grasshoppers and butterflies;
- surveys of bird populations with particular reference to the nesting activity of woodlarks and stonechats;

The risk assessor established that the Environment Agency had proposed soil screening values (SSVs) for chromium, copper, lead, zinc, benzo(a)pyrene, toluene and tetrachloroethene, but not for any of the other Contaminants of Potential Concern. The stakeholders could not agree that guideline values published by other jurisdictions were appropriate for use in the context of this risk assessment.

An intrusive investigation was undertaken at Tier 1 which involved collection of soil samples from the potentially contaminated area.

Laboratory analysis was undertaken for both the Contaminants of Potential Concern and the parameters needed to undertake availability and bioavailability corrections on the measured contaminant concentrations before they were compared with the SSVs (pH, percentage organic matter and percentage clay content). For comparison, soil samples were also retrieved from an area of the SSSI that was nearby but outside the area of potential contamination.

The measured contaminant concentrations were adjusted for availability and bioavailability using the SSV Decision Tool provided on the Environment Agency website. A number of samples had a calculated risk quotient >1, although levels of chlorinated solvents were found to be below laboratory detection limits in all of the samples analysed.

In consultation with the local authority and CCW, the risk assessor concluded that:

- pollutant linkages to ecological receptors were still reasonably possible;
- the ERA should proceed to Tier 2 because:
  - a number of contaminants had exceeded their respective SSV;

- many of the Contaminants of Potential Concern did not have a proposed SSV, or other agreed suitable screening value, for comparison with the measured concentrations.

The risk assessor, the site owner, the local authority and CCW had agreed that ecological surveys should be used as measurement endpoints at Tier 2[6]. They were designed and performed by experienced ecologists in consultation with CCW in order to ensure that the appropriate information was obtained. The results are summarised in Table 4.2.

Table 4.2 Ecological survey findings for illustrative example C

Measurement endpoint	Summary of findings
Ecological surveys to assess the extent and quality of heathland plant communities, with particular reference to counting or estimating the number of individual orchid plants.	The abundance and diversity of plant species was reported to be as would be expected for this habitat type, and similar to that recorded in other areas of the SSSI. Tracks across the site provided good habitat for rare plants – including green winged orchid – whose occurrence and population density were reported to be as would be expected. Areas of scrub invasion were restricting the extent of this species at the site, but proactive management practices appeared to be reversing this. No obvious adverse effects of contamination on plant species were reported.
Ecological surveys to assess the size and diversity of invertebrate populations, with particular reference to counting or estimating the number of grasshoppers and butterflies.	The invertebrate species composition was reported to be as would be expected for this type of habitat, and similar to that recorded in other areas of the SSSI. The surveys noted the presence of both the large marsh grasshopper and the silver studded blue butterfly. The ecologist noted that removal of scrub and alterations to drainage arrangements at the site would be beneficial to these species.
Ecological surveys of bird populations with particular reference to the nesting activity of woodlarks and stonechats.	In general the composition of bird species was reported to be as would be expected for this habitat type, and similar to that recorded in other areas of the SSSI. Both woodlark and stonechat were recorded as breeding at the site, but the presence of large areas of scrub which was colonising former heathland was noted to be unfavourable for these species.

The results of the Tier 2 risk assessment did not indicate that there was any harm occurring to the identified ecological receptors. The ecological surveys indicated that

[6] As discussed in section 2, both ecological surveys and bioassays are available as tools for use at tier 2. Either or both of these tools can be applied in any order according to the circumstances of the assessment. In this example the stakeholders agreed that a variety of ecological surveys were to be used in the first instance.

the ecology of the site, including the species of special interest, did not appear to be impacted by any widespread adverse effects other than those attributable to the loss of the heathland habitat through scrub invasion. The species composition record was similar to that found further away from the fuel depot.

The risk assessor, in consultation with CCW and the land owner, therefore concluded that progression to Tier 3 of the ERA framework was not warranted in this case and the site exited the process at this point.

4.4 4.4 Illustrative example D

4.4.1 4.4.1 A risk assessment concluded at tier 3

A local authority undertook an inspection of a former gasworks to assess whether the site should be determined as 'contaminated land' under Part 2A of the Environmental Protection Act 1990.

