CLARINET

Review of Decision Support Tools for Contaminated Land Management, and their Use in Europe

A report from the Contaminated Land Rehabilitation Network for Environmental Technologies

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Department for Environment Food and Rural Affairs

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Review of Decision Support Tools for Contaminated Land Management, and their use in Europe

Report prepared by Working Group "Decision Support Tools" of the Concerted Action "Contaminated Land Rehabilitation Network for Environmental Technologies" (CLARINET), funded by the European Commission, DG Research, under the Environment and Climate Programme and co-ordinated by the Austrian Federal Environment Agency.

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- Land Contamination & Reclamation, Vol. Nine - Number One, 2001; published by EPP Publications, 52 Kings Road, Richmond, Surrey TW10 6EP, UK, E-mail enquiries@epppublications.com
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Authors

Paul BARDOS, Anita LEWIS (r3 Environmental Technology Limited, United Kingdom), Stephen NORTCLIFF (University of Reading, United Kingdom), Claudio MATIOTTI (Aquater, Italy), Franck MAROT (ADEME, France), Terry SULLIVAN (BNL, USA)

Working Group Members

Co-ordinator: Paul Bardos (r3 Environmental Technology Limited, United Kingdom)

Detlef Grimski (UBA, Germany), Malcolm Lowe (Department of the Environment Transport and the Regions, UK), Claudio Mariotti (Aquater, Italy), Franck Marot (ADEME, France), Christoph Munz (BMG Engineering Ltd, Switzerland), Brendan O'Neill (DoE, Ireland), Francesca Quercia (ANPA, Italy), Elisenda Realp Campalans (Junta de Residus, Catalunya, Spain), Harald Solberg (SFT, Norway), Frank Swartjes (RIVM, The Netherlands), Eddy Van Dyck (OVAM, Belgium)

Further contributors

Timo Assmuth (VYH, Finland), Andrzej Baranski (Institute of Environmental Protection, Poland), Peter Booth (BNFL on behalf of NICOLE), Fotini Boura (Ministry of Environment, Physical Planning and Public Works, Greece), Jan Bronders (VITO, Belgium), Claudio Carlon (University of Venice, Italy), Barbara Lopez Dias (Instituto dos Residuos, Portugal), Barbara Gworek (Institute of Environmental Protection, Poland), Margaret Keegan (Environmental Protection Agency, Ireland), Andrea Lodolo (ICS UNIDO, Italy), Malcolm Lowe, Pierre Menger (Umweltbundesamt, Austria), Tom Mitchell (Shell Research Ltd, UK), Pavlo Molchanov (Vinnitsya State Technical University, Ukraine), John Moohan (TNTU, UK), Joop Okx (Tauw, NICOLE), Judith Petts (University of Birmingham, UK), Kenichi Soga (University of Cambridge, UK), Jaana Sorvari (VYH, Finland), Terry Sullivan (Brookhaven National Laboratory, USA), Caroline van Hoek (Delft University of Technology, The Netherlands), Terry Walden (BP, NICOLE), Eleonora Wcislo (IETU, Poland), Boris Yatsalo (OINPE, Obninsk Institute of Nuclear Power Engineering, Russia)

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FOREWORD

This report is the result of working group "Decision Support Tools" of the network CLARINET (Contaminated Land Rehabilitation Network for Environmental Technologies), a project funded under the Environment and Climate Programme of the European Commission.

CLARINET provides an interdisciplinary network on the sustainable management of contaminated land in Europe, analysed key-issues in decision-making processes and identified priority research needs on technical, environmental and socio-economic topics. The network brings together the combined knowledge and expertise of academics, national policy makers, government experts, consultants, industrial land owners and technology developers from 16 European countries. The key objective of CLARINET was to identify the means for the effective and sustainable management of contaminated land in order to

ensure the safe (re-)use of these lands

abate caused water pollution

maintain the functionality of soil and (ground-)water ecosystems.

CLARINET focused on the basis of currently applied risk-based procedures for land management in European countries, aiming to evaluate the current state of the art and to stimulate scientific collaboration on identified research needs in Europe.

To yield an integrated approach within the project, several interlinked working groups were identifying problem and solution related aspects for contaminated land management. Following themes have been addressed:

Brownfields Redevelopment

Impacts of Contaminated Land on Water Resources

Remediation Technologies and Techniques

Human Health Aspects

Risk Management and Decision Support

Furthermore, one working group aimed to stimulate collaboration between various R&D Programmes on a European level.

Based on the identified state-of-the-art in these areas, integrative concepts and recommendations for tackling contaminated land problems have be investigated, taking the different approaches in the European countries into account. Needs for further research have been identified.

The individual working group results contributed in developing an overall conceptual framework for sustainable management of contaminated land (Risk Based Land Management). This concept is also available within this series of publications.

Martin Schamann

Federal Environment Agency, Austria

On behalf of the CLARINET Steering Committee and members of the network

CONTENT

EXECUTIVE SUMMARY

Introduction

Decision support exists to help those who have to take decisions dealing with the complex and wide-ranging information involved in contaminated land management. Decision support can be provided as written guidance (flow sheets, model procedures) and / or software. It aims not only to facilitate decision making but to help ensure that the process is transparent, documented, reproducible and hopefully robust, providing a coherent framework to explore the options available. The need for decision support is widely recognised and in recent years a large number of decision support tools (DSTs) have been developed, with varying degrees of success in practical use.

The Activities of Working Group "Decision Support Tools"

The Working Group "Decision Support Tools" has surveyed decision support issues in 16 countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden[1], Switzerland and the United Kingdom. This survey was based on the use of questionnaires circulated to the CLARINET national representatives. The responses to these questionnaires were compiled and peer reviewed. The Working Group "Decision Support Tools" also undertook a review of available decision support methods and tools and set out (with Working Group "Remediation Technologies") a series of key decision making principles for remedy selection for contaminated sites. It also established an open access catalogue of decision support tools, which is available for entries from decision support tool researchers, developers and vendors, and can be viewed by anyone. The catalogue is linked to www.clarinet.at.

Full Report Contents

The report reviews the Working Group's view of the principal decision making criteria for contaminated land management and remediation: driving forces for the remediation project, risk management, sustainable development, stakeholder satisfaction, cost effectiveness and technical feasibility. Chapter 3 reviews the practice of decision support, and techniques commonly used to provide analyses for decision making: environmental risk assessment, multi-criteria analysis, multi-attribute techniques, cost-benefit analysis, cost effectiveness analysis, life cycle assessment, financial risk management; and their acceptability in the decision making process. Chapter 4 (and Annex A) report on a survey of decision support issues carried out over 16 European

[1] Information for Sweden was taken from the Swedish website – *www.environ.se*

countries by the Working Group "Decision Support Tools", and introduces an on line catalogue of decision support tools. Chapter 6 discusses decision support in the context of the Risk Based Land Management concept developed by CLARINET (VEGTER *et al.,* 2002). The final chapters contain the reports conclusions and recommendations.

In this report, contaminated land is a general term to describe sites or wider areas of land where elevated concentrations of chemicals or other substances (contamination), usually resulting from man's use of the land, may exist. It focuses on contamination resulting from past practices, that is, historic or legacy contamination.

Key Decision Making Principles for Contaminated Management

Finding sustainable technical solutions for contaminated problems is dependent on a range of parallel considerations. Decisions about which risk management option(s) are most appropriate for a particular site needs to be considered in a holistic manner. Key factors in decision making include: driving forces for the remediation project, risk management, sustainable development, stakeholders' viewpoints, cost effectiveness, and technical feasibility / suitability.

The **drivers** for remediation are typically: To protect human health and the environment, to enable redevelopment, to repair previous remediation work or redevelopment projects where past risk management has been inadequate, and to limit potential liabilities or alternatively increase land asset values.

The goal of **risk assessment** is to provide an objective, scientific evaluation of the likelihood of unacceptable impacts to human health and the environment. The goal of **risk management** is to support decisions on risk acceptability for specified land uses and to determine the actions to be taken. It is the process of making informed decisions on the acceptability of risks posed by contaminants at a site, either before or after treatment, and how any needed risk reduction can be achieved efficiently and cost effectively (FERGUSON *et al.* 1998, FERGUSON & KASAMAS, 1999). In this way, the over riding needs for the protection of human health and the environment can be clearly identified and work prioritised accordingly.

The concept of **sustainable development** gained international governmental recognition at the United Nation's Earth Summit conference in Rio de Janeiro in 1992. Sustainable development has been defined as: "… *Development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (BRUNDTLAND, 1987). Underpinning this approach are three basic **elements of sustainable development**: economic growth, environmental protection and social progress. At a strategic level, the remediation of contaminated sites supports the goal of sustainable development by helping to conserve land as a resource, preventing the spread of pollution to air, soil and water, and reducing the pressure for development on greenfield sites. However, remediation activities themselves have their own environmental, social and economic impacts. On a project-by-project basis, the negative impacts of remediation should not exceed the benefits of the project.

The stakeholders at the **core** of the decision making process for site remediation are typically the site owner and / or polluter, whoever is being affected by pollution, the service provider and the regulator and planner. However, other stakeholders can also be influential, such as:

- Site users, workers (possibly unions), visitors;
- Financial community (banks, founders, lenders, insurers);
- Site neighbours (tenants, dwellers, visitors, local councils);
- Campaigning organisations and local pressure groups;
- Other technical specialists and researchers.

Stakeholders will have their own perspective, priorities, concerns and ambitions regarding any particular site. The most appropriate remedial actions will offer a balance between meeting as many of their needs as possible, in particular risk management and achieving sustainable development, without unfairly disadvantaging any individual stakeholder.

Often the actual or envisaged use of a site to be remediated is already established, for example for housing, for a retail park etc. In these situations risk management decision making tends to focus on a set of **core goals** which are closely aligned to meeting the requirements of the project drivers and the needs of the core stakeholders. However remediation works can have wider economic, social and environmental effects. These can be described as **non-core** effects. The value of remediation projects, in the context of sustainable development, can be enhanced by selecting whichever remedial option also has the greatest benefit / minimum impact for these non-core effects.

Remediation work for aquifers is not specific for particular end uses of sites. Consequently the overall value of restoring an aquifer, in the context of sustainable development over all, is usually considered among the core goals.

For some sites no prescribed end use may have been set when the decision to remediate has been taken. For example remediation may be proceeding as a part of a larger social regeneration scheme. In these situations the most “sustainable” re-use of the site should be considered as part of the core goals. Part of this consideration would necessarily be the wider effects of the remediation routes necessary for particular site uses.

The aim of the assessment of costs and benefits is to consider the diverse range of impacts that may differ from one proposed solution to another such as the effect on human health, the environment, the land use, and issues of stakeholder concern and acceptability by assigning values to each impact in common units. Deciding which impacts to include or exclude from the assessment is likely to vary on a site-by-site basis.

A *suitable* technique is one which meets the technical and environmental criteria for dealing with a particular remediation problem. The issues that affect the suitability of a remediation technology for a particular set of circumstances are: the risk management application, treatable contaminants and materials, the remedial approach itself (e.g. can it be used for the constraints of a particular site such as space requirements), where remediation is to take place (on site, off site, *in situ*, *ex situ*), the overall strategy employed (for example combinations of different techniques may be used), how the remediation work needs to be implemented (e.g. ease of verification) and the legacy of the remediation approach used (e.g. are contaminants destroyed, extracted or removed in some way, or stabilised or contained somewhere on site).

However, it is possible that a proposed solution may appear suitable, but is still not considered *feasible*, because of concerns about its previous performance and the adequacy of its validation, the expertise of the purveyor, its cost, its duration, how verifiable performance is, and its general acceptability to stakeholders who may have explicit preferences (e.g. that contaminated materials must be dealt with off site). The duration of remedial solution is a critical factor for their practicability and a major linkage to the concept of *Risk Based Land Management* developed by CLARINET.

Describing Decision Support

The decision making process for any problem usually encompasses:

- An identification phase in which the problem is identified;
- A development phase in which possible solutions are identified and developed;
- A selection phase in which the solution to be implemented is chosen;
- A monitoring phase to prove/disprove that the chosen option or set of options has been implemented.

*Decision suppor*t can be defined as 'the assistance for, and substantiation and corroboration of, an act or result of deciding'; typically this deciding will be a determination of the best approach. Several "layers" of decision support can be distinguished: the input information, the tools to assist particular decision making issues, and the overall system in which decision making is applied.

Decision support codifies specialist expertise in a way that allows its reproducible use by many. It integrates specific information about a site and general information such as legislation, guidelines and know-how, to produce decision-making knowledge in a way that is transparent, consistent and reproducible.

The wide range of existing DS varies from simple diagrams derived from standards or regulations, to software based systems. Applications have been developed for contaminated site management, involving the characterisation of contamination, risk assessment phases, risk management, aftercare and monitoring. In the context of contaminated land management, the Working Group "Decision Support Tools" has been using a simple framework to classify DSTs based on four types of category:

1. Functional application. The functional application to contaminated land management describes whether the decision support is for risk management, reme-

diation, monitoring and aftercare, sustainable development etc. This deals with the issues that must be addressed to support the overarching decision. In practice, a number of DSTs address multiple decision criteria.

2. Analyses used. Several different techniques can be employed to assist environmental decision-making. In practice, many decision support tools use several of these techniques, or mixtures of different parts of them. For example, software tools might combine risk assessment and cost-benefit analysis techniques to generate risk maps, cost comparisons between remedial options and other decision information, such as optimal risk solutions.
3. Decision making role. The decision making role describes the type of decision making being supported, e.g. for managing a single site, or for prioritising a number of sites. This deals with the overarching decision being made at the site.
4. Nature of the product. The nature of the product describes whether the tool is written guidance; a "map" of some sort, a series of procedures or a software based system.

Conclusions

Contaminated land management is an important issue throughout Europe and the U.S.A. The need to develop techniques and approaches to improve the decision making process for reuse and/or remediation of contaminated lands is widely recognised. As a starting point, to improve communication on this topic, the following definition is offered. Decision support can be defined as: the *assistance for, and substantiation and corroboration of, an act or result of deciding; typically this deciding will be a determination of optimal or best approach*. The decision support process integrates specific information about a site and general information such as legislation, guidelines and know-how, to produce decision-making knowledge with the goal of being transparent, consistent and reproducible.

Finding sustainable technical solutions for contaminated problems is dependent on a range of parallel considerations. Decisions about which risk management option(s) are most appropriate for a particular site needs to be considered in a holistic manner. Key factors in decision making include: the driving forces for the remediation project, risk management, sustainable development, stakeholders' viewpoints, cost effectiveness, and technical feasibility / suitability.

While the risk management paradigm is broadly accepted by technical specialists and contaminated land professionals as the most appropriate decision making basis for contaminated land management, this acceptance is not universal for all stakeholders, particularly “lay” consultees.

All relevant stakeholders should be involved at the earliest possible stage of decision making. However, decision support techniques - like risk management techniques - are in their infancy.

A variety of techniques have been applied in commercial DST products, and yet others are under development. The most successful tools tend to be fairly specific, focusing on providing specialist support for niche decision making, for example determining sampling strategy. More general tools, for example for remedy selection, are less well developed and accepted. However, the major, and as yet unachieved goals, for decision support are to be able to:

- Consider sustainable development and risk management in a mutual and holistic way, and
- Support stakeholder engagement in a way that is robust and transparent, even to lay audiences

The challenge is very tough, because any decision support must not hamper efficient and cost effective decision making or cause excessive delay. A major concern of core stakeholders is that, by widening their considerations and their consultees, they run the risk of stalling the decision making process; or making it so difficult that, for instance, brownfield remediation becomes less attractive.

RECOMMENDATIONS

While DSTs are now widely used in contaminated land management for a number of decision making applications, there is a long way to go yet in providing robust, reproducible and accessible decision support for others. The principle areas requiring support are:

- Enabling a diverse and heterogeneous range of research projects applying different decision analysis tools to holistic approaches to contaminated land decision making (this work must include an integrated assessment of all three elements of sustainable development: economic, environmental and social).
- Providing a platform for the validation of decision support tools in Europe[2]. This should be related to practical decision making in the field and the measurement or estimation otherwise of the performance and effects of remediation work.
- Supporting the development of guidance, and perhaps ultimately some kind of support, for widening stakeholder engagement in contaminated land decision making, particularly involving "lay" stakeholders
- Supporting the provision of web based contaminated land information from the different Member States and the EC in a way that is accessible to, and can easily be found by, all who are involved in contaminated land management.

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[2] The US EPA has already implemented a programme for testing DSTs: the Environmental Technology Verification Program (ETV) - Sullivan *et al* .2000

1 INTRODUCTION

1.1 Background

Several billion EURO are spent in the EU, as are several billions of dollars in the USA each year on remediation of land affected by contamination. Decision-making, in the face of uncertainty and multiple and often conflicting objectives, is a vital and challenging role in environmental management that affects a significant economic activity. Although each environmental remediation problem is unique and will require a site-specific analysis, many of the key decisions are similar in structure. The large number of contaminated land problems with similar characteristics has led many countries to attempt to develop "decision support tools" (DSTs) that support the wide range of decisions related to contaminated land management and re-use using standard approaches. As part of the standardisation process, attempts have been made to codify specialist expertise into these decision support tools. The process of codifying procedures has also been found to be a useful activity for establishing and rationalising management processes.

The uses envisaged or desired for decision support include:

- Identifying realistic management choices;
- Integrating information into a coherent framework for analysis and decision making, discerning the key information that impacts decision making from the more basic information;
- Providing a framework for transparency (i.e. all parameters, assumption, and data used to reach the decision should be clearly documented) and ensuring that the decision making process itself is documented;
- Facilitating reproducible and transparent decision-making;
- Providing a consistent methodology to compare contamination issues at different sites and serve as a basis for setting priorities.

1.2 The Working Group "Decision Support Tools" Report

This report is a collation of information collected on a voluntary basis from a number of countries in Europe. The report is not intended to be definitive guidance on the selection and use of decision support tools. Rather it provides a general introduction to decision support and its applications for contaminated land management.

The intended audience for this report are all those concerned with the development and use of decision support techniques for contaminated land management and those seeking to learn more about decision support principles and techniques, particularly in Europe.

This report discusses the findings of CLARINET's Working Group "Decision Support Tools" work from 1998 to 2001. Over this period, the Working Group conducted an extensive survey of CLARINET countries to review both key factors for decision support and risk management, and to identify examples of decision support tools. These have been catalogued in a *Microsoft Access* database, which will be made available through the Internet (linked to the CLARINET web site *www.clarinet.at*). The Working Group "Decision Support Tools" has also developed a terminology for describing decision support and the tools used in this process, and made an analysis of key issues for decision making in contaminated land management. This framework has been developed in collaboration with colleagues from the NATO/CCMS Pilot Study on Remedial Action Technologies for Contaminated Land and Groundwater[3] (US EPA, 2000). It was also discussed at the workshop on Decision Support at the 2001 international "ConSoil" conference (BARDOS *et al.,* 2000).

The report reviews the Working Group's view of the principal decision making criteria for contaminated land management and remediation: driving forces for the remediation project, risk management, sustainable development, stakeholder satisfaction, cost effectiveness and technical feasibility. Chapter 3 reviews the practice of decision support, and techniques commonly used to provide analyses for decision making: environmental risk assessment, multi-criteria analysis, multi-attribute techniques, cost-benefit analysis, cost effectiveness analysis, life cycle assessment, financial risk management; and their acceptability in the decision making process. Chapter 4 (and Annex A) report on a survey of decision support issues carried out over 16 European countries by Working Group "Decision Support Tools", and introduces an on line catalogue of decision support tools. Chapter 6 discusses decision support in the context of the Risk Based Land Management concept developed by CLARINET (VEGTER *et al.,* 2002). The final chapters contain the reports conclusions and recommendations.

In this report, contaminated land is a general term to describe sites or wider areas of land where elevated concentrations of chemicals or other substances (contamination), usually resulting from man's use of the land, may exist. It focuses on contamination resulting from past practices, that is historic or legacy contamination. It does not consider decision support for radio-nuclide problems. A workshop on decision making approaches for the restoration of environments affected by radiological accidents was held in Brazil in September 1994 (IAEA, 2000), and remediation technology screening for this is discussed elsewhere (US EPA, 1996c).

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[3] The NATO/CCMS Pilot Study on Remedial Action Technologies for Contaminated Soil and Groundwater Phase 3 is a multi-national forum for the exchange of information on emerging remediation technologies and technology demonstration. The Pilot Study is an activity of NATO Committee on Challenges for Modern Society (Web site: *http://www.nato.int/ccms/info.htm)*

2 DECISION-MAKING ISSUES

2.1 Introduction

There are a number of factors that need to be considered in selecting an effective remediation solution to a contaminated land problem. These include considerations of core objectives such as risk management, technical suitability, practicability/feasibility, cost/benefit ratio and wider environmental, social and economic impacts. In addition, it is also important to consider the manner in which a decision is reached. This should be a balanced and systematic process founded on the principles of transparency and inclusive decision-making. Decisions about which risk management option(s) are most appropriate for a particular site need to be considered in a holistic manner. Key factors in decision making, illustrated in Figure 1, include: Driving forces for the remediation project, risk management, sustainable development, stakeholder satisfaction, cost effectiveness, and technical feasibility / suitability.

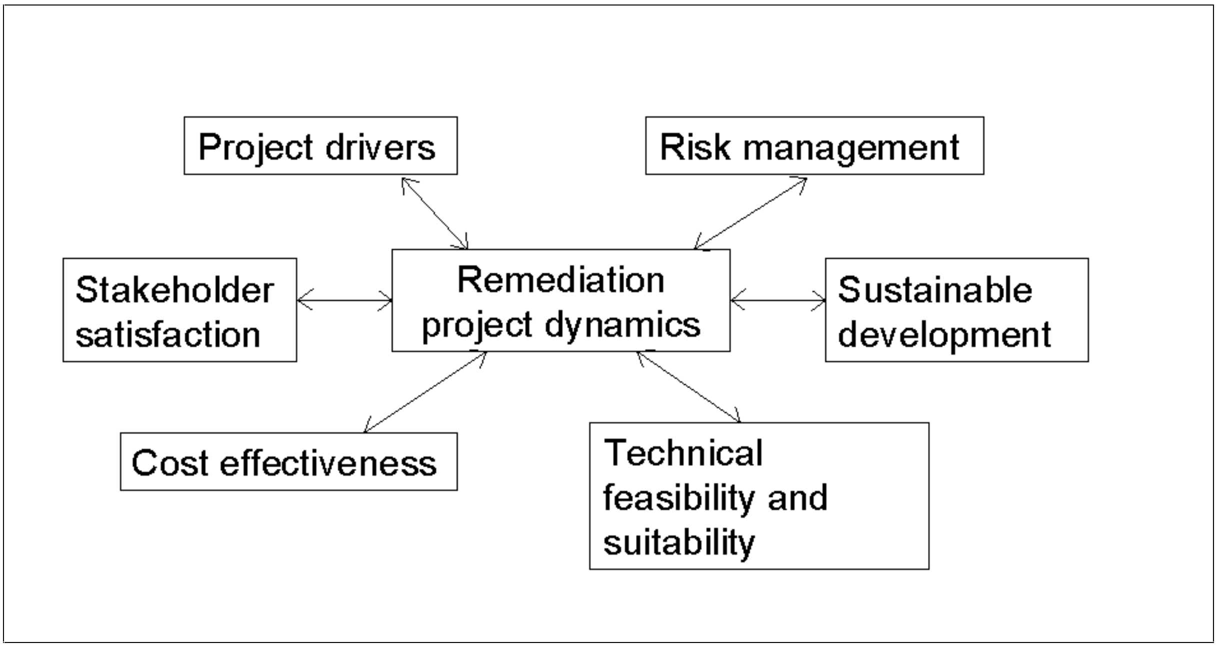


Figure 1: Dynamics for Technique Selection

2.2 Driving forces and goals for the remediation project

Most remediation work has been initiated for one or more of the following reasons:

- To protect human health and the environment. In most countries legislation requires the remediation of land which poses significant risks to human health or other receptors in the environment such as groundwater or surface water. The contamination could either be from “historic” contamination or recent contamination from an industrial process or during transport. Groundwater protection has in many countries become an important driver for remediation projects.

- To enable redevelopment. Remediation of formerly used land may take place for strictly commercial reasons, or because economic instruments have been put in place to support the regeneration of a particular area or region.
- To repair previous remediation work or redevelopment projects. Where a past remediation project has failed, or a redevelopment has been carried out with out adequate risk assessment / management, further risk management actions may be necessary. Both situations are often due to inadequate site investigation in the first instance.
- To limit potential liabilities. Remediation can take place as an investment to increase the potential value of land. Owners may perceive that a contamination on a particular site could potentially have an environmental impact, which might leave them liable to third party actions in the future.