A desk study found that the former gasworks site covers an area of 1.5 hectares and that the buildings and structures had been removed. The geological sequence beneath the site is glacial till, underlain by Mercia Mudstone, underlain by Sherwood Sandstone. The glacial till and Mercia Mudstone were considered to be non-aquifers.

A search for protected locations (as listed in Table A of the Statutory Guidance) was carried out to identify any potential ecological receptors in the vicinity. This found that the former gasworks is immediately adjacent to a site designated as a Local Nature Reserve (LNR) under Section 21 of the National Parks and Access to the Countryside Act 1949. The site was designated a LNR in 1964. Anecdotal evidence suggested that the area of the LNR closest to the former gasworks may have been used for disposal of wastes from the gasworks site when it was decommissioned in the late 1960s/early 1970s.

The LNR was designated because it contains an area of continuous scrub and woodland habitat which supports a wide variety of songbird species including hawfinch, redpoll and firecrest as well as a viable population of dormice.

The LNR is managed jointly by the Royal Society for the Protection of Birds (RSPB) and the county wildlife trust. Consultation with these conservation organisations and other stakeholders identified that:

- the functioning of the woodland ecosystem supporting the breeding birds was a Receptor of Potential Concern;
- the firecrests and dormice were species of special interest.

A baseline ecological survey had been carried out at the LNR as part of the designation process in 1964, but no formal ecological surveys have been performed since.

Based upon the information gathered in the desk study, it was considered that there was the potential for contamination on both the former gasworks site and the surrounding area from the Contaminants of Potential Concern. These were initially identified as:

- Hydrocarbons (including aromatic and polycyclic aromatic hydrocarbons);
- phenols;
- cyanides;

- sulphur;
- metals.

The risk assessor constructed a Conceptual Site Model to:

- gain an appreciation of the potential pollutant linkages;
- show the various pathways that may be active at the site.

Some of these pathways were identified as:

- direct uptake of contaminants by woodland plants via roots;
- direct contact/incidental ingestion of contaminants by dormice and firecrests;
- ingestion of contaminants contained in plant matter by dormice;
- indirect exposure of dormice to effects of contamination via loss of food plants;
- ingestion of contaminants contained in invertebrates by firecrests;
- indirect exposure of firecrests to effects of contamination via loss of invertebrate food populations.

On this basis, it was decided that pollutant linkages to ecological receptors were reasonably possible and that the ERA should proceed to Tier 1.

The assessment and measurement endpoints were agreed in consultation with the appropriate conservation organisations[7]. The assessment endpoints were based upon the Receptors of Potential Concern and it was agreed that measurement endpoints should include:

- ecological surveys to assess the extent and quality of woodland plant communities;
- ecological surveys to assess the size and diversity of the invertebrate populations on which the firecrest depends;
- ecological surveys of bird populations with particular reference to the nesting activity of firecrests;
- ecological survey of small mammal populations with particular reference to the nesting activity of dormice;
- nitrogen mineralisation bioassays to assess the impacts on the microbial community necessary for the functioning of, and nutrient supply to, the woodland ecosystem;
- plant toxicity bioassays using a variety of species to represent the diverse woodland plants and to assess any impacts on the food sources of the dormice;

[7] As discussed in section 2, both ecological surveys and bioassays are available as tools for use at tier 2. Either or both of these tools can be applied in any order according to the circumstances of the assessment. In this example the stakeholders agreed that both ecological surveys and bioassays were required.

- invertebrate toxicity bioassays using a variety of soil-dwelling invertebrates to assess any impacts on the food sources of the firecrest.

The risk assessor had noted that no soil screening values (SSVs) had been proposed by the Environment Agency for the majority of the Contaminants of Potential Concern. The stakeholders could not agree that guideline values published by other jurisdictions were appropriate for use in the context of this risk assessment.

An intrusive site investigation was undertaken at Tier 1 which included the collection of soil samples from the LNR site. So that the results could be compared, soil samples were also retrieved from an area of the LNR farthest away from the former gasworks and therefore more likely to be uncontaminated.

Laboratory analysis was undertaken for the identified Contaminants of Potential Concern. The measured contaminant concentrations for substances with published SSVs were adjusted for availability and bioavailability using the SSV Decision Tool provided on the Environment Agency website. A number of samples had a calculated risk quotient >1.