2.3 Risk Management

A hazard is a substance or situation, such as contamination in the ground, that has the *potential* to cause harm (e.g., adverse health effects, groundwater rendered unfit for use, damage to underground structures, etc.) to a particular receptor. Risk is commonly defined as the probability that such a substance or situation will produce harm under specified conditions. Risk is a combination of two factors, the probability of exposure multiplied by the consequence of exposure (PCCRARM, 1997). In the context of contaminated land management, risk occurs when three components are present (a source, a receptor and a pathway for that receptor to be exposed to the toxic substances from the source). Thus, if a hazard exists and there is a chance that a receptor will come in contact the hazardous material through any pathway, there is a risk.

Risks to human health that may be caused by contamination are becoming a primary basis for supporting decisions on remediation throughout the EU and the USA (USEPA, 1989, USEPA, 1996a, USEPA, 1996b, CLARINET & NICOLE, 1998, FERGUSON *et al.,* 1998, FERGUSON & KASAMAS, 1999). In this process, risk assessment and the subsequent step of risk management are intimately related elements that form the basis for decisions on the fitness-for-use approach to land affected by contamination. The goal of risk assessment is to provide an objective, scientific evaluation of the likelihood of unacceptable impacts to human health and the environment (see also Box 1). The goal of risk management is to support decisions on risk acceptability for specified land uses and to determine the actions to be taken. It is the process of making informed decisions on the acceptability of risks posed by contaminants at a site, either before or after treatment, and how any needed risk reduction can be achieved efficiently and cost effectively (FERGUSON *et al.,* 1998, FERGUSON & KASAMAS, 1999). In this way, the over riding needs for the protection of human health and the environment can be clearly identified and work prioritised accordingly.

A risk-based approach has been adopted for the management of contaminated land in many countries (CLARINET & NICOLE, 1998, FERGUSON & KASAMAS, 1999). The assessment and management of land contamination risks involves three main components:

- The source of contamination (e.g. metal polluted soils, a leaking oil drum);
- The receptor (i.e. the entity that could be adversely affected by the contamination e.g. humans, groundwater, ecosystems; and
- The pathway (the route by which a receptor could come into contact with the contaminating substances).

Ecological Risks **Box 1**

In the United States and Europe, there has been a recent trend to include ecological risks as a decision variable for contaminated land management. The process of ecological risk assessment follows the same paradigm as human health risk assessment with the exception that the receptors are the plants and animals that inhabit the site. For example, guidance on which receptors should be considered in ecological risk assessment (USEPA, 1997, USEPA, 2000) and how to manage ecological risks (USEPA, 1999) has been published in the USA and the Netherlands (FERGUSON *et al.,* 1998, RUTGERS *et al,.* 2000). In Europe the pollutant linkage paradigm is used to consider human health and risks to other receptors such as ecosystems, groundwater and even buildings.

A *pollutant linkage* (see Figure 2) exists only when all three elements are in place. The probability that a pollutant linkage exists needs to be assessed. Risk assessment involves the characterisation of such a relationship, which typically includes: delineation of the source, measurement and modelling of fate and transport processes along the pathway, and assessment of the potential effect on and behaviour of the receptor. A consideration of risk must also take account of not only the existing situation but also the likelihood of any changes in the relationship into the future. From a risk management standpoint, remediation technologies are applied to the control of the source term and / or the management of contaminants along the pathway.

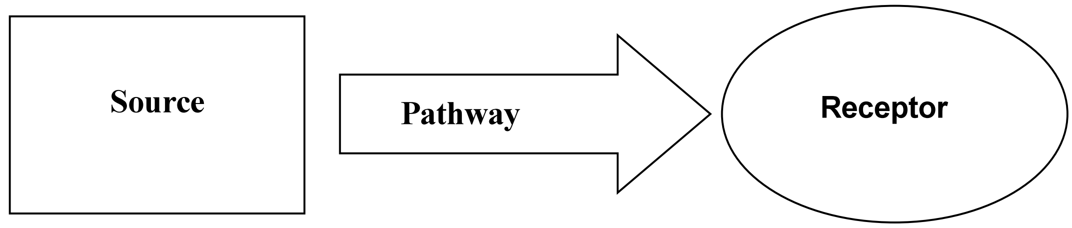
Risk management is the art of managing environmental contamination so that the risks posed by contamination are controlled or reduced to levels agreed upon by the regulators, problem owners, and other stakeholders. Risks should be assessed on a site-by-site basis to ensure that a site is suitable for its designated use.

In many European countries risk based decision making is primarily used for historic contamination. Where contamination takes place after agreement of Pollution Prevention and Control (PPC) remediation to pre-contamination levels may be required.

2.4 Sustainable Development

The concept of sustainable development gained international governmental recognition at the United Nation's Earth Summit conference in Rio de Janeiro in 1992. Sustainable development has been defined as: "…. *Development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (BRUNDTLAND, 1987). Underpinning this approach are three basic elements of sustainable development: economic growth, environmental protection and social progress.

Risk Reduction: breaking the pollutant linkage by …..



…. source reduction	***….. pathway management***	***…. modifying the exposure to the receptor***
Reducing, removing, modifying, or destroying the contaminant sources, (e.g. *in situ* bioremediation of diesel contaminated soil)	Preventing the further movement of hazardous substances *en route* to receptors, either by removing or destroying the contaminants or by preventing the transport pathway operating (e.g. by pump and treat or use of a physical barrier)	Protecting the receptor (e.g. installing an alternative water source, preventing site access, and restricting land-use).

Figure 2 Risk Management and Risk Reduction (NATHANAIL et al.*, 2002)*

At a strategic level, the remediation of contaminated sites supports the goal of sustainable development by helping to conserve land as a resource, preventing the spread of pollution to air, soil and water, and reducing the pressure for development on greenfield sites. However, remediation activities themselves have their own environmental, social and economic impacts. On a project-by-project basis, the negative impacts of remediation should not exceed the benefits of the project.

Remediation objectives typically relate to environmental and health risks and perhaps performance of geotechnical / construction measures. These may form part of a larger regeneration project with social and economic aims, such as attracting inward investment. What is realisable, and the approaches that can be taken, will be subject to certain site / project specific boundaries, for example the time and money available for the remediation works, the nature of the contamination and ground conditions, and the site location. The objectives that can be realised by remediation works represent a compromise between desired environmental quality objectives and these site-specific boundaries. This compromise is reached by a decision making process involving several stakeholders. This decision making process is often protracted and costly. The objectives set can be said to represent the *core* of the remediation project[4]. Remediation processes are then commissioned to achieve these core objectives. Good practice is for a number of remedial alternatives to be selected and compared, which have the potential to meet the core objectives.

However, the core objectives typically do not consider the overall environmental, economic and social effects of the remediation work to be carried out, i.e. they do not address its overall value in the context of sustainable development. For example, the overall environmental value of a project will be a combination of both the improvements desired by the core objectives, and also the wider environmental benefits and impacts of the remediation work, as illustrated in Figure 3. These wider effects are not considered by the core objectives, and so can be described as "**non-core**". A similar analysis can be made for the overall value to social progress and the overall value for economic growth. The overall value in the context of sustainable development is the combination of these overall environmental, social and economic values, as illustrated in Figure 4.

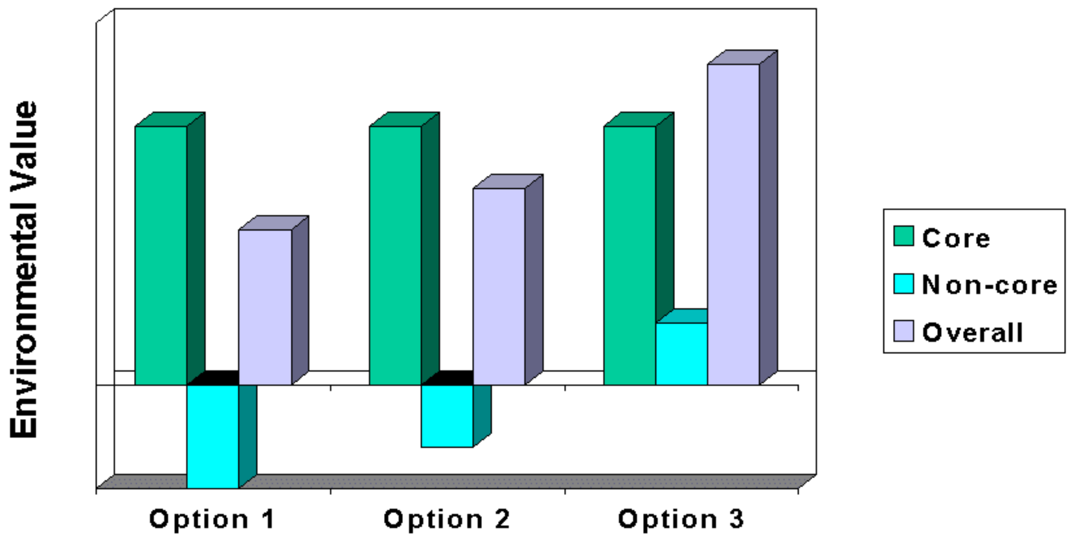


Figure 3: The Overall Environmental Value of a Remediation Project is the Sum of Environmental Outcome of the Core Objectives and its Non-core Effects

In many countries the wider effects of remediation projects are becoming increasingly important in decision making, both as a result of general policy moves to support sustainable development, and as a result of specific pressures, for example:

[4] While achieving environmental quality objectives will normally underpin any project dealing with contaminated land, the desired quality objectives selected may be driven by a combination of other technical criteria and also third party non-technical perception of risk.

- Pressure to consider a broader range of environmental effects - avoidance of transfer of pollutants, and avoidance of nuisance to local neighbourhoods;
- Pressure to consider a broader range of economic effects - need to demonstrate value for money, and particularly the added value of projects for example for investors and planners; and
- Pressure to consider a broader range of social consequences - to stimulate greater public and community interest in projects.

It is concerns about wider environmental effects (including resource use) that have hitherto been leading the debate about “sustainable remediation”, some examples are given in Table 1, and some examples of decision support tools for assessing wider environmental effects are described later in this report. Some examples of wider economic and social effects are given in Table 2.

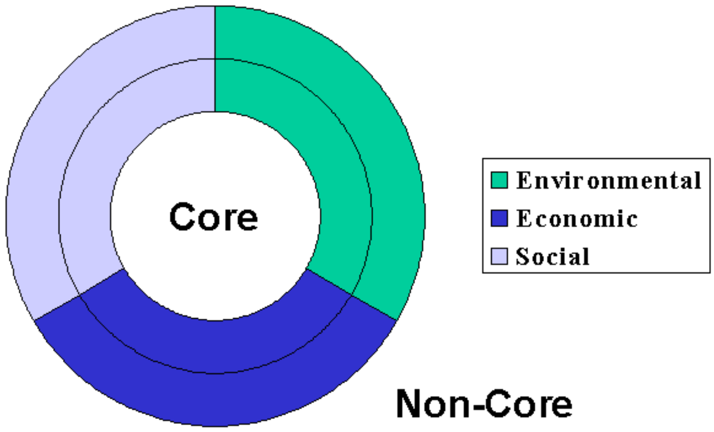


Figure 4: A Model For Assessing the Overall Value of a Remediation Project from a Sustainable Development Context

Table 1: Some Examples of the Wider Environmental Effects of Remediation Activities

Negative	**Positive**
Traffic	Restoration of landscape "value"
Emissions (e.g. volatile organic compounds)	Restoration of ecological functions
Noise	Improvement of soil fertility (e.g. for some biological remediation techniques)
Dust	Recycling of materials
Loss of soil function	
Use of material resources (e.g. aggregates) and energy	
Use of landfill resources	

Table 2: Examples of Wider Economic and Social Issues

Economic Consequences	Social Consequences
Impacts on local business and inward investment Impacts on local employment Occupancy of the site	Removal of blight Community concerns about remedial approach Amenity value of the site Provision of infrastructure[5]

From a practical viewpoint, decision making for remediation projects tends to be sequential. Firstly the core objectives of a project are set (see Box 2). Then a shortlist of remedial approaches capable of achieving those core objectives is considered. It is typically at this point that non-core or wider impacts and benefits are considered, with a view to selecting the remedial approach which, on balance, has the most benefits and the lowest detrimental impact. Of course the final selection will depend on cost, hence the current international interest in cost benefit tools for decision making.

It is worth noting in most cases some of these "wider" environmental, economic and social effects will be considered during the "core" of the decision making process. Which factors are considered as "core" will vary from project to project, depending on the views and needs of the stakeholders who are at the centre of the decision making for that particular project.

If the undesirable impacts of these remediation processes exceed the desired benefits of the core objectives, the core objectives may need to be re-evaluated. If proper risk management procedures have been followed, along with a thorough cost benefit analysis and stakeholder consultation (see Section 2.5), the risks of such a situation arising should be minimised.

At present there are no generally agreed means of carrying out sustainability appraisal for remediation projects. Although approaches to assessing the wider impacts of individual elements of sustainability (e.g. wider environmental effects) are under development in several countries, a truly integrated approach has yet to be found. There is some way to go before an international consensus can be reached about sustainability appraisal, in the way that agreement has emerged about the principles of risk assessment and risk management. This is hardly surprising given the complex interplay of economic, environmental and social factors that affect and are affected by a remediation project.

This "core / non-core" model is sequential in its nature, in that the core decisions, which reflect the envisaged use of the site, are made first. Afterwards the wider ef-

[5] For example in the UK a developer may offer the provision of infrastructure as a consideration in its planning and development negotiations with a local authority.

fects of the remediation process are considered, and preferably, the reasonable cost option with the lowest wider impacts is selected. While this model describes decision making for sites where a firm end-use is envisaged, it is not appropriate as a decision making framework for the restoration of aquifers. Furthermore, in situations where end-use is not "fixed", there may be greater flexibility to consider wider social, economic and environmental effects and risk management in parallel.

Core Objectives **Box 2**

Core objectives are those remediation objectives that need to be achieved in order to enable regulatory compliance, redevelopment, repair, limitation of liability. Typically these are to reduce risks to human health, surface and groundwaters, ecosystems and construction, to reduce liabilities, or some combination of all of these factors. They are reached after consideration of site specific factors and constraints, and taking into account the views of the stakeholders for that site.

Non-core considerations

Non-core considerations are the supplementary effects of, and/or desires for a remediation project that are not addressed by its core objectives. These can include wider environmental effects (for example use of energy and resources, emissions, waste generation), wider economic effects (regeneration, removal of stigma) and wider social effects and community concerns.

Aquifers typically pass through many land boundaries and may be subject to a number of pollutant inputs. There is a desire to protect aquifers as a resource, even if they are not in use, or do not present a risk to human health. In this case the groundwater is both pathway and receptor.

It has been argued that for aquifers the overarching value to society of the remediation effect desired, compared with the likely costs of achieving it, should be the fundamental decision making criterion for aquifer restoration (Environment Agency, 2000). In other words sustainable development criteria should be at the "core" of decision making about aquifer remediation. For example, any action to improve an aquifer below an urban area would be likely to be a massive undertaking, and have a direct effect on many site owners. It may be that in the case of some urban aquifers the resources that would need be spent on remediation, assuming it was technically feasible, are out of all proportion to the value to society of restoring that aquifer as a resource (BARDOS, 2000).

In many countries there are large brownfield areas for which there is no immediate economic driver for redevelopment. Often these are associated with primary and extractive industries that have closed down (BARTON, 2000, HANDLEY, 1996). The local communities in these areas can be deprived compared with the rest of the country concerned. In these situations restoration of land may be supported by Public Sector funds as a means of regenerating local communities in economic terms and alleviating social problems (Groundwork, 2001). Increasingly regeneration of these areas may not be able to rely solely on attracting new economic activity through inward investment (BARTON, 2000 and 2001). In these situations land restoration planning can therefore be divorced from firm views of end use. Then land restoration and sustainable development should become parallel as opposed to sequential considerations. For example, restoration of land for community use may become a tool for social regeneration (Groundwork, 2001), or the remediation process itself could be connected with a return of land to some form of economic re-use, for example biomass production (BARDOS *et al.,* 2001).

2.5 Stakeholder Satisfaction

The stakeholders at the core of the decision making process for site remediation are typically the site owner and/or polluter, whoever is being affected by pollution, the service provider and the regulator and planner. However, other stakeholders can also be influential (PCCRARM, 1997, SNIFFER, 1999), such as:

- Site users, workers (possibly unions), visitors;
- Financial community (banks, founders, lenders, insurers);
- Site neighbours (tenants, dwellers, visitors, local councils);
- Campaigning organisations and local pressure groups;
- Other technical specialists and researchers.

Stakeholders will have their own perspective, priorities, concerns and ambitions regarding any particular site. The most appropriate remedial actions will offer a balance between meeting as many of their needs as possible, in particular risk management and achieving sustainable development, without unfairly disadvantaging any individual stakeholder. It is worth noting at this point that for some stakeholders, the end conditions of the site are likely to be significantly more important than the actual process used to arrive at that condition. Such actions are more likely to be selected where the decision-making process is open, balanced, and systematic. Given the range of stakeholder interests, agreement of project objectives and project constraints such as use of time, money and space, can be a time consuming and expensive process. Seeking consensus between the different stakeholders in a decision making process is an important factor in helping to achieve sustainable development.

While this report is not intended as guidance on shareholder involvement, it is generally beneficial to involve all stakeholders believed to have a view early in the decision-making process. It is almost always counter-productive to present a solution as a *fait accompli* to a previously unconsulted stakeholder.

However, stakeholder involvement is not without problems. A joint CLARINET - NATO/CCMS Pilot Study work shop was held at the 7th International FZK/TNO Conference on Contaminated Soil, Leipzig, September 2000 (BARDOS *et al.,* 2000).

This workshop concluded that[6] while wide stakeholder involvement was important as early as possible, to facilitate involvement and avoid adversarial positions; such involvement constitutes a series of challenges for decision making. The challenges are:

- The large number of stakeholders who might need to be involved;
- How to best express the "technical" point of view in a process that is often to a large extent political, economic and social; and
- How to "support" the technical specialists so they can recognise the social and political dimensions of their efforts and identify stakeholders to be involved at an early enough stage – and facilitate the necessary communication.

Decision support tools can be useful for communicating with interested stakeholders. There is a counterpoint to this: too much simplification/distillation can be misleading and/or patronising. Stakeholders may then not able to see a part of the assumptions that led to a decision, and/or feel alienated from the decision making process. While it is important that information presented is understandable, otherwise it is not "available", there is a fine line between making information available and not being "patronising".

2.6 Costs and Benefits

The aim of the assessment of costs and benefits is to consider the diverse range of impacts that may differ from one proposed solution to another such as the effect on human health, the environment, the land use, and issues of stakeholder concern and acceptability by assigning values to each impact in common units. Deciding which impacts to include or exclude from the assessment is likely to vary on a site-by-site basis. In many instances, it is difficult to assign a strictly monetary or quantitative value to many of the impacts. Hence, assessments can involve a combination of qualitative and quantitative methods (see Section 3.5). It is also useful to include a sensitivity analysis step, particularly where this encourages decision-makers to question their judgements and assumptions through the eyes of other stakeholders.

Any good practice approach to the selection process for the remediation of contaminated sites needs to consider the costs and benefits attributable between different options. Many protocols have been developed, as decision support tools, to make such considerations, systematic, transparent and to a lesser or greater extent, reproducible. Examples of such decision support tools are detailed in Chapter 5.

The performance of remediation represents a significant source of financial risk, which, if ignored or mismanaged, can have a serious effect on the commercial success of a project or business. Financial risk management tools (as opposed to environmental risk management) are increasingly being applied to contaminated land

[6] Previously unpublished

remediation decision making, in particular in a commercial redevelopment context. Financial risk management relies heavily on accurate forecasts of the probability that remediation will fail to meet its objectives as well as the associated financial implications (FINNAMORE, 2000). It has been suggested that such modelling should be interactive, allowing a user to develop optimal scenarios from his or her perspective (IZATT, S., Personal communications, 2001).

2.7 Technical Suitability and Feasibility

A *suitable* technique is one, which meets the technical and environmental criteria for dealing with a particular remediation problem. The issues that affect the suitability of a remediation technology for a particular situation are:

- Risk management application;
- Treatable contaminants and materials;
- Remedial approach;
- Location;
- Overall strategy;
- Implementation of the approach; and
- Legacy.

These are outlined further in Table 3. However, it is possible that a proposed solution may appear suitable, but is still not considered *feasible*, because of concerns about:

- Previous performance of the technology in dealing with a particular risk management problem (in the particular region where the technique is being considered);
- Availability of services (e.g. water, electricity) and facilities on a site;
- Ability to offer validated performance information from previous projects;
- Expertise of the purveyor;
- Ability to verify the effectiveness of the solution when it is applied;
- Confidence of stakeholders in the solution;
- Its duration;
- Its cost; and
- Its acceptability of the solution to stakeholders who may have expressed preferences for a favoured solution or have different perceptions and expertise.

In general, concerns over feasibility / practicability tend to be greater for innovative remedial approaches, even if these have long standing track records in other countries. However, it is often these innovative solutions that are seen to offer more in terms of reducing wider environmental impacts and furthering the cause of sustainable development.

Table 3: Factors Affecting the Suitability of a Particular Remediation Technology (adapted from NATHANAIL et al., *2002)*

Risk management application	• *Source control,* remedial action either to remove, or modify the source of contamination • *Pathway control* remediation to reduce the ability of a given contaminant source to pose a threat to receptors by inhibiting or controlling the pathway by modifying its characteristics • *(Receptor control*)
Treatable contaminants and materials	• Contaminant(s) • Concentration range • Phase distribution • Source and age • Bulk characteristics • Geochemical, geological and microbiological limitations
Remedial approach	Type of remediation system (containment, treatment: biological, chemical etc) each of which has its own particular strengths and weaknesses, for example based on space requirements
Location	Where the action takes place (e.g.: *in situ* or *ex situ*, on site or off site);
Overall strategy	For example: • Integrated / combined approaches • Active versus passive measures • Long term / low input (”extensive”) versus short term / high input (”intensive”) • Use of institutional measures (such as planning controls combined with long term treatments)

Table 3: Factors Affecting the Suitability of a Particular Remediation Technology (Adapted from NATHANAIL et al., *2001) (continued)*

Implementation	Implementation encompasses the processes of applying a remedial approach to a particular site and involves: • Planning remedial operations • Site management • Verification of performance • Monitoring process performance and environmental effects • Public acceptability and neighbourhood relationships (risk communication and risk perception) • Strategies for adaptation in response to changed or unexpected circumstances, - i.e. flexibility • Aftercare These activities are significantly different for different choices of remediation technique, and are likely to be a significant cost element for a remediation project
Legacy	**Destruction** may be result of a complete biological and/or physico-chemical degradation of compounds, for example at elevated temperatures by thermal treatments[7]. **Extraction** of contaminants may be brought about by (a) excavation and removal (b) some process of mobilisation and recapture or (c) some process of concentration and recovery. **Recycling** might be the "ultimate" form of removal. **Stabilisation** describes where a contaminant remains *in situ* but is rendered less mobile and or less toxic by some combination of biological, chemical or physical processes.

2.8 Combining Other Decision Factors with Risk Management

Typically risks to human health risk and other receptors are used as a first basis for setting remediation goals. Other decision factors such as technical feasibility and cost are used to select from amongst different remedial alternatives. In cases when the desired level of protection for receptors can not be attained due to costs or technical difficulties in remediating the site, treatment targets may be revisited on a site specific basis. In rare cases, if the risks are viewed to be large enough, extreme measures to reduce the exposure pathway may be taken (e.g. evacuation).

[7] Destruction may be incomplete, emissions and wastes are an outcome of all approaches, hence consideration of the fate of compound should be considered during risk management and selection of remedial approach

In circumstances where contamination levels exceed general guideline values only slightly, a site specific risk assessment may be used to achieve a better resolution of risk management needs. If such a site specific risk assessment indicates that the benefits of risk reduction are only marginal, then cost benefit analysis can be used as a tool to assess the benefits of the marginal risk reduction required, against the costs and environmental impacts of achieving this risk reduction. In the context of remediation driven by a regulatory requirement, this cost benefit analysis may be a reasonable argument to set more "appropriate" measures for the contaminated site. For sites being remediated as a part of a redevelopment project or for commercial reasons such as reducing potential liabilities or enabling a property transaction, this cost benefit analysis can be complex. For example it needs to take into account the perceptions of the different actors in the property transaction. A potential buyer may not be willing to take a site on, even if a regulator has agreed the case for remediation is marginal. The buyer may perceive a long term commercial risk from the contamination, arising from, for instance, the possibility of a future change in regulatory perspective, the possibility of the site being blighted and loosing value, or the possibility that the data the decision has been made on is deficient in some way, so that in future further investigation and even a "repair" might be needed.

Not all contamination problems are necessarily considered in the sequence of setting risk management goals, and then determining remedial methods. In some cases (as described in Section 2.4) a broad array of sustainable development needs may be considered in parallel with risk management.