Levels of contamination were observed to conform to a broad trend, with contaminant concentrations decreasing with distance from the former gasworks. On this basis, the site was zoned into two areas:

- Zone 1 was the area closest to the former gasworks where contamination levels were highest;
- Zone 2 was the area away from the former gasworks where levels of contamination were generally much lower, although no samples were below the laboratory limit of detection.

The levels of contamination within soil samples collected from the area of the LNR farthest away from the former gasworks were found to be below analytical limits.

The site investigation also reported that areas of made ground had been observed in Zone 1, whereas the profile of soils in the area of Zone 2 appeared natural. The presence of areas of made ground in Zone 1 supported the anecdotal evidence that wastes had been deposited within the LNR when the adjacent gas works was decommissioned.

In consultation with the conservation organisations, the local authority decided the ERA should proceed to Tier 2. This was because:

- the Contaminants of Potential Concern were present at concentrations that exceeded published SSVs;
- many of the Contaminants of Potential Concern did not have a proposed SSV, or other agreed suitable screening value, for comparison with the measured concentrations.

The stakeholders had agreed that a combination of both ecological surveys and bioassays could be used as measurement endpoints. The results are summarised below.

4.4.2 Ecological surveys

Ecological surveys were identified as measurement endpoints for the functioning of the ecosystem and for the species of special interest. A summary of the findings is set out in Table 4.3.

Table 4.3 Ecological survey findings for illustrative example D

Measurement endpoint	Summary of findings
Ecological surveys to assess the extent and quality of woodland plant communities.	The extent and species composition of the plant communities was found to be comparable with that reported in the baseline survey undertaken at the time of LNR designation. The only exception was the area of Zone 1, which appeared to have deteriorated since the time of the baseline survey. Within Zone 1 the vegetation appeared to be low, in poor condition and sparse when compared with the other area of the site.
Ecological surveys to assess the size and diversity of the invertebrate populations on which the firecrest depends.	Although the baseline survey for the site did not contain an invertebrate survey, the species identified and their relative abundance were reported to be as would be expected for this type of scrub and woodland habitat.
Ecological surveys of bird populations with particular reference to the nesting activity of firecrests.	A survey was undertaken with particular attention to the firecrest as a species of special interest. The survey identified that the LNR site provided good foraging and nesting habitat for a number of bird species including firecrests, possibly with the exception of Zone 1 (as discussed above). The diversity and abundance of bird species was reported by the ecologist to be as expected in a habitat of this type. However, the firecrest population was considered to be lower than that identified during the baseline survey. No obvious aspects of the ecosystem were identified that might be considered detrimental to bird species in general, or the firecrest in particular, with the exception of Zone 1 which was reported to be less favourable for foraging.
Ecological survey of small mammal populations with particular reference to the nesting activity of dormice.	The survey identified that the LNR site provided good habitat for a range of mammals and signs of fox, badger, deer and hedgehog were observed, although the abundance of these species could not be determined. A specific dormouse survey was undertaken involving the identification of hazelnut shells opened by dormice, the installation of hair tubes and the checking of existing nest boxes. The survey findings reported that the population appeared to be lower than that identified by the baseline survey. No evidence of dormouse activity was identified in the area of Zone 1. This was primarily considered to be due to less favourable habitat.

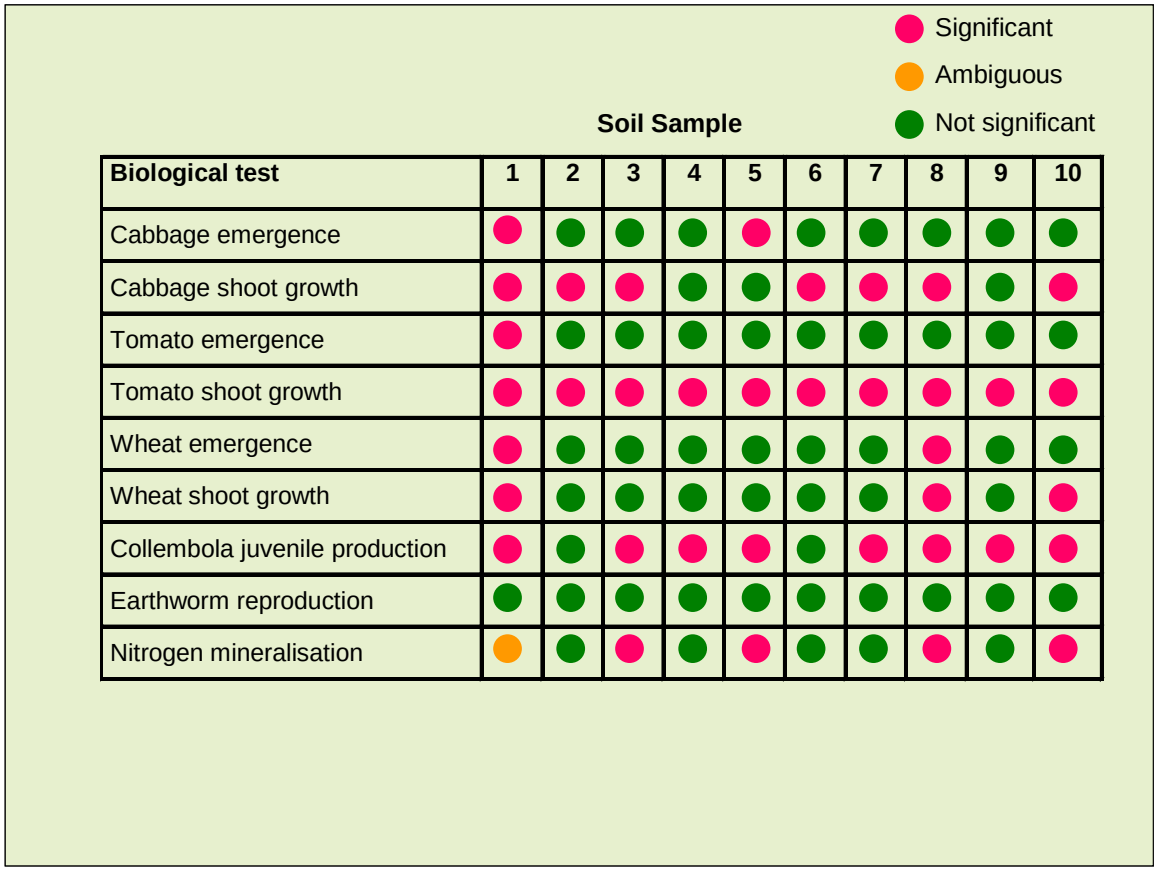
Overall, the ecological surveys did not record any observable adverse effects on the ecology of the LNR except within the area immediately adjacent to the former gasworks that broadly corresponds to the delineation of Zone 1. In this area, the plant community appeared to have deteriorated since the baseline survey. Consequently the habitat was less suitable for dormice and would not be attractive foraging or nesting habitat for birds, including the firecrest.

4.4.3 Bioassays

In addition to the ecological surveys, certain bioassays had been identified as relevant measurement endpoints. A total of 10 representative soil samples from the site were selected for testing[8]. Five of these samples (1, 3, 5, 8 and 10) were from Zone 1 and five (2, 4, 6, 7 and 9) were from Zone 2.

The biological tests were also performed on positive and negative control samples, and appropriate 'site reference control' soils obtained from an area of the LNR identified as uncontaminated during the Tier 1 investigation. The purpose of the positive and negative controls was to ensure the quality of the bioassays. The purpose of the site reference tests was to control for the potential influence of the physico-chemical characteristics of the soil. The bioassay results are summarised in Figure 4.2.

Figure 4.2 Bioassay results for illustrative example D



Biological test	1	2	3	4	5	6	7	8	9	10
Cabbage emergence	●	●	●	●	●	●	●	●	●	●
Cabbage shoot growth	●	●	●	●	●	●	●	●	●	●
Tomato emergence	●	●	●	●	●	●	●	●	●	●
Tomato shoot growth	●	●	●	●	●	●	●	●	●	●
Wheat emergence	●	●	●	●	●	●	●	●	●	●
Wheat shoot growth	●	●	●	●	●	●	●	●	●	●
Collembola juvenile production	●	●	●	●	●	●	●	●	●	●
Earthworm reproduction	●	●	●	●	●	●	●	●	●	●
Nitrogen mineralisation	●	●	●	●	●	●	●	●	●	●

The plant bioassays recorded significant inhibition of growth in 20 out of 30 plant tests (cabbage, tomato, wheat). Most notable were the results for tomato where significant inhibition of growth was recorded for all 10 soil samples. Significant impacts in all three growth tests were recorded in soil samples 1, 8 and 10, which were all taken within Zone 1 close to the site of the former gasworks. It therefore appears that contamination is inhibiting plant growth across the area sampled, but with the greatest effects observed in Zone 1.