The view of core stakeholders, of course, controls the risk management decision making. However, the views of other stakeholders can also be critical. For example, if a technically feasible solution that protects human health and the environment to within regulatory limits at an acceptable economic cost is available, but the stakeholders do not accept this solution, then remediation should not proceed until concerted efforts to find solution agreeable to all parties have been made. If remediation proceeds, it is at the risk of having substantial opposition that may cause the efforts to be stopped or modified, which can lead to increased project costs. Examples of decisions that were acceptable from a technical and regulatory perspective were not acceptable to all of the stakeholders are relatively common in waste management, and seem likely to be of increasing significance for land remediation. For example, siting of new waste disposal facilities and the use of the incineration as a treatment option have been prevented because of stakeholder concerns.

In circumstances when not all stakeholders readily agree to a proposed solution, overall agreement depends on maximising the issues where common ground can be found, and for the others where finding a way forward where there is an agreement to disagree, otherwise the project is stalled. In cases where there is a regulatory driver for the project the "core" stakeholders are obligated to reach agreement, even if this enforced. A stalled regeneration project or an enforcement position are not desirable for many reasons, not least their costs and the resulting delays. The Network for Industrially Contaminated Land in Europe (NICOLE) concludes that "Those involved in contaminated land management recognise that the actions that are finally agreed are the result of a process of negotiation, effectively bargaining, which weighs the interests of different stakeholders" (NICOLE, 2001).

However, while it is imperative that as wide a range of stakeholders views are considered and where possible incorporated into the decision-making process, it is equally important not to pursue an option that is not commensurate with the problem in hand.

3 DECISION SUPPORT

Decision making for environmental contamination problems involves integration of knowledge from many disciplines. There is also a range of contexts in which decisions have to be made, for example compliance with a regulatory need, enabling redevelopment, reducing liabilities, registering and mapping sites, and/or prioritising use of resources.

Types of management problems might include: dealing with a contaminated site; prioritising a number of contaminated sites; or setting an overall sustainable development strategy for contaminated land management in a particular region. For each problem-solving role, different functional applications for decision support can be discerned. For example in managing an individual site, decision support might be required for: site investigation, risk assessment, risk management, aftercare, monitoring, evaluating wider impacts (environmental, economic, etc.) and sustainability appraisal.

Each has their own suite of decisions. For example, consider the suite of decisions that have to be made when considering remediation as part of a redevelopment process for a particular site.

In a typical analysis, the first step in the process is to collect information about the site such as location of spills or disposal areas, the type of contamination that can be expected and the amount of contamination (area, volume, or concentrations). Based on this information, decisions pertaining to collection of site-specific data on the nature and extent of contamination must be made. These types of decisions include the number, frequency, and location of samples balanced against the cost of collecting and analysing the samples and the value of additional data in arriving at a more robust decision.

Based on the initial site characterisation data, interpolation, extrapolation, and other modelling techniques are often used to estimate the contamination levels between measured data locations. This information is often used in human health risk assessments to guide decisions on the need for remedial action (including monitored natural attenuation). If remedial action is required, decisions pertaining to what areas to treat and what level of remediation is technically and financially achievable must be addressed.

Projections of contamination levels often have a high degree of uncertainty (i.e., only a few data points are available for estimating contamination over large regions). This uncertainty requires a decision on whether more data is needed to better define the region requiring remediation or whether to select a different remedy or design the remediation plan differently.

After remedial actions are complete, monitoring is often required to demonstrate the effectiveness of the remediation. This requires further decisions on what and where to monitor, and the duration of monitoring. A similar list of questions could be generated for other management processes or functions, such as prioritising development of several contaminated sites or assessing financial risks for sustainable development.

It is apparent that there are many specialist underpinning decisions (e.g., what risk levels are acceptable, what to sample, when to sample, what technologies should be used, etc) that need to be made before general decisions on the reuse of contaminated land can be made. Table 4 lists some of the supporting secondary decisions that need to be made to make the overarching decision on contaminated land management. Table 4 is illustrative list rather than an exhaustive list.

It is unlikely that any single person will have the knowledge to perform, unaided, all of the analyses required in supporting all of the decisions pertaining to the management of land contamination. Typically, a number of people with different areas of expertise are involved in interpreting basic information and providing it in a form useful for others with less expertise in a given area.

Decision support assists the contaminated land decision maker in one or more of the following ways:

- Translating the findings of specialised analyses into a form that is usable by decision-makers with a more general range of skills;
- Carrying out specialised analyses, either as a labour saving device, as an alternative to hiring a specialists for each analysis or both;
- Ensuring that analyses used in decision making are made in a manner that is reproducible and transparent.

Table 4: Example Questions for Decision Support (BARDOS et al., *2000)*

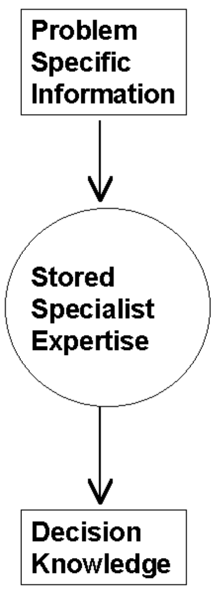
Category	**Example Issues**
Risk Management	What risks may be posed by the contamination now and in the future (considering the sources, pathways and receptors and the significance of any linkages found)? What risks may result to workers as part of the remediation effort? For affected aquifers: their use and importance How can the risks best be managed? What are the regulatory criteria? What are the success criteria for the proposed remediation? Fate of contaminants Is there contamination entering the site from outside?

Table 4: Example Questions for Decision Support (BARDOS et al., *2000) (continued)*

Category	**Example Issues**
Technical Suitability / Feasibility	What specific contamination properties need to be addressed (e.g., free-phase organics, concentration ranges, speciation, sorption, toxic by-products, etc.)? How will remediation performance be measured? The availability and suitability of existing information for the site What time-scale is appropriate for remediation? What is the site availability for remediation works? What is the size of the site? What space is available for remediation operations? What are the current uses of the site? Ground conditions (materials, surface conditions, geology) Does the remediation need to cope with underground structures, surface demoloition, and/or work under buildings? Hydrogeology and groundwater monitoring Site access, security, services and facilities
Stakeholders' / Third Parties' views	What are the adjacent properties, who owns them and how are they affected? How will stakeholder communication be managed? What impact will the remediation have on site occupants and neighbours? Restrictions: e.g. planning, covenants, other contract terms, confidentiality
Sustainable Development	What impact will remediation have on other environmental compartments and are these acceptable (wider environmental value)? Wider economic value Wider social value Use of resources, including land resources, for example: what in relation to the long-term use of the site and how this is to change
Costs	Capital and operating costs Balance of costs to benefits/cost-effectiveness Funding Restrictions: insurances, liabilities, securities

An emerging application of decision support techniques is to widen participation in the decision making process, particularly for encouraging the participation of lay audiences, for example local communities.

Hence, decision support methods codify expert knowledge and know-how into a “stored"” method or process. The “stored” process could be written guidance on how to address a problem or software that helps to analyse the problem. Decision support methods make use of problem specific specialised information, using some kind of “stored” expertise to extract from that specialised information a concise representation of the key decision making issues for that particular problem, as illustrated in Figure 5. A more theoretical discussion of decision making processes in the context of land remediation, and a practical case study is provided by OKX & STEIN, 2000.



For example, consider the decision to select between two different remedial alternatives. The analyst would start with knowledge about the nature and extent of contamination. This information would be used to estimate the volume requiring treatment based on the “stored” knowledge (e.g., best practice, regulatory limits, cost data, data management and analysis techniques including interpolation, etc.). This information could then be used as the basis for the selection and/or design of the remedial options. For example, “stored” information on typical remediation costs could be used to estimate likely project costs. Other knowledge such as the degree of uncertainty in the volume requiring remediation and the reliability of the different remedial options could also be evaluated. The decision maker would then be presented with information on costs, probability of success, and what is being treated for the money spent to support the decision on a course of action.

Figure 5: The Decision Support Process

Hence a decision support method necessarily includes interpretative steps which can be applied to different sets of problem specific data or information. This “stored” knowledge can be used again and again. Herein lies one of the strengths of decision support tools, that they facilitate reproducible decision making, or at least reproducible analyses as a basis for decision making. A good decision support tool should also be robust, i.e. its “stored knowledge”, should be based on both the state of the art, and a consensus of specialists in its particular field. A good decision support tool should also be transparent, both by ensuring that the information input, the stored knowledge applied, and the decision making information provided are care carefully documented, along with any assumptions made and any possible limitations on the output. Finally, and most obviously, decision support widens the range of tasks that contaminated land professionals are able to carry out.

These strengths also, unfortunately, contain the seeds of the weaknesses of decision support methods. They are necessarily limited in flexibility and scope because it is rarely practical to analyse and cater for the full range of circumstances a user may need to deal with. They are always at least to some extent subjective, in that they are based on an underlying set of assumptions and will be biased by the particular perspectives of their developer. These perspectives might be, for example, the contaminated land policy of the country the in which decision support method was developed. Finally, if a decision support method does contain an error of some kind, this error will be propagated on a systematic basis each time the decision support method is used.

Consequently validation of decision support methods is a crucial step prior to making them available, and indeed a fundamental principle throughout the development of a decision support method. Such validation would typically include: checking that a suitable range of problems is catered for, ensuring that its interpretative steps are adequately peer reviewed, ensuring that the interpretation is acceptable to a wide range of stakeholder groups across whatever region the tool is to be used in, and finally testing its prognoses against alternative techniques, such as conclusions of independent specialists using the same input information and data. For example, to address the issue of quality of decision support software tools, the US EPA extensively tested six different tools on existing environmental contamination problems as part of their Environmental Technology Verification program (SULLIVAN, 1999a, b, SULLIVAN, 2000 a, b, c, d).

While the focus of this report is about software and written decision support tools, it is salient to note that a decision support method might also be a technique or collection of techniques, such as a consultation process. For example, the UK's "Changing Places Programme" was a multi-million EURO programme of restoration of more than 20 sites. It was carried out by a charitable organisation, Groundwork, using a mixture of Private and Public Sector funding. A key goal of this programme was to solicit and maintain community interest and participation in the decisions being made for land restoration. A variety of techniques to identify and engage local stakeholders, and to gain their input and commitment to the restoration projects. Typically these involved a process of identifying who ought to be consulted, outreach (usually via local schools) and presentations and workshops based around scale models of possible restoration goals. Software packages and guidance publications were of no use to this decision making process, they could not substitute for a structured programme of engagement over time (Groundwork, 2001).

Figure 6 shows a conceptual framework for information use in decision making and emphasises that the "system" is the totality of the decision process. This framework follows the view of the USA Environmental Technology Program (SULLIVAN *et al.,* 1997) in that models are not considered as decision support, but rather as input. Tools, techniques, trees and maps can represent one or more component parts of the decision making process, whereas a “system” supports the totality of a particular decision making process.

Decision support exists within three broad sets of boundaries: the range of technical possibilities; the level of detail that is appropriate and the legislation and regulations pertinent to the decision. An effective decision support tool needs to offer options that are both technically and economically feasible and permitted by regulators, the public and other stakeholders. In a practical sense, it is equally important that the level of detail is appropriate. The level of detail provided to the decision-makers must be sufficiently explanatory, but it must also be readily understood. The implications of excess detail are not only reducing the helpfulness of the decision support, but also increasing the cost of the decision support knowledge. Figure 7 illustrates the needs for different levels of detail for different activities in contaminated land management.

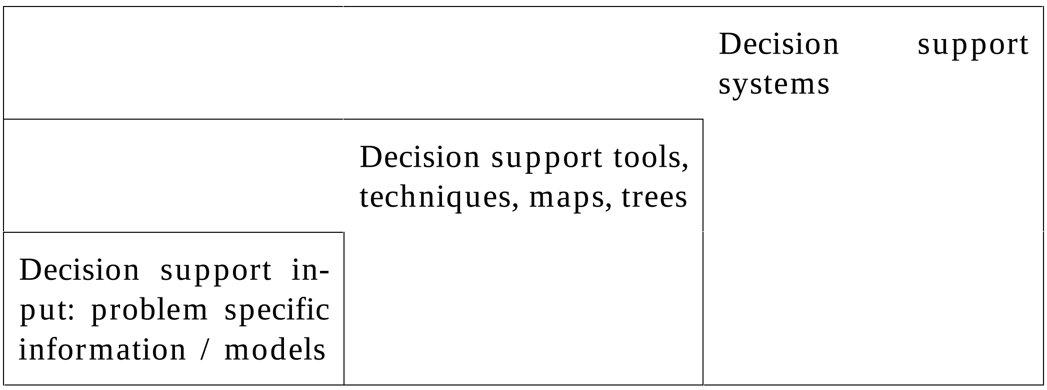


Figure 6: Decision Support Information, Tools and Systems

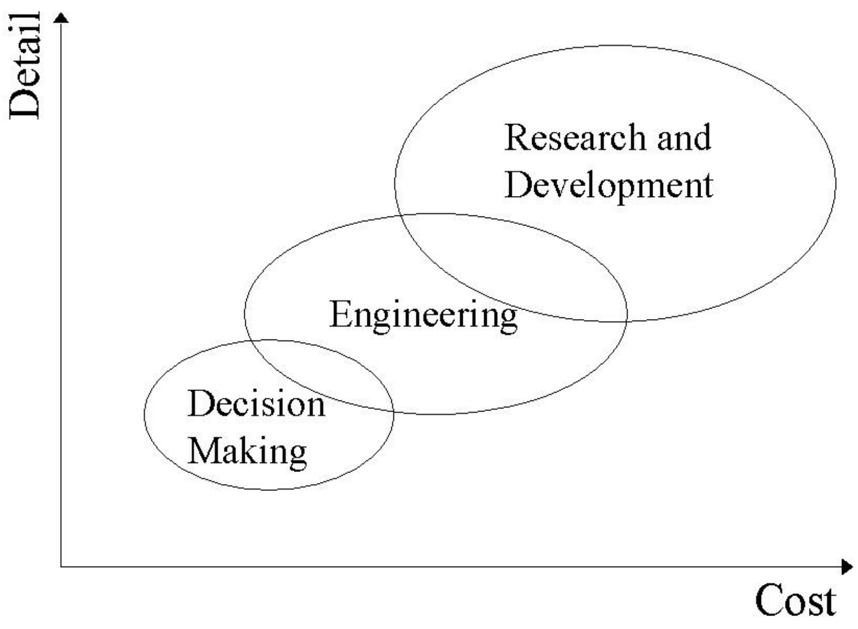


Figure 7: Level of Detail and Information Cost

Decision support methods serve different “classes” of users. For example, some decision support methods are tools used by specialists, others might be used on a research basis, but perhaps the majority are used by contaminated land management professionals, for example: site owners, consultants, contractors, regulators.

A further concern that has been expressed, for example at the NATO/CCMS[8] Pilot Study’s special session on Decision Support (US EPA, 2001), is that decision support methods might make contaminated land problems seem easier to solve, encouraging decision making by individuals with inadequate professional qualifications. In most countries the different stakeholders at the core of the decision making process would appear to safeguard against such inappropriate use of decision support methods. For example, the regulator would question a poor decision by a consultant. Nonetheless, by lowering the “entry level” in general for contaminated land decision making, it is conceivably possible that decision support analyses might be misapplied. It therefore seems beholden on decision support method developers to adequately explain not only the functions of their products, but also their requirements in terms of expertise and their limitations. Table 5 summarises the advantages and disadvantages of using decision support techniques, found by the NATO/CCMS Pilot Study Special Session on Decision Support.

3.1 Typical Applications of Decision Support

Decision support methods help to make the decision making process transparent, documented, reproducible, (hopefully) robust and provide a coherent framework to explore the options available.

DSTs are used to support all of the key steps of the contaminated sites management process (from investigation through remediation and monitoring), with different DST applied to different steps or groups of steps. A few examples of these types of applications include:

- Providing a visual depiction of the extent of contamination as a means of highlighting areas of concern (problem and risk identification);
- Providing a technical basis for sample selection based on the existing data and the probability of exceeding a regulatory limit (problem investigation);
- Defining the volume of remediation required as a function of the confidence in meeting regulatory goals (For example, one could remediate only at sample locations that are above the limit. In this case, one would have little confidence that the entire site is clean. On the other hand, one could remediate the entire site if any single measured value was above the limit. This would lead to high confi-

[8] NATO/CCMS Pilot Study Evaluation of Demonstrated and Emerging Technologies for the Treatment and Clean Up of Contaminated Land and Groundwater. Phase III

dence that regulatory goals were met, but would be very expensive in most cases).

- Providing estimates of current and future human health risks as a function of the amount of remediation (detailed risk evaluation); and
- Providing cost-benefit analysis between competing remedial technologies (selection and implementation of remedial measures).

Table 5: Advantages and Disadvantages of Decision Support Tools (DSTs)

Advantages	Disadvantages
• The major advantage of using appropriate DST's is in help ensure the decision making process is robust, consistent and reproducible. • DSTs provide a method to analyse multiple scenarios. Consideration of a range of scenarios can increase the confidence when making a decision. • DSTs can be used to optimise contaminated land management (leading to lower costs). • Some DSTs can incorporate uncertainties into the decision framework. Decisions in contaminated land management are always made with some degree of uncertainty. Addressing this directly can enhance the decision making process. For example, DST can estimate the volume and costs of remediation required as a function of the degree of certainty in achieving human health risk goals or financial risks. This permits the decision to be based on the problem holder's aversion to failure. • DSTs can provide means to document all parameters and assumptions used in the analysis for a particular decision (see subsequent discussion of data management systems). • DSTs can improve communication between various stakeholder groups. • DSTs can be used as an educational tool. For example, the effects of changing parameters on the decision variable can be demonstrated. • DSTs can improve the transparency of the process through documenting assumptions and explaining the approach used to reach a decision.	• Gaining acceptability of the tool with all stakeholders is often difficult. It takes time and effort to educate other stakeholders on the use of a tool. If the tool is perceived to be a 'black box' stakeholders not involved in the application of the tool will not trust the results. • A common approach to DSTs is to provide output in the form of a single set of decision variables, and in some cases a single variable or index. In reporting only the decision variable the rationale behind its algorithms, supporting data and assumptions may not be understood. The effect of this reporting approach may be to perpetuate a lack of trust of the analysis, which may be viewed as "black box" information. This is likely to be a particular problem where DSTs are used or interpreted by "non-experts". It also flags the need for clarity and good supporting information on the part of the system designer AND user. • Decision support tools must be maintained to keep current. For example, for remedial options as new cost data are obtained they must be incorporated into the appropriate database for use in the analysis. In addition, human health risk decision support tools often have a database for risk parameters. These parameters are continually being updated to reflect the latest scientific findings. • Garbage In – Garbage Out. A decision support tool is only as good as the data and assumptions used to perform the analysis. The assumptions include not only those used to develop the DSTs, but also those used in the conceptual model of how to represent the problem. Therefore, the analyst should be trained in the use of the tool and in the approach to represent the contamination problem.

Overarching decision support *systems* include the “Model Procedures”, written guidance under development in the UK (DETR & Environment Agency, 2000). Overarching decision support systems remain the goal of a number of decision support software development teams.

The preceding examples focused on addressing issues at a single site. DSTs are also used to address problems at multiple sites. For example, life cycle cost analysis tools are useful to examine a range of problems and to identify the problems with the largest life-cycle costs and the areas that lead to the greatest costs. This can be used as one basis for identifying areas of opportunity to reduce costs.

DSTs have also been used to support litigation. In the USA litigation often occurs when the responsible party is difficult to identify due to complex geology or multiple sources. In these cases, DSTs have been used to analyse the data using detailed technical models, abstract and interpret the model output to address the technical questions, and present this information (often through visualisation techniques) for use by a non-technical audience (judge and jury) (GREEN, 2000).

Figure 8 illustrates the stages used to arrive at decision support knowledge for a typical site. The starting point is to define the objectives for contaminated land management and the constraints on how to manage the land. For a single site, the objective may be to remediate the land to a level that is acceptable for residential use. For a series of contaminated sites, the objective may be to prioritise which sites to remediate first to minimise risks while maximising the amount of land available for use. In both cases, the constraints could be time, budget, technical feasibility, and public acceptability. Decision support can then assist the identification of the optimal way to meet the objectives within the constraints. The stages of the decision support process are confined within the dotted lines of Figure 8. These five stages form the basis for decision support, which uses information abstracted from other (and often more detailed) analyses. Taking the decision is the responsibility of the decision maker, not the tool or the system.

1. The first stage in the decision support process is to use experience and site-specific information (for example relating to the source terms, pathways and receptors) and site-specific data (for example, soil properties and hydrology). Early stakeholder involvement is beneficial both to avoid later delay and costs from subsequent arguments with unconsulted stakeholders and, in many countries, for reasons of open governance.
2. The second stage uses this information to develop simple conceptual models of the site behaviour. The conceptual model is the basis for all subsequent analyses.
3. The third stage combines information on the technology being proposed (if any) and the information used to form the conceptual model. Often all of this information is processed in computer software. There are several reasons for the use of software. First, the sheer amount of data in many problems favours electronic storage and manipulation. Second, the complexity of the analysis (e.g. geostatistics, groundwater flow and transport, human health risk assessment) requires many calculations, which can easily be done on a computer. Third, the use of

computers permits rapid evaluation of the effects of changing parameters or scenarios. This may permit uncertainties to be addressed. One perceived limitation of computers is that people tend to accept computer output as being correct and therefore not examine the underlying assumptions. A caveat applies to all computer-generated output; the output is only as good as the data and modelling assumptions used by the software. For example to determine the effectiveness of different remedial options, estimates of contaminant concentrations before and after remediation may be determined through a combination of data, geostatistical interpolation and flow and transport models.

4. Usually this information has to be interpreted and analysed in terms of the decision variable (fourth stage in the process). In this example, the contaminant concentrations can be compared to regulatory thresholds and the region that exceeds the threshold can be defined for each remedial option. The computer software may facilitate the interpretation and analysis, but it is the responsibility of the analyst to insure that the analysis is accurate and the output is in a form useful for decision making.
5. The knowledge supplied to the decision-makers (fifth stage) should be transparent and readily understandable by different stakeholders, not just specialists. Indeed, even specialists might struggle with the sheer volume of detail that arises from many sites, and so require some form of rational abstraction of information into a more manageable volume and level of detail.

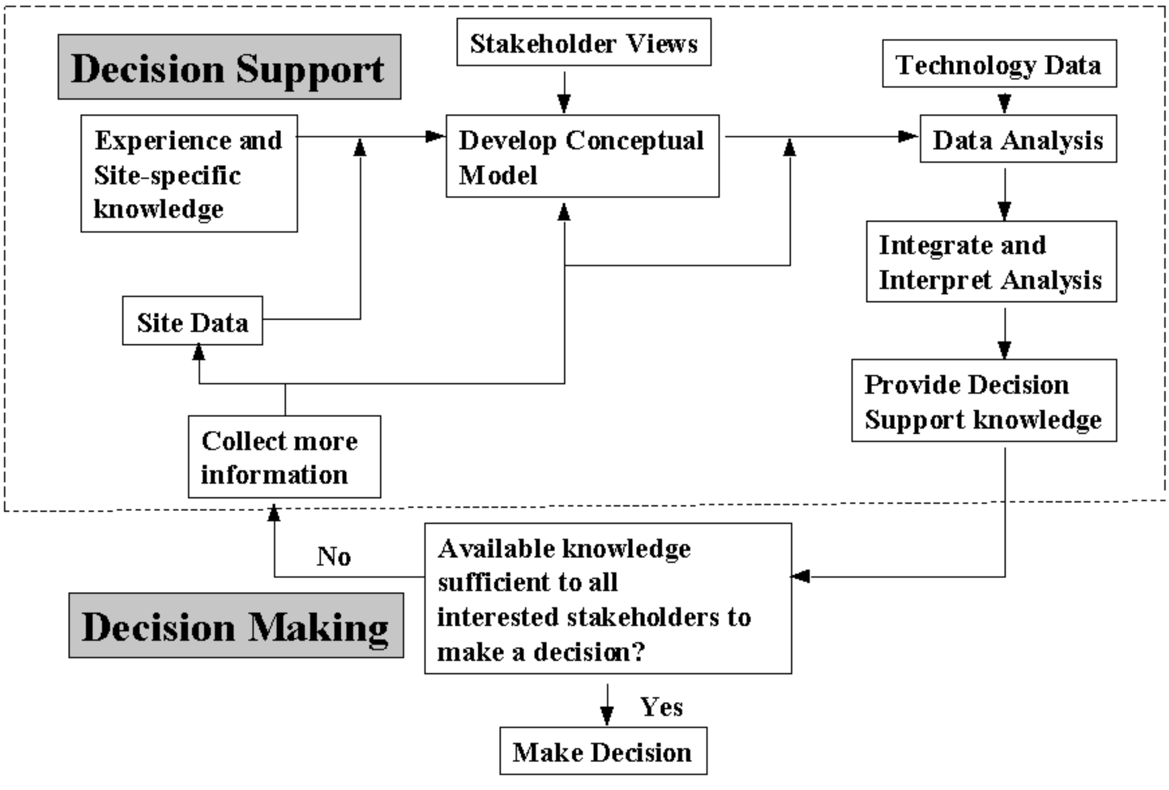


Figure 8: Flow chart containing the key steps in the decision support process (Adapted from US EPA, 2001)

Decision knowledge is supplied to the decision-makers, who then evaluate whether all stakeholders agree that the information provided is sufficient to support a decision. All environmental decisions are made with some degree of uncertainty. Complete knowledge is never available or attainable, but sufficient knowledge is usually attainable. If the stakeholders conclude that a decision can not be made, they may request additional data, improve conceptual models, consider different technologies or refine the analysis. The process of providing decision support is repeated with the new information until a decision can be reached. In some cases, it may not be possible to get all stakeholders to agree to an approach. When this occurs, the process may be vulnerable to litigation.