I[8]n the invertebrate bioassay, the collembolan reproduction tests reported significant results for eight of the 10 soil samples (including all five in Zone 1). This indicates that the contamination is having an adverse effect on invertebrate reproduction across the area sampled, but with the greatest effects observed in Zone 1. However, none of the earthworm tests showed any significant results, suggesting that either contaminant levels are not having adverse effects on this species or the tests had not been suitable for the Contaminants of Potential Concern. The laboratory positive and negative controls performed within pre-defined limits of acceptability.

[8] For further information on taking appropriate samples for bioassays, including site reference controls, consult ERA 2c (Guidance on the use of bioassays).

Four of the 10 soil samples showed significant inhibition in the nitrogen mineralisation test, with another sample giving an ambiguous result. All five of these results were from soils from within Zone 1. The test therefore indicates some potential for inhibition of nitrogen production within Zone 1.

After considering the results of the bioassays and ecological surveys, the risk assessor revised the Conceptual Site Model to assess whether the identified potential pollutant linkages could still be considered reasonably possible.

The findings of the ecological surveys had identified that plant communities in the area of Zone 1, immediately adjacent to the gasworks, were deteriorating and consequently presented less suitable habitat for the firecrest and dormouse species of special interest. The population size of both species appeared to be declining from that recorded during the baseline survey of the LNR.

The bioassays supported this conclusion by indicating a significant potential for adverse effects on ecological receptors in this area. This is illustrated by the results for soil sample 1 and, to a lesser extent, for soil samples 3, 5, 8 and 10. The key adverse effects were related to plant growth, nitrogen mineralisation and collembolan reproduction.

Although it was not clear from the results of the bioassays and ecological surveys whether contaminants were having a direct toxic effect on the species of special interest, it was apparent that the food resources on which they depend – plants and seeds (dormice) and insects and spiders (firecrests) – were likely to be impacted. The evidence includes the reduction in plant diversity in the ecological survey and the extensive inhibition of growth in the plant bioassays. The evidence for impacts in invertebrates is less convincing, with no effects observed in the earthworm bioassays and with the diversity in the ecological surveys being as expected. However, the degree of impact in the collembolan reproduction tests – arguably the most representative assay for soil-dwelling insects taken by the songbirds – combined with the lack of baseline information against which to judge the invertebrate ecological survey means that adverse effects in this group cannot be discounted.

Therefore, with the agreement of all the stakeholders, the risk assessor concluded that there was evidence for:

- adverse changes to the functioning of the scrub and woodland ecosystem in Zone 1;
- potential harm to the species of special interest. Evidence from the bioassays demonstrated that adverse effects on their food sources were likely.

Consequently it was decided that the risk assessment should progress to Tier 3.

At this tier, a further review of the evidence was made and consideration given as to whether the contamination was responsible for the adverse effects observed in the measurement endpoints that inferred harm to the ecological receptors. This review was based on the general principles of Hill's Causal Criteria (see ERA 3e, Guidance on the attribution of cause and effect). The findings are set out in Table 4.4.

Table 4.4 Review of evidence based on Hill's causal criteria

Criterion	Suggested 'weight' in decision-making	Comments
Strength of association	+++	Principle Component Analysis (PCA) was performed. The levels of cyanide and phenols were found to be the principal components accounting for the effects observed in the bioassays.
Consistency of association	++	The risk assessor found only very limited evidence from other sites regarding ecological effects of gasworks contaminants.
Experimentation	++	Dose–response experiments between contaminant levels and receptors were not performed on this occasion.
Ecological gradient	++	Simple spatial mapping of contaminant concentrations and the results of the ecological surveys and bioassays illustrated a clear relationship between greater levels of contamination and greater biological impact. There was also a clear relationship between contaminant levels and distance from the former gasworks.
Plausibility	++	The contaminants of concern at the site include substances for which there is a great deal of scientific literature on adverse biological effects. The known effects of these substances include phytotoxicity – as observed in the plant growth bioassays and the ecological surveys.
Coherence	++	The observed biological responses agree with current knowledge about the effects of the contaminants of concern on plants (see above).
Analogy	+	Case studies on the effects of similar contaminants at other locations were sparse.
Temporality	+	The baseline ecology survey undertaken at the time of the LNR designation illustrates that the site has not always been adversely affected by contaminants from the former gasworks. Therefore, the effects observed in the ecological surveys appear to have occurred since the contaminated wastes were deposited.
Specificity	+	A number of variables, including physical disturbance or aridity of the soil, can cause the effects observed in the ecological surveys. However, many variables are reduced by conducting bioassay tests in controlled conditions and by using a site reference soil.