There is an element of choice in which stakeholders to involve in the decision-making process, however some, for example the regulator, will be an obligatory consultee. There is a difficult balance to be drawn between who to involve and who not to involve. Involving a larger number of stakeholders in decision making will add to the costs, complexity and duration of decision making. However, there is a *quid pro quo*, in that this involvement may save future difficulties that might be caused by the reactions of aggrieved stakeholders who were not consulted early enough.

Figure 8 also includes the idea that using models is **not the same** as decision support. Rather using models, and modelling techniques and software, is a step in information collection that precedes decision making. It is the integration of model results and their interpretation in terms of the decision variable that supplies decision support. This is an important distinction and is made on the basis that *decision support implies making usable information available to a variety of stakeholders*. A variety of stakeholders may play a role in contaminated land decision making. For example, land owners/problem holders; regulators and planners; site users; those with a financial connection to a site; the neighbours to a site including the local community; the consultants, contractors, researchers and vendors involved in designing and implementing the remediation. In some cases, advocacy groups and pressure groups may also seek involvement. Clearly, it would be an unlucky site manager who had to defend his decision making against all of these stakeholders simultaneously, but any decision made should be clear to them. In particular the site owner and a busy regulator, dealing with a variety of issues, not just contaminated land, will want *reliable* information that can be *easily and quickly* understood.

3.2 Terminology Of Decision Support

The range of decisions and their inter-relationships lead to a great variety of decision support approaches. CLARINET WORKING GROUP "DECISION SUPPORT TOOLS" has found that these address different management problems, different segments of each problem, and that they operate on a variety of scales and complexities, using a variety of analysis and techniques. The broad range of decision support tools available in the USA has been reviewed by SULLIVAN *et al.* (1997, 1999-2000), and new methods are regularly announced on the US Environmental Protection

Agency's (US EPA) *TechDirect* service[9]. The language used to describe decision support methods has not been found to be consistent by these studies. A common terminology (as far as such a thing is possible), and a general conceptual framework for describing decision support methods, would greatly assist comparisons of methods and their applications, particularly in an international context.

Table 6: Terms Used in Decision Support

Term	**Contemporary Usage**	**Dictionary Definitions (UK)**
Map	A figurative illustration of decision processes, the route taken for a decision	*A delineation. To arrange or plan in detail.*
Roadmap	A diagram showing the major steps in reaching a decision.	*Colloquial: A detailed plan for achieving specified objectives.*
Technique	A principal, series of operations used to assist decision making	*A mode of artistic performance or execution, a mechanical skill in art, craft etc*
Tool	A document or software produced with the aim of supporting decision making, i.e. something that carries out a process in decision support	Includes *anything used as an instrument or apparatus in one's occupation or profession*
Tree	A logical progression of decision making steps	*A diagram with branching lines*
System	Variable: for some people "system" is synonymous with "tool" above, for others "system" conveys the entire approach to decision making, including all its components. For them this totality is the decision support system, and something that deals with just a component part would be a "tool" rather than a "system"	*Co-ordinated arrangement; organised combination; method; a co-ordinated body of principles facts, theories doctrines etc; a logical grouping; an organised combination of things working together performing a particular function; any complex and co-ordinated whole*

The dictionary definition of "decision" is: "the act or result of deciding; the determination of a trial, contest or question". The dictionary definition of "support" includes, amongst other things: "to furnish with necessaries, to provide for, to give assistance to, to advocate, to defend, to substantiate, to corroborate". So for the purpose of providing clarity "decision support" can be defined as: the *assistance for, substantiation and*

[9] Information on *TechDirect* is available at *www.clu-in.org*

corroboration of, an act or result of deciding; typically this deciding will be a determination of an optimal or best approach. Although obvious, it is important to point out that decision support is NOT the same as taking a decision. The actual *deciding* has to remain the shared responsibility of those with a legitimate stake in the outcome of the decision, i.e. the *stakeholders*. As outlined in Section 2.5.

Decision support can come in the form of written guidance or in the form of software. Written guidance is frequently provided by regulatory agencies as a means of obtaining a standardised, reproducible approach to reaching a decision. Most regulatory agencies view written guidance as an essential part of the approach to contaminated land management. In many cases, this guidance is translated into computer software to assist in the calculations (e.g., risk assessment). Software tools are also developed to assist in the decision process for computationally intensive analysis, e.g., flow and transport, geostatistical modelling, and multi-criteria analysis (see Chapter 5).

The following words are often used in the context of decision support for contaminated land management: *map*, *technique*, *tool*, *tree* or *system*, e.g.. "decision support tool", "decision support system". This list is not necessarily exhaustive. General current usage is outlined in Table 6.

While the terminology used is on the whole efficient, the use of “system” problematic. It is used to refer to both a component part of the overarching set of decisions necessary, or the whole set, both meanings are in line with the dictionary definition.

For clarity this report uses just one of the two alternative meanings for “system”, even although this is more limiting than English language usage. In this report “system” conveys the entire decision making approach, including all its components. The reasons for this selection are that (1) “tool” already conveys the component part definition, and (2) there are those who believe that general rules can be drawn up for the overarching system, and not just its component parts. Figure 9 illustrates the distinction drawn in this report between “tool” and “system”.

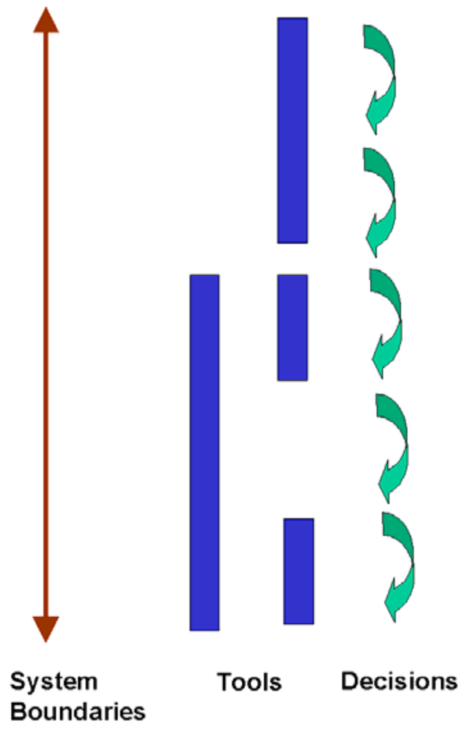


Figure 9: "System" Conveys the Whole Decision Making Structure, a "Tool" Supports One or More Decision Making Steps

3.3 Categories of Decision Support

CLARINET uses four categories to describe decision support tools and other approaches (as shown in Table 7):

- The decision making role of the approach
- Functional application, i.e. the contaminated land management application
- The analytical techniques used in the decision support approach
- The nature of the decision support product

The decision making role describes the type of decision making being supported, e.g. for managing a single site, or for prioritising a number of sites. This deals with the overarching decision being made at the site.

The functional application to contaminated land management describes whether the decision support is for risk management, remediation, monitoring and aftercare, sustainable development etc. This deals with the issues that must be addressed to support the overarching decision.

Several different techniques can be employed to assist environmental decision-making. POLLARD *et al.* (1990) identified the following: life cycle analysis (LCA); environmental risk assessment (ERA); environmental impact assessment (EIA); cost benefit analyses (CBA); multi-criteria analysis (MCA); multi-attribute analysis (MAT); environmental audit; and sustainability appraisal. Some of these techniques are analyses of environmental information, and some are procedural tools. These techniques are reviewed in more detail in Section 3.5.

The nature of the product describes whether the tool is written guidance; a "map" of some sort, a series of procedures or a software based system. In practice, a number of decision support tools (DST) address multiple decision criteria. For example, software tools might combine risk assessment and cost-benefit analysis techniques to generate risk maps, cost comparisons between remedial options and other decision information.

Table 7: Examples of categories of decision support

Functional Application	Problem Identification Site investigation Risk assessment Risk Management Aftercare Monitoring Evaluating Wider Impacts (environmental, economic, etc) Sustainability appraisal
Decision Making Role	Identification of problem sites Prioritisation Comparison of options Strategy development Policy Site specific functions
Nature of the Product	Software system Written guidance Flow charts Protocols and procedures
Analyses Used	Environmental risk assessment Cost benefit analysis Life cycle assessment Multi-criteria analysis Sustainability appraisal Protocol[10]

[10] Some decision support tools may not use analyses *per se*, but are systematic protocols to ensure that similar considerations are made for each decision.

3.4 Analytical Techniques Used In Decision Support

The principal analytical tools and techniques so far used to support environmental decision making for contaminated land management are:

- Environmental Risk Assessment (ERA)
- Multi-Criteria Analysis (MCA)
- Multi-attribute techniques (MAT)
- Cost-Benefit Analysis (CBA)
- Cost Effectiveness Analysis (CEA) - at least in the UK
- Life Cycle Assessment (LCA)

These techniques are discussed in more detail below. Examples of contaminated land management decision support tools applying these techniques are provided in Chapter 5.

The EC supported CHAINET Project (European Network on Chain Analysis for Environmental Decision Support) has published an extensive report critically reviewing the various analyses available to support environmental management decision making in general (WRISBERG *et al.*, 2000), albeit for production systems. However its report does indicate that there are perhaps a wider range of techniques that could be applied to contaminated land decision analyses.

Figure 10 presents CHAINET's conceptual framework for the supply of environmental information for decision making. This framework identifies two broad classes of analytical tools: those based on physical metrics (parameters capable of objective measurement) and those based on non-physical metrics. These analytical tools are applied in procedural tools such as: environmental impact assessments, total quality management and others. From the perspective of Table 5, it is different implementations of these procedural tools that constitute the different decision support tool "products", such as software, protocols, guidance etc.

One further technique, not covered in detail by CHAINET, is being increasingly used for contaminated land decision making, particularly for commercial redevelopment projects. This tool is financial risk management, which is also outlined below.

CHAINET's choice of categories for non-physical metrics is interesting. Firstly, it included a number of quantitative techniques, such as CBA as non-physical metrics. It is important to understand that a quantitative method is not necessarily one that is based on objectively measurable parameters. In the case of CBA, assessments are based on a series of value judgements rather than measurements. Secondly, CHAINET explicitly identifies regulatory analysis, stakeholder analysis and socio-economic assessment as analytical tools. However, CHAINET does not offer actual techniques that carry out these analyses, for example a protocol, which if followed ensures that a stakeholder analysis or socio-economic assessment has been carried out. These analyses may be component parts, either explicitly or implicitly, of techniques such as MCA or CBA.

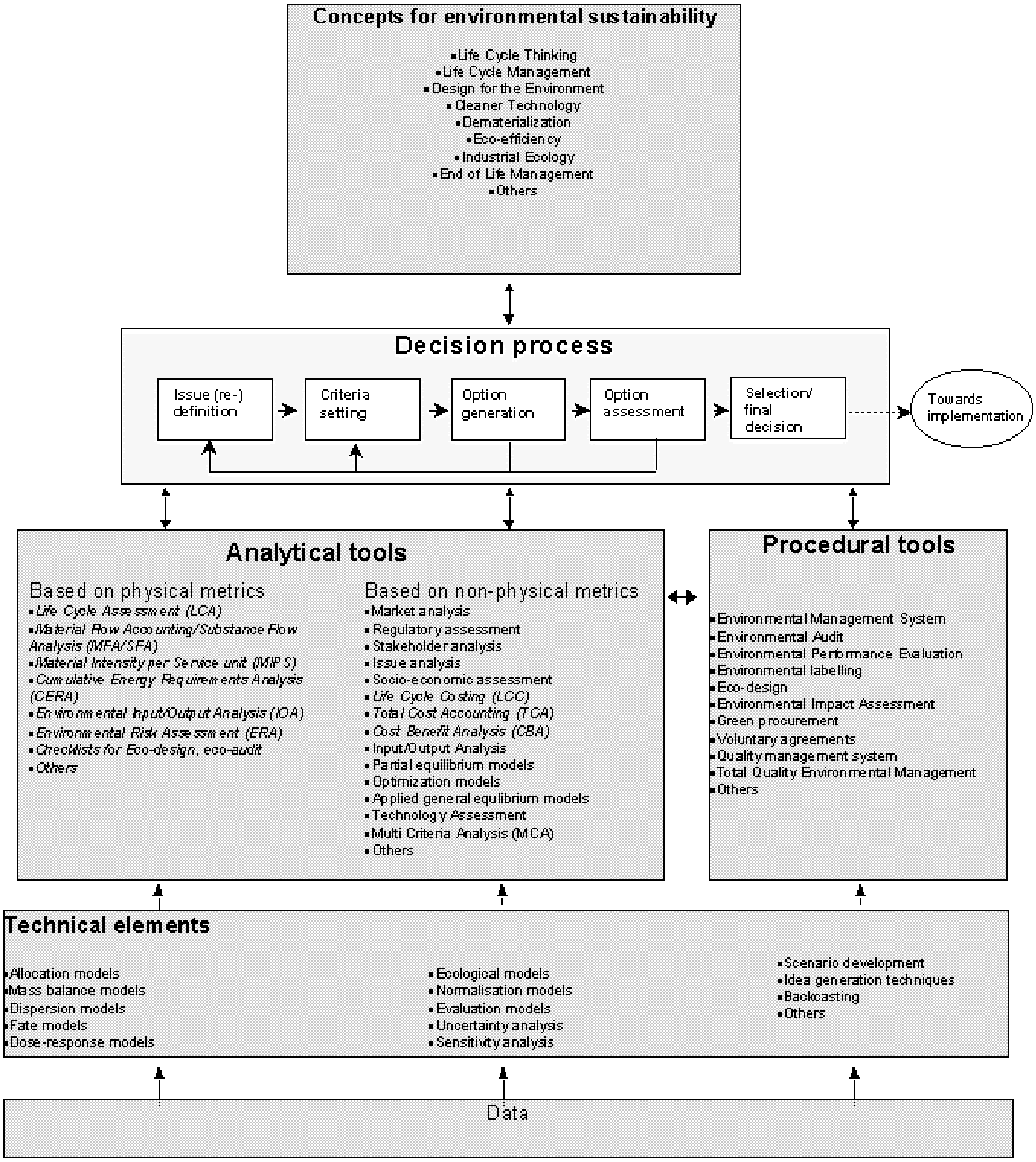


Figure 10: Framework for the Supply of Environmental Information for Decision Making (Taken from WRISBERG et al., *2000)*

The CHAINET framework draws the same distinction between processing data and decision making as Figures 6 and 8 above. Models, or "technical elements" as

CHAINET describe them, are seen as providing input to decision analyses. The CHAINET process is illustrated as a sequential decision process. In practice, much contaminated land management decision making is iterative. For example, in the USA where there has been an emphasis on using a three step process involving systematic planning, dynamic work planning and on-site analysis to assist technical decision making at a contaminated site (CRUMBLING, 2000). In this approach, data (for characterisation or monitoring) are analysed on-site, risk assessments are updated based on the new data, and the need for additional samples is evaluated and the work plan is altered to reflect the most recently available data. The approach is intended to provide a more efficient characterisation and better technical support for decision making compared with following steps in a sequential manner.

The CHAINET framework is predicated on decision making for environmental sustainability. Sustainability appraisal tools able to consider, in a holistic sense, the environmental/resource, economic and social elements of sustainable development of contaminated land decisions remain a conceptual goal.

3.4.1 Environmental Risk Assessment

Environmental Risk Assessment (ERA) is the examination of risks that threaten ecosystems, animals, people and other receptors (groundwater, buildings). Human health risk assessment techniques for contaminated land management decision making have been developed in many countries, and have been comprehensively reviewed by CARACAS (FERGUSON *et al.,* 1998, FERGUSON & KASAMAS, 1999). Developments in ecological risk assessment have been recently reviewed by a CLARINET conference (ANON, 2001).

3.4.2 Multi-Criteria Analysis

Multi-criteria Analysis (MCA) is often used in decision making. MCA is a structured system for ranking alternatives and making selections and decisions. Considerations used in MCA are: how great an effect is (score) and how important it is (weight). A general outline of the MCA method is shown in Figure 11. MCA describes a system of assigning scores to individual effects (e.g. impact on traffic, human health risk reduction, use of energy etc). These can then be combined into overall aggregates on the basis of the perceived importance (weighting) of each score. With MCA, ranking and decision making processes can be made very transparent (BARDOS *et al.,* 2000, WRISBERG *et al.,* 2000).

MCA is not an analytical tool in that it directly analyses physical information or monetary information like the other analytical tools. It rather is an analytical tool at a higher level, bringing together different considerations in a structured way. However, techniques such as CBA, CEA and LCA apply MCA principles in their use of weightings, scoring (valuations) and aggregation.

MCA describes a range of techniques, and at its most complex might include analyses of individual preferences of stakeholders for weightings and quantitative valuations (such as LCA techniques) for deriving scores[11]. MCA techniques are widely used in contaminated land DSTs, as illustrated in the case studies outlines in Chapter 6. No international standardisation exists for MCA.

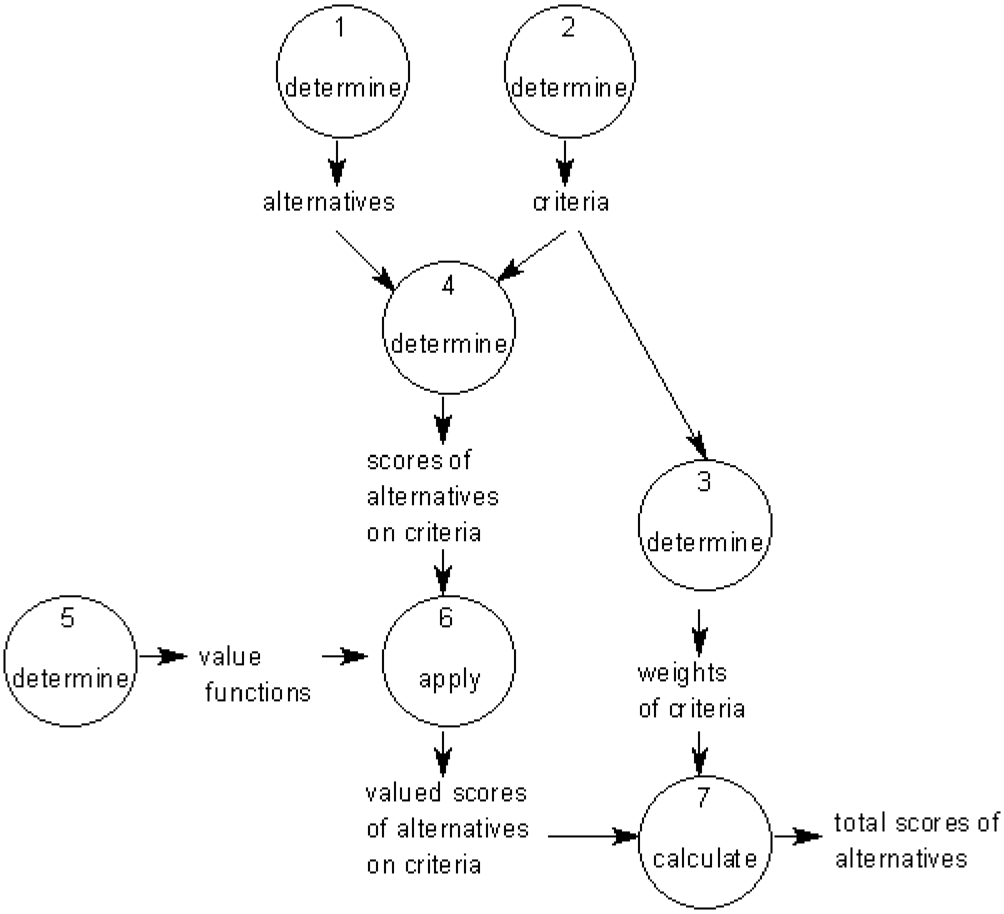


Figure 11: A General Outline of the MCA Method (BARDOS et al., *2000)*

3.4.3 Multi-Attribute Techniques

Multi-attribute techniques (MAT) for are a refinement of MCA principles, and have been extensively reviewed by OKX (1998 and 2001). This brief summary is taken from OKX, 2001. The majority of decision situations share important similarities. First, decision-makers evaluate a set of **alternatives**, which represent the possible choices. The **objectives** to be achieved drive the design (or screening) of alternatives and determine their overall evaluation. **Attributes** are the measurements of the ob-

[11] In this scenario MCA approaches are used both in making valuations, and combining different valuations, for example environmental impacts and costs.

jectives and specify the degree to which each remedial alternative matches the objectives. Finally, **factual** information and **value** judgements jointly establish the overall merits of each option and highlight the best compromise solution (BEINAT, 1997). Figure 12 summarises the information that plays a role in a multi-attribute model.

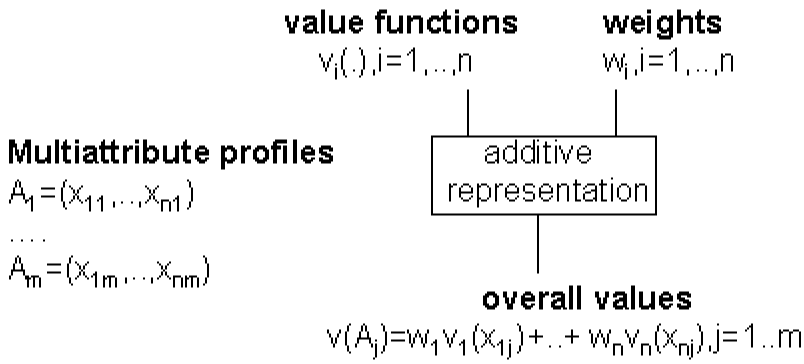


Figure 12: Information Items in a Multi-attribute model (BEINAT, 1997)

The information items are the multi-attribute profiles ($A_1,..,A_m$) allowing measurement of the achievements of the (remedial) alternatives, the value functions (v_i , $i=1,..,n$) representing human judgements, the weights (w_i , $i=1,..,n$), and the multi-attribute value function that associates an overall value with each alternative ($v(A_j)$, $j=1,..,n$). In this example, the overall merit of a decision alternative is computed as a weighted sum of single-attribute performances regarding all attributes. Although this evaluation scheme is very common and widely used, it is important to stress that it can be applied only under very precise conditions. In particular this additive approach can be applied only if independence conditions across attributes are met. This, in turn, calls for a careful structuring of the decision problems and a careful choice of the attributes.

3.4.4 Cost-Benefit Analysis

Cost-Benefit Analysis (CBA) is an economic tool for determining whether or not the benefits of an investment or a policy outweigh its costs. The tool has a very broad scope and aims at expressing all positive and negative effects of an activity in a common unit, namely money (WRISBERG *et al.,* 2000). Economic and environmental considerations are all expressed as monetary values. Typically, CBA begins with a determination of which costs and benefits are examined. CBA then tries to value these costs and benefits and finally weighs them against each other. However, as an objective environmental decision making tool, CBA suffers from several limitations (MARTIN *et al.,* 1997, NOBIS 1995a, b):

- Monetary valuation of environmental benefits and impacts are hard to quantify on a reliable and consistent basis;

- Concerns exist about discounting future effects to net present value, when the potential for deleterious (or positive) environmental effect in the long term is important;
- The appropriateness, or lack of it, of a monetary value for less tangible environmental values e.g. biodiversity;
- The limitations of converting all decision factors to a single dimension (which also holds true for LCA based simple indices).

3.4.5 Cost Effectiveness Analysis

Cost-effectiveness analysis (CEA) is a simplified derivative of cost-benefit analysis. The aim of CEA is to determine "… the least cost option of attaining a predefined target…" without a monetary measurement of benefits (Environment Agency, 1999). Costs are calculated conventionally and benefits are scored individually. An aggregate score for benefits is then divided by cost to provide a measure of "cost effectiveness". The derivation of scores is an application of MCA (see above).

3.4.6 Life Cycle Assessment

CHAINET describes the aim of life cycle assessment as specifying the environmental consequences of products or services from cradle-to-grave, and its use as studying different options to supply a given *function* (WRISBERG *et al.,* 2000). In the context of contaminated land, such a function might be the remediation of a contaminated site. CHAINET describes the main features of LCA as follows:

- LCA follows a *cradle-to-grave approach*: all processes connected with the function, from the extraction of resources until the final disposal of waste, are being considered.
- LCA is *comprehensive* with respect to the environmental interventions and environmental issues considered. *In principle*[12], all environmental issues connected with the function are specified as resulting from extractions, emissions and other physical interventions like changes in land use.
- LCA may provide *quantitative* or *qualitative* results. With quantitative results it is easier to identify problematical parts of the life-cycle and to specify what can be gained by alternative ways to fulfil the function.

Figure 13 illustrates the principal steps in LCA. LCA methodology has been standardised by the International Standards Organisation (ISO 14040 series: ISO 14040, ISO 14041, ISO 14042, ISO 14043). In outline the typical steps or "phases" of LCA are as follows (BARDOS *et al.,* 2000a).

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[12] *Our emphasis*: in most applications LCA is subject to a number of simplifying assumptions in order to make the analysis practically achievable. These simplifications can introduce a large degree of subjectivity into the analyses.

The definition of the goal and scope exerts a strong influence on the result of LCA and encompasses: the purpose of the analysis; the function being considered, the boundaries of the analysis, the data quality desired and how the analysis will be validated.

During inventory analysis the process being assessed is broken down into parts, to allow the impact of each unit operation to be separately considered. This allows a more exhaustive and objective understanding of the overall process.

The impact assessment is the quantitative and / or qualitative process to characterise and assess the effects of the environmental interventions / use (resource use, emissions) identified in the inventory table. The different categories of impacts are identified and classified by type. The impacts in each class are then characterised in a way that allows their relative effect on different classes of environmental effect to be assessed, for example with respect to global warming potentials, ozone depletion potentials etc. For quantitative assessments these assessments are then normalised in such a way that they become dimensionless indices, with the same range (e.g. 0 to 1) for each class. The indices are then capable of being combined, usually with weightings. These processes rely on a series of value judgements. While these may be made in the basis of "natural science", they can also be based on the views of different stakeholders and either implicitly or explicitly will include political or ethical values.

Interpretation includes both the validation of the LCA findings and also the communication of decision making information.

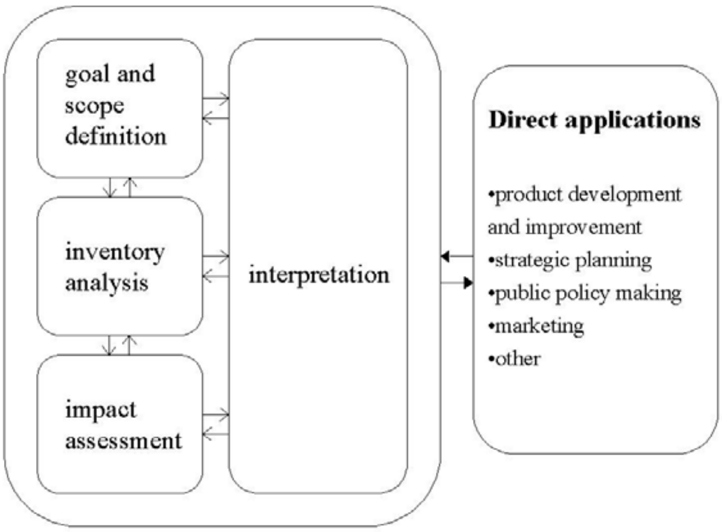

Figure 13: Standard Stages in LCA (WRISBERG et al., *2000)*

3.4.7 Financial Risk Management

For many businesses, remediation of soil and groundwater has assumed greater importance through its potential to influence liquidity, solvency and overall financial performance. Others recognise the commercial opportunities that remediation can generate in terms of enhancing the value of brownfield sites. Whatever the business case, there are corresponding financial risks relating to a company's ability to meet its corporate and project objectives. The precise nature and extent of financial risk depends on the context in which remediation is undertaken. Where remediation forms part of an investment project, such as brownfield site reclamation, the underlying financial risk surrounds the internal rate of return (IRR) or Net Present Value (NPV). The IRR, which represents the return that can be earned on the capital invested in a project, can be greatly reduced to a point at which a project becomes non-viable commercially. The IRR reflects the volatility in the risk - the two factors tending to show a positive correlation (see Figure 1). NPV represents the present day cost of some action taken at some time in the future; in essence the present day value of that distant cost is discounted by the applicable interest rate over that period of time.

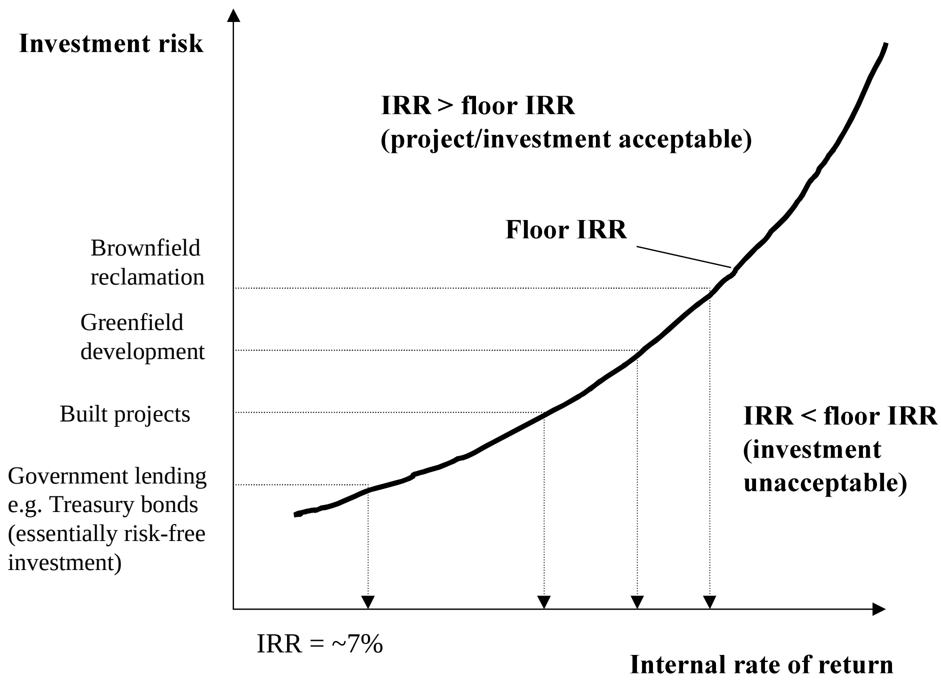

Figure 14: Illustration of the relationship between IRR, project risk and project acceptability (FINNAMORE, 2000)

The effectiveness of remediation can be judged financially in terms of:

- meeting, or preferably beating, projected cost estimates (**project costs**)
- ensuring timely release of the property asset for income generating use (**revenue**)
- maintaining, or preferably, enhancing the value of the property (**asset value**)
- increasing the liquidity of the asset (**liquidity**)

- reducing/avoiding existing liabilities whilst avoiding creating new liabilities (**risk management**)

The financial risk associated with remediation stems from an inability, or perceived inability, to forecast its effectiveness in meeting these project objectives.

FINNAMORE (2000) discusses an analytical approach and methodology, based on stochastic modelling, to translate the technical risks of remediation into monetary expressions of risk. This approach provides an invaluable management tool that can generate real business benefits. Most importantly, commercial decisions - which inevitably require a company to take a risk - are made with greater confidence and certainty. There are then opportunities to optimise the management of risk by contractual mechanisms and structuring of project finance.

3.4.8 Acceptability of Analytical Tools for Decision Making

In practice many DSTs use several analytical techniques, or mixtures of different parts of them. Environmental decision-making is in its infancy as a general discipline, and so current approaches tend to be fragmented and overlapping (POLLARD *et al.,* 1999, TONN *et al.,* 1999).

The involvement of different stakeholders (e.g. Consultant, community, regulator, problem owner) in a consistent decision making process is increasingly seen as being important (POLLARD *et al.,* 1999, ESRC, 1997, PCCRARM, 1997, USEPA, 1995, USEPA ,1998b). Decision making also has to encompass an increasing range of viewpoints and disciplines, not just soil science and environmental engineering but also economic, political and social aspects.

These analytical decision making techniques should not be seen as providing definitive answers that prescribe which decision to make. Rather they are a component part of decision making, and judgement must be exercised as to how reliable each technique (and its subsequent findings) are on a case by case basis. All of these techniques are based on a combination of science and value judgements, perhaps to differing degrees. They can therefore be seen as subjective by some stakeholders, for example those who have technical reservations about a particular technique, and especially those who have not made a contribution to the analysis. It is also important to realise that the perspective of different stakeholders on even the basic premise of decision making may be profoundly different. As CHAINET concluded (WRISBERG *et al.,* 2000) stakeholders starting from a precautionary perspective may not be convinced by information from tools which fit a risk assessment perspective. NICOLE, the Network for Industrially Contaminated Land in Europe, reached similar conclusions in its 200 workshop in IJmuiden (NICOLE, 2000). NICOLE reported that while risk based decision making was seen as the optimal approach for contaminated land management by most technical specialists, it was not necessarily seen as appropriate by other stakeholders such as local communities. Not only is it important to be inclusive about involving stakeholders in decision making in general, it is important to reach a consensus as far as possible about the framework and approach to decision making including the analytical tools used. The advantages and disadvantages of using these analytical techniques to support decision making are, of course, the same as those for DSTs in general, summarised in Table 5.

DSTs tend to be written for specialists or at least contaminated land professionals. Most, if not all, DSTs do not cater for the involvement of "lay" audiences. However, a number of procedural techniques have been devised for engaging lay audiences and the public in general, such as citizen juries and opinion polling (SNIFFER, 1999) - see Box 3. However, there may be no substitute for spending time with people when involving lay "audiences", as the Groundwork experience illustrates. Often their wishes and perspectives are different to those that professionals would wish. For example, in one of the *Changing Places* programme projects in the UK, Groundwork found that while the local community, eventually, supported a restoration project with recreation and conservation as end uses, they did not want woodland to be planted. This was not what Groundwork had expected, they had thought that recreational woodland would have been popular. The desire not to have woodland was in fact based on common sense wishes and concerns. For instance, the public wanted open space where children could play. There was concern that woodland would make the open space less secure for its users (Groundwork, 2001), by providing cover for people with criminal intent.

Some Tools for Lay Participation **Box 3**

Citizen's juries – Involves major stakeholders in the process of the identifying and appraising of options - lay people brought together to deliberate on an issue, call witnesses and come to a verdict.

Citizen's advisory groups - lay people bought together over a period of weeks to act as the voice of the community - can turn into a monitoring group once the decision has been made.

Supporting broad stakeholder involvement seems likely to be of increasing importance in contaminated land decision making, as more brownfield land is used for housing and interest increases in "bottom up" decision making to give local communities a stake in land restoration, for example, to assist social regeneration in deprived areas (HANDLEY, 1996, HANDLEY *et al.,* 1998).

Some commentators also believe that the "market" for redevelopment sites for industry will diminish over time, as economic activity becomes more concentrated as a function of land area - at least in Europe and North America. This is seen as a consequence of the relative growth of service and knowledge based industries in these regions compared with manufacturing and extractive industries (BARTON, 2000 and 2001). If this is true, the linkage of brownfield land re-use to specific end uses such as housing, industry etc, may be likely to decline in the long term. BARTON believes that this will lead to an increasing use of brownfield land for social rather than commercial purposes.

Hence, while DSTs have made great advances and are now routinely used in contaminated land decision making, two major deficiencies in provision are apparent:

- Tools that facilitate the involvement of lay audiences; and
- Tools that are able to carry out a sustainability appraisal in a holistic sense, considering environmental / resource, social and economic aspects (POLLARD *et al.,* 2000).

Because the judgements and assumptions that underpin decision support analyses are so often subjective (i.e. depend on a stakeholder's perspective), their acceptability to all will be dependent on a consensus about decision making approach and values being reached. Hence it seems likely that DSTs able to address a holistic sustainability appraisal will also have to be capable of engaging stakeholders who are not contaminated land professionals. Whatever tools are developed, it seems likely that these will be based on MCA / MAT (OKX, 2001). The technical challenges of developing such wide ranging MCA will be enormous; the challenge of making them inclusive and transparent to lay audiences will be even greater.

4 SURVEY OF DECISION SUPPORT IN CLARINET COUNTRIES

4.1 Introduction

The Working Group "Decision Support Tools" conducted a survey of decision support issues in Europe over 1999/2000 through its participating country representatives. The survey was based on a questionnaire, drawn up by the participants in the Working Group, covering decision support and risk management issues. The aim of the questionnaire was to ascertain the current approaches to, and procedures for decision-making for, the remediation of contaminated land in Europe. The questionnaire was broadly organised into the following sections:

- Decision Making (decision support and decision makers);
- Risk Management and Risk Assessment;
- Special Provisions for particular situations;
- Wider Environmental Effects and Sustainability;
- Support procedures and Primary drivers for decision-making

16 CLARINET countries took part in the survey: Austria, Belgium (Flanders and Walloon), Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the UK. The responses were collated and summarised. The country representatives were invited to check and up-date the final drafted summaries in June 2001. This chapter overviews the findings of this survey. Its detailed results are presented in Annex A.

4.2 Analyses of Responses

4.2.1 Decision Making for Contaminated Site Management

Legislation for the management of a polluted site is usually covered either by contaminated land legislation or by waste management legislation. In some countries legislation and/or regulations for managing contaminated land are still under development (Belgium – Walloon, Finland, Portugal). There are some general steps in contaminated land management are which are common for all of the countries surveyed. These are:

- initial identification of the problem (including a historical assessment, and thus the identification of potential sites);
- investigation of the problem and the need for remediation;
- identification of actual and potential risks;
- detailed evaluation of the risk and the identification of the remediation goal;
- selection and implementation of remedial measures;
- monitoring of sites following remediation and aftercare.

Flow diagrams and decision support tools (DST) for decision making are specifically referred to in some legislative frameworks, and in some countries a sequential series of actions is described in the framework for contaminated land management. The flow diagrams vary in both their complexity and the unequivocal nature of the decision steps within the sequence.

These general decision support systems vary in the detail required to undertake the risk assessment and in the nature of the guidelines provided. Where decision support tools are under development there is frequently an attempt to relate to other available approaches within Europe. In some circumstances the procedures may outline a mandatory framework, in others it is advisory and there is reliance upon specialist knowledge and experience.

Examples of Current Approaches to Decision-Making from the WG2 Survey Box 4

***Austria*:** Austrian legislation does not provide any tools for decision making. Therefore the Austrian Standards Institute produced a sequence of guidelines to assist the management of contaminated sites. A tiered approach of procedures and activities for the management of contaminated sites using a flow diagram provides a general guide for dealing with investigation, assessment and remediation of contaminated land and incorporates a number of standards dealing with subsets of the contaminated land problems. The flow diagram provides the framework for decision-making; the integration of the various steps is provided by the progressive nature outlined in the flow diagram. In addition a general outline for risk assessments defines guideline values for contaminated land related to the protection of groundwater resources as well as the safe use of land.

Switzerland: There are four main stages in contaminated site management in Switzerland:

- Registering of sites;
- Preliminary investigation (does the site need remediation? A basic risk evaluation);
- Detailed investigation (detailed risk assessment, definition of remediation goals, definition of delays to be expected); and
- Planning and realisation of remediation including monitoring of the site.

There is a computer based decision support system for the registration of sites and to support the initial decision on the necessity of an initial investigation. Development work is underway for later stages in the process, involving more detailed information. This will focus in particular on the link between soil and land as a source of pollution through the unsaturated zone into groundwater.

The Stakeholders involved in decision-making

The stakeholders involved in decision making vary from country to country (see Table 8). In some it is the responsibility solely of either the regulators at the national level (agencies and administrative bodies), or local administrative bodies (often with the support and involvement of national environment agencies). In others, particularly in northern and western European countries, there is a clear acknowledgement that the polluter (both present and historical) has a major responsibility, together with the site owner and potential developer for the remediation of the contaminated land. These are the main players are at the heart of the decision-making process, although individuals or companies affected by remedial actions may also be involved. In addition, financiers and insurers may be involved as the costs of remediation may affect the value of the assets embodied in the site.

Table 8: Participation in Decision-Making Reported by Countries

Country	**Core Decision-makers**	**Other stakeholders**	**Community involvement**	**Information communication**
Austria	Authorities Landowner Problem holder	Neighbours involved if linkage is suspected	Neighbours informed	Public meetings Mail circulars, flyers Internet
Belgium – Flanders	Site operator / Site owner Or government (OVAM)		Municipal government	Public meetings
Belgium – Walloon	Waste Office of Wallonia Regional Development Administration	Public Society for Environmental Quality Improvement		
Denmark	Municipalities Regional Councils	Danish EPA	Property owners Interested parties	Public meetings Information letters
Finland	Authorities from regional environmental centres Municipality of Helsinki	Landowners Polluters Insurance companies	All neighbours	Public meetings Local and national TV, radio, newspapers
France	Departmental prefects Inspectors of DRIRE	Site owners / Polluter, or ADEME and the ministry responsible for the environment (for orphan sites)	All stakeholders including local population Specific guidance available	Via representatives of the population – Mayor, Public meetings

Table 8: Participation in Decision-Making Reported by Countries (continued)

Country	**Core Decision-makers**	**Other stakeholders**	**Community involvement**	**Information communication**
Germany	Local authorities	Polluters Landowners	All those who may be affected must be informed	Documentation available for public inspection
Greece	Government Regional, local and prefectural authorities	Environmental organisations, NGOs, industry, prefectural councils, citizens, interested parties		
Ireland	Local planning authorities, Department of Environment and Local Government, EPA, site developers		Citizens may make submissions and raise objections	All information available to the public
Italy	Regional, municipal and provincial administrations Ministry for the Environment for sites of national interest	Polluter / Site owner Regional Environment Agencies. National Environment Agency, Ministry of Health at sites of national interest	Trade unions, environmental NGOs	Public debates Media
Netherlands	Competent authorities Party remediating the site		Other parties are encouraged to be involved if relevant	
Norway	Environmental authorities	Polluter Owner		Newspapers Public meetings
Portugal	Environmental and economic ministries	Universities Municipalities Regional authorities, Government Industries	Local inhabitants Environmental organisations	Newspaper articles Conferences Public debates

Table 8: Participation in Decision-Making Reported by Countries (continued)

Country	Core Decision-makers	Other stakeholders	Community involvement	Information communication
Spain	The regional government Local authorities	Polluter, Owner		
Spain (Catalunya)	The regional government Local authorities	Polluter, Owner Consultants, Developer	Neighbours are informed, if they are affected	
Sweden	Information not collected			
Switzerland	Federal and local authorities	Communities and citizens may be involved	Communities and citizens	Register of polluted sites lists sites and remedial actions – open to the public
United Kingdom	Landowners and occupiers Developers, Regulators Practitioners Financiers and insurers	Environmental groups Local community	Local community	General guidance is available

Involvement of the community, citizens and or environmental organisations

Most countries involve the local community and individual citizens in the decision-making process (Table 8 and Figure 15) although the extent of involvement in decision-making varies from country to country. In some there is a formal requirement to inform and involve local communities in all steps of the process; in others there is the possibility of local communities being informed and involved. The involvement of environmental organisations is encouraged in some countries.

Examples of Community Involvement in Decision-Making from the WG2 Box 5

France: A key element in the French policy is the participation of the full range of stakeholders involved in dealing with contaminated land including the local population. There is specific guidance describes how to keep Municipalities and the population fully informed of the state of play at a contaminated site and actively involved in the decision making process. The Prefect can decide to inform representatives of the population (for example, the Mayor, environmental organisations and residents associations) through special meetings called CLIS (Commission of Local Information and Monitoring) during the whole of the investigation and/or at the treatment steps. The information should be presented so that is will be widely understood.

United Kingdom: Stakeholders involved in the decision making process include all parties with an interest in land contamination including; land owners, occupiers, developers, regulators, practitioners, financiers, insurers, environmental groups and local community groups. Involvement of the local community in the decision making process from the earliest stages of the implementation of risk management is strongly encouraged. An agreed strategy presented in non-technical language is necessary for genuine communication with all concerned parties in order to gain public and stakeholder confidence in the approach adopted. A recent publication from the Environment Agency entitled 'Consensus Building for Sustainable Development' provides guidance.

The communication of information to non-specialists is widely recognised by countries as being important, and well-developed protocols exist in Denmark and the Netherlands. Where responsibility for the actions lies at a local rather than a national/federal level there may be considerable variability within a country in the level of involvement and the encouragement of such involvement. There are some attempts to present the information in a form that the general public will readily understand, although it is recognised that this is not always possible with some technical information.

4.2.2 Risk Management

In all of the countries surveyed decision-making for the past legacy of contaminated land is based on risk management principles, using source-pathway-receptor linkages, almost always taking in to account current or planned land use. New contamination incidents, such as an spillage from a tanker, may also be dealt with on a risk management basis. However, an increasing number of industrial, waste management and other process are coming under Integrated Pollution Prevention and Control (IPPC) Regulation (IMPEL, 1998). IPPC typically requires that before a process can be licensed its site must be subject to an investigation. The general presumption, for example in Belgium (Flanders) and the UK, is that following any subsequent contamination, the site must be remediated to this "background" condition. (NB if the initial site investigation indicates contamination under "historic" contamination legislation, remediation is also likely to be required at this stage).

Risk management principles are used throughout the countries surveyed to make decisions about remediation approaches, taking into account current or planned land use. Risk based generic limit values / limit value systems may be used as a basis for decision-making in a risk assessment (Table 9). In some countries the limit values are used as guidelines, in others as fixed standards. Where no national limit values are available 'imported' values from other European or North American countries are often used. The limit values are in some countries linked to exposure models based on ecotoxicological criteria, or to different land uses with varying action when limits are exceeded.

Risk Assessment

Risk assessments are site-specific throughout all countries surveyed and are used to determine whether or not a risk is acceptable. The risk assessment requires different levels of precision depending upon the site management step undertaken. Lower levels of precision are used at the initial site assessment stage with higher levels of precision for detailed investigations and remediation plan developments. Different levels of precision for risk assessment are incorporated into the legislation/regulations of some countries. Where different levels/degrees of risk assessment are identified there is variability in how they are incorporated; they may be broadly grouped into human health risk and land use related risk. A consideration of the pathways linked to these receptors is an important element in some cases and in some cases the risks may also be related to the potential for remediation. There are variations in the amount of information considered necessary for each step in the decision making process.

Different levels of stringency are not always provided for in the legislation but may be used. Generally, lower levels of contamination may be considered acceptable if there is a sensitive receptor, and higher levels of contaminants may be considered to be acceptable if the site targets cannot be achieved following BATNEEC[13] principles. In the latter case a change of site end use may be permitted; a risk assessment may be used to determine land use options.

The *Ad Hoc* Working Group on Contaminated Land is an informal coalition of professionals from regulatory agencies and government departments with responsibilities for contaminated land management (*http://www.adhocgroup.ch/*). Responses to its *Amsterdam questionnaire*[14] (VISSER *et al.,* 1999) are largely in agreement with the responses in the Working Group "Decision Support Tools" survey. Site specific risk assessments are used by most countries surveyed to determine remediation objectives, to assess the need for further investigation and for prioritisation. Some countries also use risk assessments to validate the results of a remedial action or to deregister the site. Guideline values are generally used, the principal receptor considered

[13] BATNEEC Best Available Technology Not Entailing Excessive Cost

[14] The Amsterdam questionnaire (VROM, 1999) was circulated in 1997 to all of the Ad Hoc Group participants. It is an update of the Vienna Questionnaire (1993). The aim of the questionnaire is to provide basic information across the following areas: Policy and legislation, Liability, Funding, Information on contamination, Assessment and prioritisation, Remedial treatment.

is human health, soil, water and the ecosystem are also considered. However, some countries were still in the early stages of developing their guideline values.

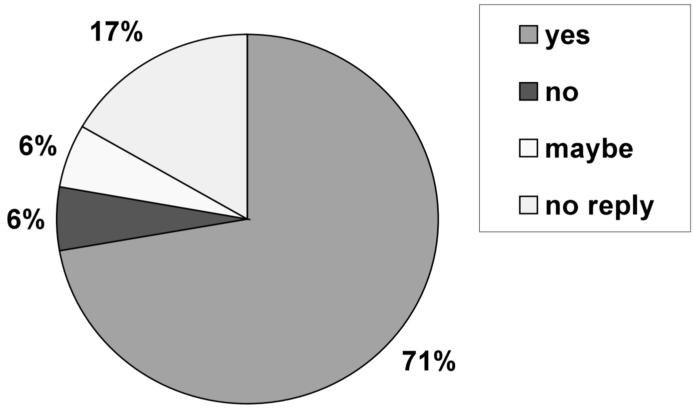

Figure 15: Community Involvement Decision-making

Communication of information to non-specialists, communities, neighbours

Handling, recording and use of risk assessment results

Most countries report some system for recording the results of risk assessments, although procedures vary widely throughout the countries surveyed. The information may kept by national or local authorities, recorded in national registers, or form part of the file of site information. In other countries one would assume that risk assessment reports are kept by the client and technical consultant. In other countries risk assessment information is made more widely available, particularly to potential purchasers of a site and site developers. For example, in Austria the risk assessment results of 'seriously contaminated sites' are recorded in the Register of Contaminated Sites. Flemish Belgium too has a Register of Contaminated Sites. There may also be a requirement to register the changes in risk due to remediation actions.