The review identified that the criteria for strength of association, ecological gradient, plausibility, coherence, temporality and specificity were satisfied. The weighting of analysis was in favour of concluding that the adverse effects observed during the ecological surveys and bioassays were caused by the presence of the contamination.

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7 List of abbreviations

AONB	Area of Outstanding Natural Beauty
BTEX	benzene, toluene, ethylbenzene and xylenes
CCW	Countryside Council for Wales
CSM	Conceptual Site Model
ERA	Ecological Risk Assessment
LNR	Local Nature Reserve
MTBE	methyl tert-butyl ether
OM	organic matter
PAH	polycyclic aromatic hydrocarbon
RQ	risk quotient
SAC	Special Area of Conservation
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
SSV	Soil Screening Value

8 Glossary

Assessment Endpoint	An explicit expression of the environmental resource that is to be protected. It is defined operationally in structural terms (e.g. a population of a particular species) or functionally (e.g. supporting processes that are typical of a particular habitat).
Availability	The total amount of a specific contaminant in soil that is in equilibrium with the contaminant in soil solution.
Bioassay	A laboratory test in which the toxicity of a contaminant or environmental sample is measured by exposing a specific organism and measuring a life-cycle parameter (for example, survival, reproduction, development, growth). In general, bioassays are conducted under controlled conditions so that the effects of environmental factors that could confound interpretation of results are avoided.
Bioavailability	The degree to which a chemical can be taken into the tissues of an exposed organism.
Conceptual Site Model	A representation of the characteristics of the site in diagrammatic or written form that shows the possible relationships between contaminants, pathways and receptors.
Contaminant	In general terms, a substance that is in, on or under the land and that has the potential to cause harm or to cause pollution of controlled waters. Within ecological risk assessment the specific emphasis will be on contaminants that have the potential to cause harm to ecological receptors.
Contaminant of Potential Concern	A contaminant identified as being present or likely to be present at the study site, included in the CSM and agreed to be of concern by all the stakeholders.
Desk Study	Interpretation of historical, archival and current information to establish where previous activities were located, and where areas or zones that contain distinct and different types of contamination may be expected to occur, and to understand the environmental setting of the site in terms of pathways and receptors.
Dose-response relationship	The relationship between the dose of a contaminant administered or received and the incidence of adverse effects in the exposed population. From the quantitative dose-response relationship, values are derived that can be used to estimate the likelihood of adverse effects occurring at different exposure levels.

Ecological Survey	Surveys for habitats and species; a method of gathering spatial and / or temporal ecological data on a site.
Measurement Endpoints	Quantifiable indicators that relate directly to assessment endpoints, for example, viable offspring per female bird.
Pathway	A route or means by which a receptor could be, or is exposed to, or affected by a contaminant.
Pollutant Linkage	The relationship between a contaminant, pathway and receptor.
Protected location	A location protected by a nature conservation designation of a type listed in Table A of the Statutory Guidance on Contaminated Land.
Ecological Receptor	In general terms, [a receptor is] something that could be adversely affected by a contaminant, such as people, an ecological system, property or a water body. Within ecological risk assessment, an ecological receptor will be an organism, population or community that might be affected by exposure to a contaminant of concern.
Ecological Risk Assessment	Evaluation of the likelihood of adverse effects on organisms, populations and communities from chemicals present in the environment.
Receptor of Potential Concern	An ecological receptor identified as present or likely to be present at the study site, included in the CSM and agreed to be of concern by all the stakeholders.
Risk Quotient	An expression of ecological risk described by the ratio between the measured concentration of a contaminant in soils and the Soil Screening Value.
Soil Screening Values	Concentrations of chemical substances found in soils below which there are not expected to be any adverse effects on wildlife such as birds, mammals, plants and soil invertebrates, or on the microbial functioning of soils.
Species of Special Interest	A species within a protected location that, through discussion with relevant conservation organisations has been established as being of special interest.

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