Table 9: Risk assessments

Country	Role of RA	Different levels/stringencies	Role of limit values in RA	RA results RA procedures
Austria	Considered important but no defined procedures	Not provided for in the legislation	Guideline values (trigger values and limit values) used to set target values	RA results of 'seriously' contaminated site are recorded in the Register of Contaminated Sites
Belgium – Flanders	RA is part of a Descriptive Soil Survey (evaluated and approved by OVAM).	Not provided for in the legislation	Limit values are set for 5 different land use types. Remediation is obligatory for post 28/10/95 contamination, and if risk is unacceptable for pre 28/10/95 contamination	Decisions are recorded in the Register of Contaminated Sites
Belgium – Walloon	RA role not yet defined		Indicative values will be into RA tools in forthcoming legislation	RA procedures not yet defined
Denmark	RA are used	Levels and stringencies used depend upon the sensitivity of the receptor	Generic levels are used; if exceeded there may be a risk	No systematic central records
Finland	RA is risk management tool	Not provided for in the legislation	Based on generic values, occasionally site-specific target levels are used.	RA reports are prepared for decision-makers and recorded as part of remediation permit records
France	RA used on a case by case basis	RA can be in 2 stages: I. SRA (simplified RA which is a qualitatitve method) and, if required, following the SRA results II. DRA (detailed RA which is a quantitative method)	Generic values used in SRA	Consultants undertake the RA; the administrative authorities approve the RA results. These results can lead to remediation and/or monitoring.

Table 9: Risk assessments (continued)

Country	Role of RA	Different levels/stringencies	Role of limit values in RA	RA results RA procedures
Germany	Risks considered in terms of pathway models		Trigger values indicate more investigation, action values indicate remediation required	RA form part of regional registers of (potentially) contaminated land.
Greece	RA used on a site specific basis	Not provided for in the legislation	OECD screening levels used where appropriate	European or US EPA approaches used
Ireland	No legislation on RA	No legislation on RA	Not used but maybe in the future	Licence conditions (Integrated Pollution Control Licence or Waste Licence) may be based on a RA.
Italy	Site specific RA to allow for residual concentrations higher than generic limits	Higher levels may be permitted where generic limits are not achievable (following BATNEEC)	Generic limits are used; if exceeded the site must be remediated. Higher levels may be permitted by site specific RA	Municipal authority evaluates the RA. Reports are kept with local planning records, except for sites of national interest when central government is in charge.
Netherlands	Specific RA used to assess the urgency of the remediation.	Different levels and stringencies are provided for depending upon the end use.	Generic values used at first stage	Consultants undertake the RA; the province must approve the RA results and proposed solution
Norway	Site specific RA	Different levels and stringencies are not considered in the legislation but may be used.	Generic values used at first stage, operative limit values are used on a case by case basis	RA are the basis for decisions. Filed with other site information. No specific procedures.
Portugal			US EPA and Canadian criteria used where appropriate	No specific procedures at present

Table 9: Risk assessments (continued)

Country	**Role of RA**	**Different levels/stringencies**	**Role of limit values in RA**	**RA results** **RA procedures**
Spain			Limit values are under development	No specific procedures at present
Spain (Catalunya)	RA identifies if risk is acceptable		Soil Quality Values are fixed for industrial and non-industrial uses. If exceeded then more investigation is indicated.	No specific procedures at present. Consultants carry out RA, which is considered in defining remedial objectives
Sweden	Hazard and RA use guideline and reference values.		Guideline values are given which must not be exceeded. Reference values indicate 'natural' background levels (natural levels + general pollution).	
Switzerland	Specific RA needed at all stages	Different levels of input data at different levels of investigation	Limit values indicate the need to monitor or remediate a site	Local authorities use the results on a case by case basis; they notify the Federal Agency of remediated sites and measures undertaken
United Kingdom	RA determines that risk at a site is acceptable according to 'fitness for purpose' principle.	RA is used for historic contamination, recent contamination must be remediated to pre-pollution standards.	Not used. Source-pathway-receptor principle used.	RA carried out by developers consultants, by the regulatory agency in the case of an orphan site or in the case of a regulatory action.

Examples of Approaches to Risk Assessment from the WG2 Survey Box 6

Belgium (Flanders): Fixed, generic and/or other limit values play a role in decision making; soil standards are set for five different land use types (and varying with Soil Organic matter and Clay content): - a. Natural; b. Agricultural; c. Residential areas; d. Recreational Areas; and e. Industrial areas. When the limits are exceeded on a recently contaminated site (post 28/10/95) remediation is obligatory; for old sites remediation is obligatory only if the risk is not acceptable.

Legislation and regulation in Flanders do not provide for different levels/stringencies of risk assessment. In case of uncertainty about important parameters, however, additional measurements can be demanded. According to land use (and water use) type, different scenarios for receptors are defined, resulting in different concentrations of contamination that are may be acceptable without posing a risk.

France: French policy is characterised by two successive steps of assessment, a simplified risk assessment (SRA) and a detailed risk assessment (DRA). Generic and/or limit values are used in the SRA to score the level of expected impact as a function of future land use. National guideline values have been defined for two end uses (sensitive (residential) and non-sensitive (industrial) uses). Guidelines are calculated from the main exposure pathways (soil ingestion and soil contact and by vegetable ingestion for sensitive use). In the first step of the risk assessment (SRA), only risk for humans and water resources are considered. If a site is found to be in Class 1, a second step is then needed. At this level a quantitative assessment is conducted, taking into account specific receptors such as human health, water supplies, ecosystems and buildings.

4.2.3 Special Provisions for particular situations

Aquifer Considerations

There is a considerable body of legislation and regulation relating to the protection of water and water supplies across European countries, mainly enacting EU Directives. The focus of the regulation varies from country to country, depending upon the extent to which sources of water supply are seen as coming from surface or groundwaters. There is legislation in all countries in relation to drinking water quality, and this is commonly linked to both current and potential sources. The potential link between soils/soil processes and water quality is identified in a limited number of countries. There is regulation in relation to soil uses in broad terms, but only limited regulation that addresses specific soil uses.

Examples of Aquifer Considerations **Box 7**

Belgium (Flanders): Groundwater vulnerability is taken into consideration when assessing the need for site remediation

UK: The Water Resources Act (1991) and the Groundwater Regulations (1998) regulate Protection of controlled waters (surface and groundwater). Abstraction of water requires an abstraction licence, and discharges of or to water to the environment require a discharge consent.

Brownfield Sites

The concept of brownfield sites is relatively new in many countries, however there is an increasing awareness of the nature of brownfield sites and the need to be able to evaluate the risks at these sites to determine the requirements for remediation and their potential future uses. Some countries have legislative programmes, or legislation is planned to consider brownfield sites. In some countries there are financial incentives for the successful development of these sites.

Example of Approaches to Brownfield Sites from the Working Group "Decision Support Tools" Survey **Box 8**

Belgium (Wallonia): Brownfield sites are managed by the Regional Development Administration under the Regional Planning Act and Building Code which considers rehabilitation. An environmental study is undertaken before rehabilitation involving history, soil, water and gas analysis. This information is discussed with the site owners to decide upon one of three future actions:

a. More information required; b. Continue with current actions; or c. Change site use.

Portugal: Brownfields sites are a new concept in Portugal. The industrial waste plans include a proposal to create a fund (similar to 'Superfund') to rehabilitate the identified sites.

Diffuse pollution

The respondents to the Working Group's survey reported that diffuse pollution is seldom considered (with the exception of the application of sewage sludge residues to agricultural land for which there are many national and European controls). The application of other wastes to soils is likely to be subject to controls similar to those for sewage sludge as the practice becomes more widespread. There are examples of agricultural guidance provided through codes of good agricultural practice.

The current thinking is centred on the (perhaps more visible) point source contaminated sites such as former gasworks, factories, solvent extraction and recycling plants, military sites etc. There is some movement towards dealing with the problems caused by diffuse pollution (which can range from elevated levels of lead and polynuclear aromatic hydrocarbons (PAHs) at roadsides to fall out from iron foundries and steelworks which can be spread over a wide area, kilometres from the source). The issue of diffuse pollution was discussed at the Ad Hoc Working Group meeting in Copenhagen 1999; it will probably be given more attention in the near future.

4.2.4 Wider Environmental Effects

The environmental impacts of the remediation system are considered in most countries (for example Germany, Netherlands, Portugal) but not specifically in others. This is effected in different ways. In Switzerland 'ecobalancing' is prescribed for the various possible remedial actions in order to enable selection of the option which provides optimum environmental impact. In the UK the environmental impact of remediation processes is controlled through the Waste Management Licensing Regulations.

Examples of Approaches to Diffuse Pollution from the Working Group Survey
Box 9

Denmark: Point source pollution and diffuse pollution are not differentiated in the Danish Soil Contamination Act (1999) although both are included. The Danish law considers liability, risks to the environment and costs. Danish thinking is that point source pollution and diffuse pollution are end members of a continuum.

Finland: A Council of State Decision gives general guidelines for the re-use of sewage sludge with maximum permissible concentrations of some heavy metals according to the use of the sludge (agriculture, gardening, landscaping). A Code of Practice and Guideline Values (permissible concentrations and maximum permissible solubility values) are used to assess the environmental acceptability of the use of mineral wastes (ash, slag, waste concrete, contaminated soil, etc.) in land construction.

Many countries do not formally consider sustainability and 'environmental merit' as a specific criterion for contaminated land remedy selection. Sustainability is only specifically mentioned by Switzerland, although there is an implicit recognition that sustainability is important in most countries. Consideration of wider environmental impacts (such as "environmental sustainability" and "environmental merit") is beginning to be considered in some countries (Netherlands, Switzerland and the UK); they are implicit in some aspects of the planning process. However, wider environmental effects and principles of sustainability are currently considered after the immediately important 'primary drivers' such as costs, timescales and feasibility. There are few objective criteria for judging the secondary drivers for sustainability, environmental merit, economic merit and social and community concerns.

4.2.5 Primary factors driving decision making and Support procedures

The primary factors driving decision making for risk management reported by the countries surveyed (see Table 10) are:

- Cost
- Flexibility
- Technical feasibility
- Planned site use
- Protection of people
- Protection of the environment

Cost and feasibility appear to be the major criteria in the determination of remediation and reuse of contaminated land, particularly for problem site holders. Minimisation of risk to human health and the environment are also important criteria. These factors would all be taken into consideration in the process of determining a site remediation strategy. The primary concerns and their relative rankings vary depending upon whether they are viewed from the position of the developer, the community / local authority or the regulator.

The reported procedures available to support the selection of remedial approaches for polluted sites are BAT (Best Available Technology) or BATNEEC (Best Available Technology Not Entailing Excessive Cost) principles (important in most countries) and decision support tools such as BOSS and REC (Risk Reduction, Environmental Merit, Cost) may be used in Flemish Belgium and the Netherlands, respectively. There is often recommended guidance for risk assessment and management, for example:

- The German 'Federal Soil Protection Ordinance' specifies the requirements for designing a remedial approach for polluted sites;
- In England and Wales the 'Model Procedures for the Management of Contaminated Land' will provide recommended approaches.

Analysis of the costs and benefits of the remediation work itself and the different remedial approaches that might be employed to reach a given set of core goals are also an important part of the selection procedure.

4.3 Use of Decision Support Tools

A number of individual DSTs were identified by the Working Group "Decision Support Tools" survey, by a web survey by Aquater, and from information provided by the Brookhaven National Laboratory (BNL) USA. Decision support input products such as models were also identified. By June 75 DSTs from 14 countries had been listed. This listing is not comprehensive. Figure 16 summarises the number of DSTs and models listed so far by country.

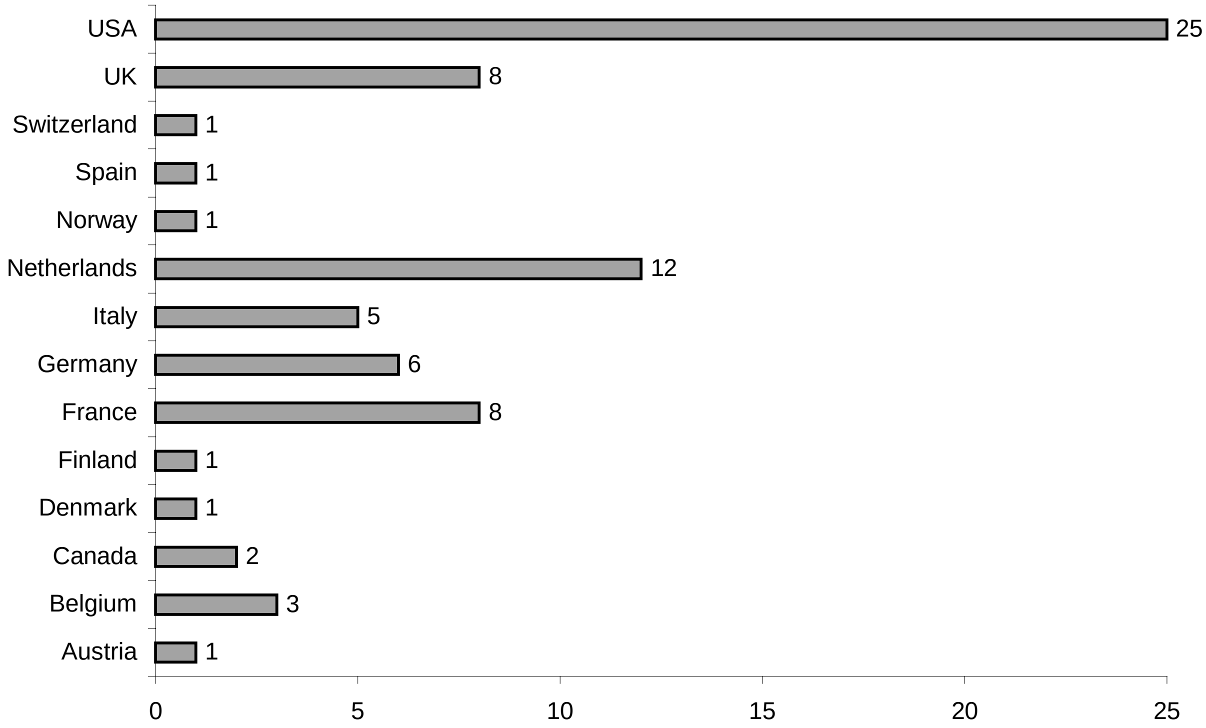

Figure 16: Distribution of DSTs and Models Identified by Country as of June 2001

The full listing is available on a web page linked to the CLARINET web site (*www.clarinet.at*) in the Section for Working Group "Decision Support Tools". The listing includes a brief description of each entry and an e-mail contact address and web link, if available. The listing includes both commercially available products and DSTs under development. For some countries it also includes written DSTs such as procedures and protocols. It is open to any stakeholder to extend the information available.

The web based listing is open to all at no cost, after registration. It is fully searchable, and can also be added to by DST developers and vendors, regulators and researchers[15]. The listing can be searched by:

- DST name
- Country
- Language (of the DST)
- The decision making role of the approach,
- Functional application, i.e. the contaminated land management application
- The analytical techniques used in the decision support approach
- The nature of the decision support product

[15] Entries can also be edited - but only by the person who made the initial entry, or by the webmaster

This web-based listing will be maintained and monitored until the end of 2001. Its future existence will depend on the interest shown in it.

4.4 Discussion of Survey Findings

The CLARINET Working Group's survey indicates that for evaluation of contamination at a single site, there is a general commonality of approach that is emerging internationally, albeit with some differences at the operational level. A similar set of management tasks has been identified for dealing with land contamination, which typically include:

a) problem identification (including historical assessment and as a result the identification of potential sites);
b) problem investigation determination of the need for remediation;
c) risk identification (actual and potential);
d) detailed risk evaluation and the identification of the remediation goal;
e) selection and implementation of remedial measures;
f) monitoring of sites following remediation and aftercare.

Although these tasks have been listed sequentially, in practice efficient implementation of the process often involves feedback and iteration between them.

A commonality of approach in contaminated land management should not be surprising. The nature of the basic steps of evaluation and remediation are determined by the practicalities of contaminated site management, which of course is not country dependent. Decision making in many countries is now increasingly seen as seeking a balance between "cost" and "benefits". 'Costs' are increasingly seen from an environmental as well as an economic perspective. In all countries, resources are limited so remediation work must show a clear balance of benefits over costs.

Although there is a general commonality in approach to contaminated land management, differences in the decision making process exists between different countries and even within different regions of the same country. When this occurs, it is, generally because of one or more of the following:

- differences in the applications of general principles (such as which receptors are to be considered);
- differences in the use of analytical techniques, datasets and assumptions;
- differences in priorities for environmental protection;
- differences in administrative approach;
- regional variation in characterisation of land, land use, society and economy
- differences in the level of regulation and guidance available.

Table 10: Primary factors Driving Decision-Making

	Costs	**Feasibility**	**Protection of people**	**Protection of Environment**	**Other**	**Risk-based remediation objectives**
Austria	considered	considered	yes	yes		
Belgium – Flanders			yes	yes		yes
Belgium – Walloon		Will be considered	Will be con-sidered	Will be considered		
Denmark	considered		yes	yes		
Finland	yes			considered	Long-term performance Reliability	
France	yes	considered	yes	Will be considered in some cases		yes
Germany				considered	Risks for soil functions	
Greece	considered	considered	yes	yes		yes
Ireland	considered	considered			BAT, BATNEEC	
Italy	considered	considered	yes	yes	Compliance with limit values	yes, in some cases
Netherlands	considered	considered		yes	Fitness of current or future use	
Norway					legislation	
Portugal	yes	yes			BATNEEC Future use	
Spain			yes	yes		

Table 10: Primary factors Driving Decision-Making (continued)

	Costs	**Feasibility**	**Protection of people**	**Protection of Environment**	**Other**	**Risk-based remediation objectives**
Sweden						
Spain (Catalunya)	yes	yes	yes	yes	Future site use	yes
Switzerland	yes	yes		yes	Sustainability Time and space constraints	yes
United Kingdom	yes	yes	yes	yes	Time, space and technical constraints, durability, effectiveness and practicability. Legislation Social and political factors	yes

Differences in priorities for environmental protection often underpin the differences in end use consideration. A major difference between countries is the way in which groundwater not currently in use is considered as a resource. This can be markedly different for countries depending on their surface water resources. More generally, while there is considerable awareness of the need to address issues of sustainability (wider economic, environmental and social effects), these are explicitly considered only in a limited number of cases.

Decision support considerations show some regional variation. These variations include: the extent to which industrialisation and industrial change has occurred, the attitude to accepting risks, differing social priorities, and the financial and technical resources that are available to deal with any problems. Both economic factors and the attitude of society to contaminated land problems determine the resources made available.

The technical state of the art in contaminated land management has moved forwards considerably since contaminated land policies in Europe such as those described by VISSER (1993) were documented. At this time the main policy discussions were on developing risk assessment and contaminated land management procedures. The developing situation in Europe in the mid 1990s was documented (MARTIN *et al.,* 1997) and subsequently by the Ad Hoc Working Group 1996 *Amsterdam Questionnaire*[16] (VISSER *et al*., 1999). This report indicated that many countries are reviewing and revising their policies to develop practical, effective approaches to the problems posed by contaminated land, i.e., to seek integrated solutions that combine environmental, socio-economic and planning viewpoints, while co-operating with market forces and a long-term perspective. The Amsterdam Questionnaire also reported an increase in the availability of published guidance for assisting in the selection of remedial options compared with a previous survey of Ad Hoc group participants.

By the late 1990s the policy frameworks in Europe were largely developed and have been described in the CARACAS publications:

"Risk Assessment for Contaminated Sites in Europe. "Risk Assessment for Contaminated Sites in Europe: Volume 1 Scientific Basis" (FERGUSON *et al,* 1998) focuses on scientific aspects of contaminated land risk assessment such as the fundamental concepts of risk assessment, receptors, site and source characterisation, transport and fate of contaminants, screening and guideline values, models.

"Risk Assessment for Contaminated Sites in Europe: Volume 2 Policy Frameworks" (FERGUSON & KASAMAS, 1999) summarises the policy backgrounds dealing with soil protection and remediation of contaminated sites and details how contaminated land risk assessment and risk management are carried out in the countries which participated in CARACAS.

[16] The Questionnaire Survey which preceded the Copenhagen information described above

This latest survey by the Working Group "Decision Support Tools" provides a snapshot of the current thinking in decision support for contaminated land management in Europe as it is probably fair to say that the group of CLARINET countries can be taken to represent Europe as a whole. Most countries now have, or are in the process of having, systems to assist in their decision-making procedures. These are currently based on the 'core' remediation objectives (as described in 2.4 above); the wider environmental, social and political effects are taken into consideration but in a non-systematic way. Work beyond 2001 will probably begin to assimilate the 'non-core' objectives into the decision-making framework in a more systematic manner. These issues will become more prominent as the importance of taking a sustainable development based approach becomes increasingly important.

5 DECISION SUPPORT TOOLS: EXAMPLES AND APPROACHES

Within this chapter are a number of case studies of decision support tools used in contaminated land decision making in different countries. These case studies have been drawn from presentations made to CLARINET, the NATO/CCMS Pilot Study Evaluation of Demonstrated and Emerging Technologies for the Treatment and Clean Up of Contaminated Land and Groundwater. Phase III 2000 Special Session Decision Support and the US EPA Environmental Technology Verification Program. Several of these DSTs apply more than one decision analysis technique, but have been arranged across categories to illustrate the range of decision analysis techniques discussed in Section 3.5.

5.1 Examples of DSTs Deriving from Environmental Risk Assessment

5.1.1 Spatial Analysis and Decision Assistance, USA (Software Product Under Development)

Spatial Analysis and Decision Assistance (SADA) is an environmental software product that incorporates tools from various fields - including visualisation, geospatial analysis, statistical analysis, human health risk assessment, cost-benefit analysis, sampling design, and decision analysis - into an interactive environment. SADA relies mainly on statistical and geostatistical algorithms (STEWART, 2000) to quantify the nature and extent of uncertainties in environmental data and various cost-risk methods to provide objective guidance on key decision analysis needs. SADA provides the information in a visual form, as two-dimensional (2-D) and three-dimensional (3-D) graphics, to assist the user in data interpretation and provides statistical information about the contamination (e.g., area or volume of contamination, standard deviation, probability of exceeding cleanup goals). SADA's assessment capabilities are:

Human Health Risk SADA provides the user with a full human health risk assessment module and associated databases. The risk models follow EPA's *Risk Assessment Guidance for Superfund* (EPA, 1989) and can be customised to fit site-specific exposure conditions. Updated toxicological databases and default scenario parameters can be downloaded over the web directly from SADA. For radioactive and non-radioactive contaminants, SADA simulates five land-use scenarios (residential, industrial, agricultural, recreational, and excavation) and five exposure pathways (ingestion, inhalation, dermal contact, external [radiation], and food consumption). The exposures resulting from different pathways and contaminants can be summed to provide total exposure from all contaminants.

Geospatial Analysis SADA provides several tools for performing geospatial analysis. These include methods for measuring spatial correlation among data, modelling spatial correlation, and producing concentration, risk, probability, variance, and cleanup maps. Among these tools are four geospatial interpolators: ordinary kriging, indicator kriging, inverse distance, and nearest neighbour. With these tools, the user can generate concentration-contour, probability, risk, and remedial design maps.

Decision Analyses SADA's decision support tools include cost-benefit analysis, defining areas of concern, and sampling optimisation. SADA produces cost-benefit curves that demonstrate the relationship between the remediation goal (concentration- or risk-based) and the cost of remediation. Based on the decision rule, SADA estimates the location of areas of concern. The decision rule includes components such as the remediation goal, the level of confidence, and whether the goal applies to the entire site or any part of the site. These areas of concern can then serve as a basis for remedial action design. SADA allows the user to choose from a variety of strategies for determining where to collect data in the next round of sampling. Depending on the chosen geospatial interpolator, the following five strategies are available: adaptive fill, estimate rank, variance rank, percentile rank, and uncertainty rank.

This technology has been independently assessed under the US EPA Technology Verification Programme (SULLIVAN *et al.,* 2000a). SADA is distributed free via the Internet - *www.sis.utk.edu/cis/SADA*.

5.2 Examples of DSTs Deriving from MCA/MAT

5.2.1 Conceptual Framework for Wider Environmental Value, UK (in development)

This project has focused on the use of a qualitative approach to the assessment of the "wider environmental value" (WEV) of remediation work. The difficulty with such assessments is in achieving objectivity, or at least a perception of fair consideration of all relevant issues. Different stakeholders are likely to perceive environmental values in different ways. Attempting to find objective measurements is one of the drivers for the use of LCA techniques in environmental decision making. However, use of LCA can be expensive and is a specialised business that may make decision making more opaque to some stakeholders, even if putatively more objective. In that case the benefit of objectivity is likely to be lost. The approach suggested by this project was to collect the input of different stakeholders at a qualitative level (BARDOS *et al.,* 2000a). Finding a consensus across these perceptions could be used as a means of gaining a degree of objectivity, at least in the context of decision making for a particular project.

Features of this approach are (i) its use of layered sets of choices to remove potential decision making conflicts, (ii) the recording of these choices as individual rankings which are combined to provide an overall ranking at the end of the assessment process; (iii) consulting more than one stakeholder to gain a degree of objectivity in the rankings, and (iv) being able to filter rankings of optimal remedial approach to use effects that are seen, for instance, as "important" or "less important", "local" or "distant", "temporary" or "permanent". The type of environmental effects that might be considered by WEV are listed in Table 11.

This premise of this type of approach is that it does not initially seek to derive a quantitative comparison based on putative environmental effects, rather it seeks to find a consensus view across stakeholder viewpoints, using a transparent and reproducible framework for supporting discussions, and a simple MCA for collating findings. Adopting this approach, only in situations where such a qualitative approach is unable to achieve consensus would quantitative methods be necessary. Furthermore, the quantitative technique need only be applied to particular points of disagreement (e.g. impacts on traffic levels, or atmospheric emissions) rather than as an across the board technique. This would allow a more transparent and accessible use of quantitative techniques, rather than an across the board application of what might seem to some stakeholders a “black box[17]”. A further advantage of the WEV approach is that it allows consideration of a wider range of environmental effects, in a form that may be more easily understood by many stakeholders. For example, (1) effects on traffic and energy use can be directly considered and not sublimated into some universal classification such as carbon dioxide emissions (2) concerns which are less tangible, but nevertheless often important can be included in the WEV assessment, such as impacts on local amenity or landscape.

5.2.2 Decision Aid for Remediation Technology Selection, Italy/UN (Software in Development)

Decision Aid for Remediation Technology Selection (DARTS) is currently being developed by the United Nations Industrial Development Organisation at ICS in Trieste Italy, in particular to support decision making in the former communist countries and the countries of the Mediterranean Basin. Its aim is to help decision makers (site owners, local community representatives, environmentalists, regulators, etc.) identify and rank remedial options for particular sites. Identification of options is based on a decision tree, effectively a sequential progression of choices that can be made for particular site conditions.

The assessment is based on technical, financial, environmental, and social criteria. Rankings are based on stakeholder views of the relative importance of different criteria for a particular project. A multi-attribute / MCA technique is then used to combine how particular techniques compare with each other for each criterion, with stakeholder views about the relative importance of these criteria for their project (LODOLO, 2000).

Views on the relative importance of decision making criteria can be collected from a number of stakeholders, for example: consultants, environmental managers, technology providers, policy makers, local community representatives. A “preference function” is then used to determine a weighting for each criterion based on these view-

[17] I.e. a system into which data and information are pumped in, and an analysis is pumped out with no clear understanding of what has happened in the analytical process.

points (alternatively a user can use default values in the system). The weighting can be changed to assess sensitivity of solution or to reflect different opinions.

The DARTS software draws upon a database of criteria derived for a series of remediation techniques. These criteria are valued on a comparative basis using a numerical rating of 1 (= better), 2 (= average) or 3 (= worse) for each technology. Costs for each technique, duration, ability to reduce particular contaminant concentrations, reliability and maintenance, and public acceptability are provided as ratings. For example, cost ratings used are: 1= Less than $110/metric tonne; 2= $110 - $330/metric tonne; and 3= More than $330/metric tonne. The assessment algorithm used is an “outranking” method - *PROMETHEE* - (BRANS & VINCKE, 1985) which orders the possible decisions in order of their likely acceptability to stakeholders. The algorithm returns a value that represents the “intensity of preference”.

Table 11: Summary of Categories that might be Considered in an Assessment of Wider Environmental Value (BARDOS et al., *2000)*

Theme	**Main Categories**
Aggravation Factors	• Impacts of materials and organisms added during remediation • Impacts of remediation by-products and emissions • Impacts of vehicular traffic • Noise and vibrations • Intrusiveness • Impacts of remedial operations on local amenity value
Air and Atmosphere	• Impacts of substances added during remediation • Impacts of remediation by-products and emissions
Water Function	• Impacts of substances added during remediation • Impacts of remediation by-products and emissions
Ground Function	• Impacts of substances added during remediation on soil systems • Impacts of added organisms on soil systems • Impacts of process by-products and emissions on soil systems • Impacts of the intrusion or exclusion of water • Soil resource depletion (e.g. organic matter, soil structural water) • Impacts on soil mineralogy of remediation work • Impacts on subsurface structure of remediation work • Changes in soil function

Table 11: Summary of Categories that might be Considered in an Assessment of Wider Environmental Value (BARDOS et al., *2000) (continued)*

Theme	**Main Categories**
Legacy	• Impacts on landscape • Impacts on the built environment • Infrastructure changes • Waste generation • Functionality of the site (e.g. restrictions on site use and possible need for future remediation) • Fate of treated contaminants (destruction, versus removal, versus containment /stabilisation , permanence of the solution) • Need for long term care • Benefits following remediation
Resource and Energy Use	• Use of water, taking into account its scarcity • Availability of the treated land area for use • Recycling / Recovery (water, energy and material resources) • Waste minimisation • Use of material resources by the remediation work • Use of energy • Use of landfill resources, taking into account regional availability • Use of energy and materials resources for aftercare
Conservation	• Impacts of organisms added during remediation (e.g. bacteria, fungi, plants) on ecosystems • Impacts on the "quality of nature" • Conservation of the built environment and of landscape (historical buildings, archaeological sites etc)

5.3 Examples of DSTs Deriving from CBA/CEA

5.3.1 The WILMA System for Cost benefit analysis / multi -criteria analyses for a remediation project, Germany (Software Under Development)

The WILMA system has been developed for the German Higher Finance Office (OFD). It is intended to support selection of the optimal approach to site remediation on the basis of both economic and “ecological” considerations (WETH, 2000). The technical rationale for WILMA was developed by a research and development project of the

Federal Environmental Agency, Germany (UBA) on these wider economic and environmental issues (GRIMSKI *et al.*, 1998, Federal Environmental Agency, 1999). WILMA provides two values whose application is illustrated in Figure 17:

- A dynamic cost efficiency calculation considering also – expressed in monetary terms – the loss of use of a contaminated site and the duration of the remediation measure, and
- An analysis of the ecological effects of a remediation scheme.

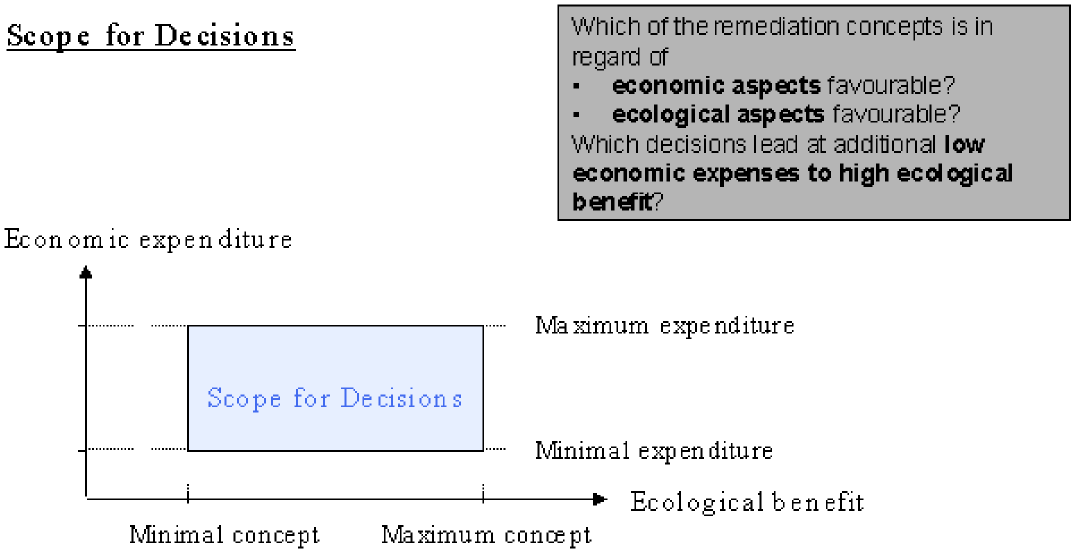

Figure 17: Decision Making with WILMA (WETH, 2000)

WILMA is based on the premise that it is only considering options that will achieve desired risk management goals. Costs are calculated on the following basis of Table 12. Ecological effects are valued on the basis of "primary" and "secondary" effects, as shown in Figure 18. Primary effects are defined as those which can be measured in the immediate vicinity of the site. The secondary effects are defined as those that have a regional effect.

With WILMA different use scenarios can be simulated in connection with location specific factors: "children's playground", "living use, general", "park/public green space", "fallow area" and "industry and trade area".

At present WILMA contains data for around 20 of the most common remediation methods. Its database is designed so that it can be adapted for different regional conditions.

Table 12: WILMA Cost Calculation Basis

Value level	**Description**	**Process**	**Efficiency calculation approach**
Cost level	Costs of the remediation process	Comparative cost method	static
Expense level	Benefit due to increased value of decontaminated site	Comparative profit method	static
Investment level	Costs due to different lengths of time needed for remediation	Capital value method	dynamic

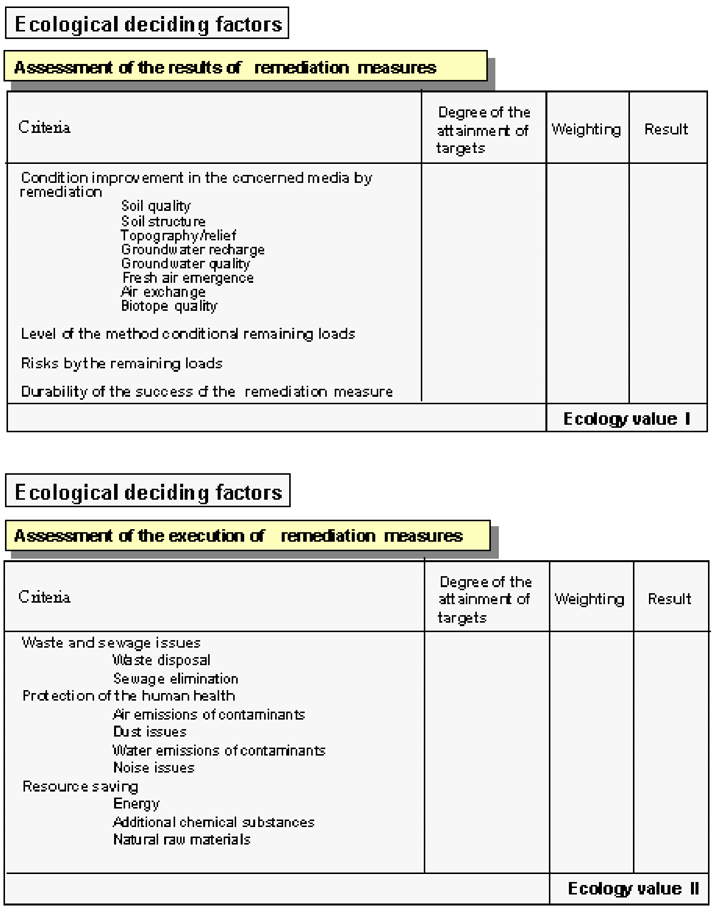

Figure 18: Primary and Secondary Ecological Effects in the WILMA Approach

5.3.2 The Land Value Balance, Germany

Under a research and development project commissioned by the German Federal Environmental Agency, an assessment system (Land Value Balance) has been developed for a holistic appraisal of the exploitation of both brownfield and greenfield sites (GRIMSKI, 2000, Federal Environmental Agency, 1999 and 2000). This technique widens the economic criteria typically considered by CBA to account of the social dimension of land depletion in particular. It quantifies the individual qualities of the sites from the points of view of local authorities and investors, as well as their significance with regard to ecological issues, urban development and regional structure. Monetarisation of the assessment criteria makes it possible to undertake a direct comparison of the relevant site attributes and the costs and revenues, in order to document as costs the actual consequences of using the land for commercial purposes.

In order to systematise the complex structure and permit an overall portrayal of the individual aspects, three assessment perspectives are used. The basic premise is that every site has a greater or lesser basic suitability for safe use as an industrial site. This basic suitability is assessed from three different points of view, that of: the local authority and the investor, and society. The assessment groups follow a different fundamental approach in each case as they are based on specific individual interests.

Local authorities and investors value a given site on a target-oriented basis with regard to its economic value, and hence specifically with regard to its marketability and suitability as a commercial site. The social significance of greenfield and brownfield sites considers sites both in terms of their ecological significance and as part of a structured system with urban development and regional structure aspects.

In order to take appropriate account of these different levels of demand, the value attitudes of the individual target groups are clearly distinguished from one another in the following three assessment groups:

- Site potential: Basic suitability for use as a commercial site from the local authority point of view;
- Use potential: Suitability of site for safe commercial use from the investors' point of view;
- Site value from a social point of view.

Site value from a social point of view is itself further divided into three assessment subgroups:

- the Ecological value is based on the importance of the site for the natural regime;
- the Urban development value is defined as the "importance" of the site for the municipal situation and development;
- the Regional structure value addresses the "importance" of the site from the point of view of ideas about the organisation and development of regional structure.

These three subdivisions are subjected to a before and after comparison. The scale of impacts is determined by the extent to which the value of the impact structure and its components differs before and after commercial exploitation; it is denoted as the “site value delta”.

Site potential, use potential and site value are specified by a set of 26 criteria. Each of the 26 criteria is first assessed on a five-point or three-point value scale. Allocated weighting factors are then applied to each of the criteria according to the relative importance.

A monetary value for each of the 26 criteria is calculated. Because there are no market prices either for the natural assets concerned or for the urban development and regional structure aspects, monetary equivalents have been determined by analogy with the market. This cost approach expresses each of the 26 assessment criteria and each score on the five-point scale as a specific value with the unit DM/m² that can be directly compared with the individual site preparation costs.

The approach was tested in practical usability trials at local authority level. This study found that local authority staff found this tool a practical one to use, and that it brought greater transparency to site decisions and their rationales, for example with regard to sustainable regional development.

5.3.3 Methodology for Assessing the Full Costs and Benefits of Groundwater Remediation, UK (Procedural Guidance)

Recognising the need to take account of the likely costs and benefits in enforcing groundwater remediation (Environment Act, 1995), the Environment Agency in England and Wales has recently published a framework for assessing groundwater remediation alternatives (Environment Agency, 2000).

This CBA methodology is linked directly to existing UK guidance on risk assessment for contaminated sites. The approach is iterative, starting with high level analysis of the likely costs and benefits of remedial objective options and the technical approaches, which are best suited for reaching those objectives. The benefits analysis includes both private benefits, and if possible wider external benefits (often described as the value of damage averted by taking action). Valuation of external benefits of remediation is not straightforward, and can include the value of damaged resources, option values, and intrinsic worth (existence and bequest values). Often, only partial monetisation of some benefits can be practically achieved. However, benefits can be compared with expected annualised costs for achieving overall specific remedial objectives, allowing a preliminary identification of the economically optimal objective. The framework provides a tool that allows the Agency to “take account of likely costs and benefits” in exercising its statutory powers, and with which firms and regulators can negotiate a position that balances their respective concerns (social optimum against private optimum). Once the remedial objective has been set, and with it the most economically attractive approach, technology selection becomes merely a least-cost analysis. In many cases, the hidden costs of certain remedial objectives and approaches are revealed.

5.3.4 Cost Benefit Analysis for Remediation of Land Contamination, UK (Procedural Guidance)

This DST is a procedure intended to support the selection of the most appropriate means of remediation to reach a particular set of risk management objectives (Environment Agency, 1999). It is intended to follow the selection of a short list of potential remediation techniques. The procedure can be followed through increasing levels of complexity depending on need. The first stages are screening and qualitative analyses. The third stage is a MCA with an associated CEA. The fourth is a CBA. Decision makers would only proceed as far as needed to clearly identify the most favourable remediation approach. Sensitivity analyses are used as means of checking that the procedures findings are not unduly influenced by specific assumptions and value judgements.

Impacts and benefits are assessed in the following four broad categories, and compared with the projected remediation costs of the remediation work: human health, environment, land use, and third party or stakeholder concerns.

Screening Stages This first step is intended to ensure that all significant impacts have been considered in sufficient detail, and to determine the level of complexity of the analysis required.

Qualitative Analysis A summary table of the factors for each theme is drawn up. Factors are considered in rows and remedial options in columns. Summary tables are drawn up considering the site before remediation, during remediation and after remediation. At this point entries to the table consist of *yes* (there is a *significant* impact); *yes?*; *no*; and *no?*. “Significant” is defined as an “impact that is noticeable”. The subjectivity of this definition is dealt with by suggesting that the views of “other stakeholders” should be sought.

Combined MCA/CEA This stage expands the summary tables of qualitative analysis into individual tables for each theme (e.g. environment). Scores are assigned for each option between –100 to +100. No explicit means of deriving scores (e.g. based on LCA) is put forward. Rather scores are derived by a value judgement based on available information. For example, considerations might include for groundwater quality the issue of residual contamination, with the possibility of residual contamination leading to differences in score of 5 to 20 “points”. The scores can also be given uncertainties e.g. +/- 10 points, which are derived on a similar basis. The score for each theme is summed, with a maximum range of –600 to +600 possible for the environment theme. –400 to +400 is possible for “risks to the public”. These scores are then normalised to –100 to +100 for each theme (e.g. by dividing by 6 for the environment theme). Scores for themes can then be summed to give an overall score across all themes.

The procedure also allows for the weighting of normalised scores, e.g.:

Total = 1.0 x "risks to public"
0.8 x "environment"
0.6 x land use
+ 0.4 x stakeholder concerns
Total score

Dividing the total MCA score by the remedial option cost is used as a measure of cost-effectiveness for ranking options.

CBA The CBA is based on replacing the various MCA scores with more formal valuations. A number of suggestions are provided for deriving these values.

5.3.5 *Environmental Visualization System Pro,* USA (Commercial Software Product)

Environmental Visualization System (EVS-PRO) unites interpolation, geostatistical analysis, and fully three-dimensional (3-D) visualisation tools into a modular software system. This was developed to address, among other things, sample optimisation and cost-benefit analysis. EVS-PRO's capabilities can be used to provide 3-D maps of geologic structure, subsurface contamination, and regions containing contamination above specified threshold levels at a fixed probability level. EVS-PRO can also perform geostatistical analyses that suggest optimal sample locations for site characterisation and can estimate volumes and mass of contaminated media for use in cost-benefit analysis. EVS-PRO can quantify the statistical variation in the contaminant volume and mass estimates resulting from the current extent of characterisation. EVS-PRO was developed to meet the needs of the geologist, the environmental engineer, and the environmental program manager as they relate to the following areas:

Site assessment: Determination of optimal locations for collecting data in order to best determine the spatial extent of contamination at the lowest possible cost.

Site evaluation: Determination of the spatial extent of contamination. EVS-PRO's "Min-Max Plume" technology quantifies the statistical variation in the volume and mass estimates resulting from the current level of characterisation.

Geology: Creation of a 3-D model of the geology of a site and determination of the relationship between the geology and the contaminant plumes. This information allows for better-targeted remediation plans that consider the effect of geology on the migration and capture of contamination. EVS-PRO can also compute plume volumes and masses on a (geologic) layer basis.

Communication: Visual presentation of site geology and contamination is critical for effective communication. EVS-PRO can integrate geologic information, environmental contamination data, site maps (showing buildings, roads, and other features), and aerial photographs into a single visualisation. EVS-PRO provides both still and animated 3-D visualisation.

This technology has been independently assessed under the US EPA Technology Verification Programme[18] (SULLIVAN *et al.,* 2000d).

5.4 Examples of DSTs Deriving from LCA

5.4.1 Environmental and Economical Evaluation and the Optimising of Contaminated Sites Remediation, Denmark, Norway (Project Specific Tool)

The Danish National Railway Agency and The Danish State Railways carried out the development project "Environmental and Economical Evaluation and the Optimising of Contaminated Sites Remediation" from 1997-2000 (ELLEFSEN *et al.,* 2001). The project had a budget of 16 million Dkk, and was financed by EU's Life programme (NO.Env96/Dk/0016) and The Danish Environmental Protection Agency's "Programme for the Development of Technology, Soil and groundwater Contamination".

The project developed a methodology that includes the total environmental costs and benefits as decision parameter - together with traditional parameters time, finances and function. The methodology developed for environmental assessment includes both general and detailed evaluations, including overall evaluations illustrating remediation costs and benefits. The detailed Environmental Assessment includes evaluating resources, environment and human beings. The general environmental assessment can be used for the selection of remediation strategies, while the detailed assessment is used for documentation of the chosen strategy. The method is based on simplified assessments of the life cycle of the materials and processes, which are part of a remediation project. The expected environmental costs are compared with the expected environmental benefits resulting from the completion of the specific remediation project. The method has been tested in a number of demonstration projects where increased knowledge regarding the optimisation of the chosen remediation methods has been gained.

5.4.2 The REC System: Risk Reduction, Environmental Merit, Costs, The Netherlands (Procedural Guidance)

LCA and MCA/MAT techniques have been applied to considering wider environmental impacts in the Dutch "REC" system (NOBIS, 1995a, b), which provides decision makers with an illustration of likely costs, wider environmental effects and risk reduction benefits from different remedial options under consideration for a particular project. Figure 20 (OKX, 2001) provides an example of the REC results for three remedial options for a polluted site:

The MF option (multifunctional option: soil excavation and groundwater extraction) provides high risk reduction and environmental merit at high costs.

[18] The CBA mechanism is not reported in detail by this report.

The ICM option (Isolation and Control Management) has a much inferior risk reduction, a negative environmental merit balance, but is the cheapest option.

An *In Situ* option (biological remediation) provides high risk reduction, intermediate environmental merit performances at rather low costs.

The selection of a remedial alternative is a multipurpose problem. Ideally, the alternative selected is that which maximises risk reduction and environmental merit and minimises costs. However, in practice such an alternative is rare, and therefore the final selection is usually based on weighing the advantages and disadvantages of each remedial alternative.

The REC methodology yields the information required for such a weighing. The indices for R, E and C:

- indicate the main consequences of remedial operations in a simple, direct manner;
- introduce a structure to the decision-making process;
- clarify the situation for the decision-makers and therefore make it easier for them to arrive at their decision.

The final quality of the remedial alternative in a certain decision context is a function of the R, E and C indices as well as other factors not associated with the REC methodology. This function may either be determined explicitly or will implicitly play a role in the consultations held between different participants in the decision making process.

The REC methodology is also being applied in further DST developments, for example "Phyto-DSS". This tool is being developed in an EU supported project. Its aim is to support the assessment of the potential of phytoremediation in the management of heavy metal polluted soils. This DST is outlined in an Annex to this report (Annex B).

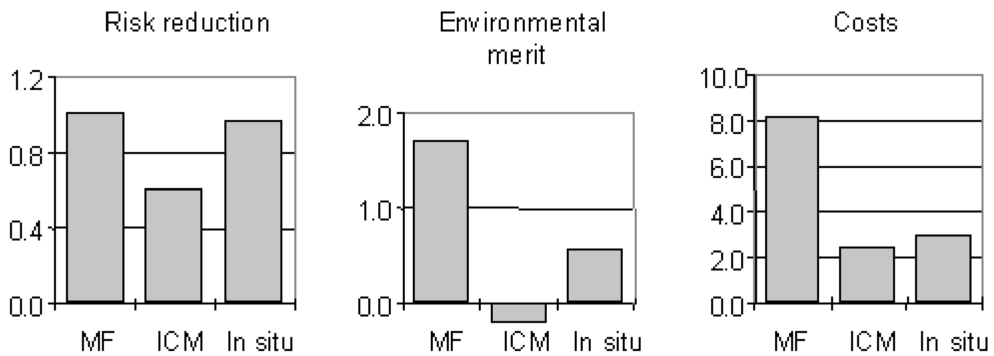

Figure 19: The indices for R, E (both dimensionless) and C (in millions of guilders) in the Example case

5.4.3 Environmental Balancing of Soil Remediation Measures, Germany (Available Software Tool)

The German state Baden-Württemberg has supported the development of a LCA based tool for the evaluation the potential environmental impacts of soil remediation options (BENDER *et al.,* 1998, VOLKWEIN, 2000), and in 1999 released a software tool "Umweltbilanzierung von Altlastensanierungsverfahren" or "Environmental balancing of soil remediation measures". This tool links typical environmental data for a range of remediation unit processes these process data to generic LCA data and to a LCA model. The calculation of the life cycle impact assessment is automated. Results of the life cycle impact assessment and the life cycle inventory are transformed to a "disadvantage factor table". The aim of this tool is to rank remedial options for a particular risk management problem in order of the calculated "secondary" environmental effects, i.e. their non-core environmental effects as described in Section 2.4.

The tool is modular, based on a database of generic life cycle inventories (LCIs) for some 60 unit processes used in remediation projects, for example:

- Mobilisation / demobilisation of equipment;
- Transport of persons;
- Drilling and well construction (including consumption of material);
- Discharge to groundwater;
- Groundwater treatment by air stripping;
- The data for the LCIs is based on "average" equipment and services.

5.5 Other Decision Support Tools

This section lists examples of DSTs used for archiving and integrating information, for the visualisation of information (not strictly a DST function) and procedures to ensure reproducible decision making. This section also includes specialist decision support tools, for example to assist in developing site sampling strategies.

5.5.1 The "Model Procedures", UK (Procedural Guidance)

When published, the Model Procedures will set out good practice for the overall process for managing contaminated land (DEFRA and Environment Agency, *in preparation*). They combine the tasks carried out when dealing with land which is, or may be, contaminated into a sequence of risk based steps. This framework incorporates existing good technical practice for assessing and managing the risks associated with contaminated land into a systematic process for identifying, making decisions about and taking appropriate action to deal with the contamination in a way that is consistent with UK legislation. The three primary model procedures are:

- Risk assessment;

- Evaluation and selection of remedial measures;
- Implementation of risk management actions.

These primary procedures are part of a hierarchy of documents, which increases in complexity and technical detail at each tier. They are to be supported by supporting secondary model procedures (e.g. Verification of remedial treatments for contaminated land) and technical guidance / reports.

5.5.2 SitePro™, USA (Commercial Software Product)

SitePro™ provides environmental decision support by integration of data from multiple sources (spreadsheet, drawing, and database files) into a platform that supports query operations, data manipulation, and visualisation. SitePro places the information into a visual context through two-dimensional (2-D) mapping of data and surface features. SitePro allows analysts to manage and share their site data using a single file.

SitePro's specific features are categorised as mapping, site assessment and characterisation, and data presentation and reporting. SitePro maps site and facility features using CAD and GIS features. Enhancement of an existing site map or site feature is accomplished with SitePro's map drawing and generation tools. SitePro supports field data entry and analysis to make field decisions. Users can generate contour maps during soil and groundwater investigations and soil-gas surveys. Hydrographs and chemical concentration curves can be generated with SitePro's graphing tool. Report-ready boring logs, well construction logs, and geologic cross-sections can be generated during site characterisation activities to improve site understanding. This technology has been independently assessed under the US EPA Technology Verification Programme (SULLIVAN *et al.,* 1999a).

5.5.3 ArcView® GIS, USA (Commercial Software Product)

ArcView® GIS version 3.1 is also a computer-based tool for mapping and analysing processes and events that are related by their location. Geographic information systems (GIS) technology integrates common database operations, such as query and statistical analysis, with the visualisation and geographic analysis benefits offered by maps. ArcView integrates data from multiple sources (i.e., spreadsheet, drawing, and database files) into a platform that supports query operations, data manipulation and visualisation. ArcView can generate two-dimensional maps of data and surface features. The 3D Analyst extension provides the capability to layer two-dimensional maps to provide a quasi–three-dimensional representation of site features (e.g., geologic layers, contamination). This technology has been independently assessed under the US EPA Technology Verification Programme (SULLIVAN *et al.,* 1999b).

5.5.4 *SamplingFX,* USA (Commercial Software Product)

SamplingFX is a geostatistics-based software program intended to provide decision makers and analysts a means of evaluating environmental information relative to the nature and extent of contamination in surface and subsurface soils. Key attributes of the product include the ability to delineate, provide visual feedback on, and quantify uncertainties in the nature and extent of soil contamination (e.g., concentration distribution, probability of exceeding a soil cleanup guideline); to provide objective recommendations on the number and location of sample locations; and to provide statistical information about the contamination (e.g., average volume of contamination, standard deviation, etc.). This technology has been independently assessed under the US EPA Technology Verification Programme (SULLIVAN *et al.,* 2000c).

5.5.5 *GroundwaterFX,* USA (Commercial Software Product)

GroundwaterFX is a decision support system intended to provide decision makers and analysts a means of evaluating environmental information related to the nature and extent of contamination in groundwater. Key attributes of the product include the ability to delineate, provide visual feedback, and quantify uncertainties in the nature and extent of groundwater contamination (e.g., concentration distribution, probability distribution of exceeding a groundwater cleanup guideline); to provide objective recommendations on the number and location of sampling points; and to provide statistical information about the contamination (e.g., average volume of contamination, standard deviation, etc.). This technology has been independently assessed under the US EPA Technology Verification Programme (SULLIVAN *et al.,* 2000b).

5.5.6 Example of an Industry Sector Based Procedure (Procedural Guidance)

The European oil industries have also developed approaches to decision-making. The CONCAWE[19] have developed procedural guidance for the risk based assessment of contaminated sites. CONCAWE report that single screening values for each contaminant must necessarily assume the most severe exposure conditions, i.e., "conservative multi-functionality". Thus it is important to develop a range of scenarios that are closer to the likely exposure to potential receptors and so determine a different set of RBSLs for each scenario. The user of the RBSLs should evaluate which set to use in their risk assessment. In addition, RBSLs can be used in the Site Conceptual Model to eliminate areas that represent no significant risk

The CONCAWE guidance is a three-tiered approach to corrective action decision-making. Tier One describes the initial assessment of the site, which involves gathering general data including potential sources of contaminants, obvious evidence of con-

[19] CONCAWE is the The CONservation of Clean Air and Water in Europe industry network or "the European Downstream Oil Industry's Organisation for Health, Safety and the Environment), *www.concawe.be*

tamination, land use, presence of potable groundwater, etc., and identification of the pathways by which contaminants could reach populations and environmental receptors. The chemical data is compared with Risk Based Screening Levels (RBSL) – a conservative set of trigger values for soil and groundwater which, if exceeded, indicate that further study is required - and any other relevant criteria. Tier Two and Three are refinements of the process which take into consideration site-specific details, including identification of potential environmental and human receptors and possible pathways. These pathways are then modelled to prepare quantitative risk estimates that can be compared with acceptability criteria. There is an option at the end of the tiers to develop a corrective action programme based on remediation to the newly derived Site Specific Target Levels (QUERCIA & MARIOTTI, 1998).

5.6 Portability of Decision Support Tools

Although there is a general commonality in approach to contaminated land management, differences in the decision making process exists between different countries and even within different regions of the same country. When this occurs, it is, generally because of one or more of the following:

- differences in the applications of general principles (such as which receptors are to be considered);
- differences in the use of analytical techniques, datasets and assumptions;
- differences in priorities for environmental protection;
- differences in administrative approach;
- regional variation in characterisation of land, land use, society and economy.

These differences tend to mean that decision support tools intended for an operational application are not always directly transferable from country to country. Another important reason that DST are not always transferable between countries is that it may be difficult to judge the suitability and quality of the tool for use in a different country unless the tool has received extensive documentation, application, verification testing and peer review in that country. Table 13 presents the key transferability issues, providing examples in terms of analysis of soil or groundwater contamination. However, the major issues still apply to other types of analysis (e.g. Life cycle analysis, multi criteria analysis, etc).

Differences in applications of general principles can, for example, include whether or not ecological impacts are explicitly included in guideline values. Other differences include the characterisation and treatment of uncertainty in the decision process and how end uses are categorised and then considered for risk assessment tools.

Table 13: Issues in Portability of Decision Support Software Tools Between Countries (US EPA, 2001)

Criteria	**Issue for Portability**
Documentation of models and assumptions	Are the model assumptions reasonable and appropriate? Analysis of environmental problems requires conceptualisation of the 'real world' into a conceptual model that permits analysis using a computer. This conceptualisation process involves a number of assumptions. It is important for the models and assumptions to be thoroughly documented to permit an evaluation of the models relevancy to specific problems.
Multiple lines of reasoning	Can the model address uncertainty in data and model parameters? The variability in natural systems makes analysis difficult. Often, multiple approaches can be used to define the extent of contamination. Models that can easily provide multiple realisations of the problem can help address uncertainty issues.
Applications on similar problem	Has the model been successfully used for similar applications? Successful application of a tool on similar problems can build confidence in the tool.
Validation / benchmarking	Has the model been validated or benchmarked? Comparison of model predictions with analytical solutions (validation) and predictions of other accepted models (benchmarking) can build confidence in the model.
Ease of use	Is the software easy to use? Some software has features that improve the usability of the product. For example, it is advantageous to use software that allows data to be imported or exported in many formats, to write scripts to perform repetitive tasks, to generate reports, to document all model parameters, and to generate hardcopy graphics and visualisations. Software that is easy to use is more efficient at using the analyst's time.
Training and technical support	Are training and technical support available? Many of the DS tools require specialised expertise (i.e., flow and transport modelling, geostatistics, human health risk). Training and the availability of technical support to address non-routine issues are crucial for effective use of many tools.
Efficiency and range of applicability	Is the model flexible enough to handle other problems that you might encounter in the future? Some DS tools are limited to specific problems or a narrow range of problems while others can simulate a wide range of problems. The tool must be applicable to the set of conditions anticipated for the analysis.

In addition, DST are not always transferable between countries because it may be difficult to judge the suitability and quality of the tool for use in a different country unless the tool has received extensive documentation, application, verification testing and peer review in that country.

6 DISCUSSION: DECISION SUPPORT AND RISK BASED LAND MANAGEMENT

Risk Based Land Management (RBLM) is a strategy for contaminated land management in which environmental risks are assessed and minimised. RBLM, as used by CLARINET, is a phrase with a broad meaning. Its three main components are defined thus (VEGTER *et al.*, 2001):

Risk describes the possibility of any adverse environmental effects from contamination. The aim for sustainable contaminated land management is to decide what risk is unacceptable and when and how to reduce it. Risk reduction is used in order to return contaminated land to an economically viable condition.

Land represents an area with geographical boundaries – it is assumed to be an area such as a single industrial site, or a region such as municipality. In this sense, land includes groundwater as contaminated land can impact on ground and surface water and vice versa.

Management is a set of activities involving decisions about issues such as assessment, remediation, land-use restrictions, monitoring, spatial planning, and aftercare. In the context of risk management it is a much broader activity that 'selecting a remedial technique' - it includes all aspects of developing and implementing a sustainable approach.

CLARINET's general approach is that Risk Based Land Management is a framework for the integration of two assessments:

- The timetable for remediation: Priority setting based on current risks and Society's needs to change the use of contaminated land.
- The design of the solution: to meet all requirements in a sustainable way, including environmental effects, available space and facilities, local perceptions and other issues.

The two key strands of RBLM are the time frame for remediation and the choice of solution. These strands are independent and have a strong bearing on both risk management decision making and implementation as the range of available solutions is almost always critically dependent on the time available for the risk management to become effective.

The critical considerations in the choice of solution have already been discussed above. What is interesting is the linkage of the choice of solution with the time frame for remediation. Solutions can be considered in terms of: the urgency of the action and the time available for a risk management process to be effective. These considerations are often linked. For instance, actions may be urgent because:

Risk assessment indicates a severe problem.

The site owner has their own pressing need for a project to take place, for example the site is to be redeveloped and sold, the site owner wants to rapidly increase the value of his property portfolio, or a site owner wants to deal with the negative impact on his business of a particular environmental problem.

There are pressing social reasons for re-use of land, for example for social regeneration of a deprived area.

The urgency of a site remediation is therefore a function of one or more of these environmental, economic and social factors, and for most large projects a function of a combination of all of them.

The Public and Private Sector resources that can be directed towards contaminated land management are finite. Indeed they are often relatively limited, and to increase them would not be a sustainable development as they would be withdrawn from other deserving problems, or might be crippling for the businesses concerned. As resources are limited, dealing with risk management problems may need to be **prioritised**, so that the most urgent solutions are dealt with first.

However, it may also be prudent not to rely strictly on urgency as a means of ordering contaminated land decision making and action. As a rule of thumb, the greater the amount of time available for remediating the site, the greater the range of applicable solutions, and the greater the feasibility of low cost long term (**extensive**) solutions (reviewed in VIK *et al.,* 2001). There are several consequence of this line of reasoning, as follows.

1) While the most urgent sites should clearly be dealt with first, and perhaps command the lion’s share of resources, all of the sites prioritised will have significant problems, otherwise they would not have been “detected” as risk management problems. There may be a case for investing the remaining budget in lower cost longer term solutions for some of these less urgent sites. Potentially, these sites could be treated by the low input approach in the same time frame as if action had been delayed until resources for a more intensive remediation approach had become available.

2) In some cases the risk management solution is effectively “postponed”, for example, an industrial site owner may be aware of contamination on site that does not pose a problem under its current use, but would preclude his site being sold in the future for other uses. In this situation there may be an opportunity to apply an extensive treatment solutions to risk management problems, such as monitored natural attenuation, so that the sites risks have been managed for a broader range of uses of the lifetime of its current industrial use.

3) The technical solution itself can be used to postpone a more complete environmental solution. For example:

Containment (for instance by hydraulic or barrier means) may provide an immediate risk management effect, which can be used to buy time for a longer duration extensive solution to effect a permanent risk management solution.

The envisaged end-use of a site may be used in an analogous way to containment, in that and end use may itself control pathways between sources and receptors, providing time for a long term and permanent solution to become effective, while the site is under that particular end-use. Where no long term solution is employed, the range of end uses for that particular site cannot be extended. Whether this is seen as a problem or not is effectively a social and economic perception, considering for example the effectiveness of long term spatial planning controls, or a site owners economic time horizon for use of the site.

4) The technical solution may be combined with returning the site to use while risks are managed and / or the site is being remediated. For example, short rotation coppice combined with organic matter applications (from waste derived sources) could manage risks and generate income, in a way that allows the sustainable management of a site over time (BARDOS *et al.,* 2001). This kind of approach may be particularly appropriate for large areas of denuded and derelict land, whose very scale makes more immediate or conventional risk management solutions impossible.

The interface between RBLM and the development and selection of solutions is discussed below, first by using the components to identify common issues, and then by examining the aspects of RBLM in practice in relation to the assessment of the problem.

6.1.1 Fitness for use

In the context of RBLM "fitness for use" describes the relationship between different envisaged uses for a site and the risk management action necessary to limit risks to a level that is acceptable (or better) for that envisaged use. However, from a project standpoint, remediation works need to achieve "fitness for purpose", which includes, along with fitness for use, that the site should be capable of supporting whatever constructions are to be put on it, that there should be no undue obstructions to services or to groundwater flow, and perhaps other remediation targets, for example that the appearance of the remediated site is acceptable.

Most countries have now produced decision support, in the form of guidance, for setting risk management goals for sites, based on the concept of "fitness for use". Software based tools, from commercial providers or Public Sector agencies, may exist to provide support individual steps or a series of steps within this guidance. However, provision is not complete, and as discipline development of DSTs for this application is in its infancy.

In many cases risk management goals are considered in advance of any detailed consideration of the wider environmental, economic or social consequences of the remediation work required to meet them. These have usually implicitly or explicitly been considered to be trivial compared with the benefit of achieving risk management, particularly as process emissions (for example volatile organic compound emissions to atmosphere) will themselves be controlled by licensing or other similar pollution prevention and control (PPC) regulations. However, considering these wider consequences is becoming increasingly important as a result of general sustainable development policies, and a desire to be able to demonstrate appropriate use of resources and value for money.

There is a general consensus about what constitute the key decision support issues for contaminated land management on a project by project basis, as summarised in Chapter 2. In many countries a decision making system for contaminated land management exists in the form of procedural guidance encompassing risk management and analyses of costs and benefits. Technical publications, such as NATHANAIL *et al.*, 2002, provide a basis for identifying suitable remediation options. In some countries, such as the Netherlands, government has supported the publication of detailed catalogues and handbooks for remedy selection and design (see Annex A). Many contaminated land professionals are able to access this information for their work, or at least the information arising from their own countries.

Hence procedural based decision support tools for risk assessment, cost benefit analysis and the identification of potentially suitable remedial techniques is now widely available. In some cases tools are available as software, and a number of further software tools are under development.

However, decision support for considering sustainability appraisal both for remedial objectives and for remediation work in a holistic sense has yet to emerge, either in written or software form. A number of analytical tools such as LCA and MCA have begun to be applied to considering wider environmental benefits, but less work has been done on providing tools for considering the social and economic aspects of sustainable development for remediation. A further problem is that DSTs are not necessarily always acceptable to all of the stakeholders involved with a contaminated land project. Some decision makers may find them: obscure, unvalidated or may even disagree with their basic premises. Indeed these difficulties may be even greater when “lay” stakeholders become involved in decision making. Hence the two major challenges for supporting contaminated land decision making in the future are considering decision making criteria in a more holistic sense and making them relevant to a wider range of stakeholders.

6.1.2 Protection of the environment

Treatment technologies aim to protect environment and often to restore a resource. However, remediation approaches themselves should be evaluated themselves in terms of any harm / pollution and in terms of safeguarding resources.

A number of projects in Europe, for example in the Netherlands, Germany, the UK and Switzerland have suggested approaches to considering the wider environmental impact of remediation work. Several examples are reviewed in Chapter 5. A recent review from the UK (Environment Agency, 2001) has made a summary of the potential wider environmental effects from remediation work that might impact different groups of stakeholders. These were listed above in Table 9.

However, as already noted above, protection of the environment represents only one of the three basic elements of sustainable development. Sustainable development is a balance of environmental, economic and social factors in a holistic sense.

6.1.3 Long-term care

Conceptually, the use of formal analyses in support of decisions could provide a clearer evaluation of the balance of advantages between longer term aspects against short term approaches for different remediation approaches for particular problems. Indeed, particularly for aquifers, it may be legitimate to ask whether any kind of a solution with available technologies represents a net gain in sustainable development terms. A number of DSTs have been developed that try to address these questions (reviewed Chapter 5), for example:

- Procedural guidance on cost benefit analyses for aquifers and for contaminated sites from the UK (Environment Agency, 1999 and 2000);
- The Dutch REC model (NOBIS, 1995 a, b);
- The WILMA model in Germany (WETH, 2000).

While DSTs like these can certainly assist the evaluation of different options by informed practitioners, the state of the art is really such that they require rather careful use, for several reasons. Firstly, the decision making premises may not be immediately apparent. Secondly, they all rely ultimately on value judgements, which typically require a relatively high degree of technical knowledge. Thirdly, they are, effectively, unvalidated against field observations. Indeed this may be hard to achieve, given that few sites would be able to support parallel investigations of different short and long term remedial options. There is also the question of who should pay for such systematic long term appraisal of performance and wider environmental effects. Fourthly, most of these DSTs were not designed with stakeholder engagement in mind, nor are they able to balance environmental, economic and social considerations together in a holistic appraisal. Because of these limitations, at present decision support for this application is really only able to provide tentative suggestions, and not firm conclusions that are robustly defensible at a technical level, and able to reflect common ground between all stakeholders. An interesting development has been the application of financial risk approaches to remediation decision making, principally in a redevelopment context (FINNAMORE, 2000). While this approach communicates only with one group of lay stakeholders (the financial community), it does show how DSTs can be used to facilitate the involvement of "lay" stakeholders in decision making, in a way that the engagement is meaningful.

6.1.4 RBLM in practice

It is important to note that decision support tools have a wider range of applications than considering the overall management issues for contaminated land. These specific technical applications include: determination of a site sampling strategy; visualisation of risk contours for contaminated sites; selection of analytical techniques; design of remedial solutions for different sites for specific technologies. A large number of DSTs are available, both as procedures and software, in support of these activities and are widely used without significant difficulty.

7 CONCLUSIONS

Contaminated land management is an important issue throughout Europe and the U.S.A. The need to develop techniques and approaches to improve the decision making process for reuse and / or remediation of contaminated lands is widely recognised. As a starting point, to improve communication on this topic, the following definition is offered. Decision support can be defined as: the *assistance for, and substantiation and corroboration of, an act or result of deciding; typically this deciding will be a determination of optimal or best approach*. The decision support process integrates specific information about a site and general information such as legislation, guidelines and know-how, to produce decision-making knowledge with the goal of being transparent, consistent and reproducible.

The complexity of environmental remediation problems necessitates several layers of decision support including:

- Technical decisions on sample collection (how many and where);
- Economic decisions about whether costs are worth the benefits; and
- Social / political decisions on sustainable land development.

Each of these layers may need to be addressed as part of the overarching decision on land management and many of these 'layers' are interdependent. In all cases, the decision support process takes basic input information (problem definition); uses decision support tools to integrate, analyse and abstract from the information and provides knowledge directly relevant to the decision. Approaches to contaminated land management have been found to follow a similar broad outline independent of the country where the problem is located.

The large number of contaminated land problems with similar characteristics has led to several attempts to develop tools (DST) that support the wide range of decisions related to contaminated land management and re-use. One objective of development of these tools is to obtain a consistent, reproducible and transparent approach to supporting decisions. Another objective is to provide a consistent methodology to compare contamination issues at different sites and serve as a basis for setting priorities. DSTs have seen widespread use in all steps of the contaminated site management process (from investigation through remediation and monitoring).

Finding sustainable technical solutions for contaminated problems is dependent on a range of parallel considerations. Decisions about which risk management option(s) are most appropriate for a particular site needs to be considered in a holistic manner. Key factors in decision making include: the driving forces for the remediation project, risk management, sustainable development, stakeholders' viewpoints, cost effectiveness, and technical feasibility / suitability, as discussed in Chapter 2.

Despite the similarities between contaminated land problems throughout the world, there are differences in the approach to these problems. These include differences in application of general principles (e.g. some countries consider ecological risk as one basis for analysis while others do not); differences in priorities (e.g. groundwater management is more important to countries with limited surface waters); differences in administrative and regulatory approach; and differences in social attitudes towards risk and the resources available for land management.

While the risk management paradigm is broadly accepted by technical specialists and contaminated land professionals as the most appropriate decision making basis for contaminated land management, this acceptance is not universal for all stakeholders, particularly “lay” consultees. For example local communities may not accept a risk basis for decision making, perhaps because it has not been explained adequately, perhaps for other reasons - for example they want zero risk. This perspective is not unlike that of many prospective purchasers of contaminated sites, or companies considering inward investment.

All relevant stakeholders should be involved at the earliest possible stage of decision making. However, decision support techniques - like risk management techniques - are in their infancy. A variety of techniques have been applied in commercial products, and yet others are under development. The most successful tools tend to be fairly specific, focusing on providing specialist support for niche decision making, for example determining sampling strategy. More general tools, for example for remedy selection, are less well developed and accepted. However, the major, and as yet unachieved goals, for decision support are to be able to:

- Consider sustainable development and risk management in a mutual and holistic way; and
- Support stakeholder engagement in a way that is robust and transparent, even to lay audiences.

The challenge is very tough, because any decision support must not hamper efficient and cost effective decision making or cause excessive delay. A major concern of core stakeholders is that, by widening their considerations and their consultees, they run the risk of stalling the decision making process; or making it so difficult that, for instance, brownfield remediation becomes less attractive.

8 RECOMMENDATIONS

Future development of decision support is likely to see an increasing transfer of procedural guidance to software applications. Some applications of decision support are already well established, for example, those relating to setting risk management and making choices about site investigation and other specialist decisions, as described above.

It was very clear from Working Group "Decision Support Tools" and Working Group "Remediation" work, and at the CLARINET Final Conference, that the integration of risk management and sustainable development considerations is the likely direction of future contaminated land management. However, effective decision support for this kind of holistic decision making has yet to emerge.

It is also apparent that similar elements of thinking are taking place in parallel in many countries at this time. RBLM and the decision making criteria outlined above provide an opportunity for a consistent and coherent framework for the discussion of contaminated land decision making at an international level, and a theoretical framework and vocabulary for the development of more practical decision support techniques.

Any decision support must be able to present its findings in terms of clear costs and benefits. It is important that decision making is transparent, coherent, reproducible and reflects a technical consensus. However, no technique is free from limitations and all depend on value judgements. Tools such as MCA and MAT can integrate different decision making criteria, and have begun to be used in contaminated land decision making. However, these decision making processes are not able to support wide stakeholder involvement, nor are their premises necessarily agreeable to all.

CARACAS, CLARINET, NICOLE and other international initiatives have been a major cause of the emerging consensus about which decision making principles are important for contaminated land management. These international networks have also been instrumental in transferring expertise and ideas between countries. Through these networks, participants have become aware of the wide range of information available in support of contaminated land decision making in many countries. However, this community represents only a fraction of contaminated land decision makers. Many decision makers, for example in businesses, local authorities and Accession States simply do not have access to this information. CLARINET has begun the process of collating this information as a series of reports and on its web site. However, the state of the art is dynamic, detailed and heterogeneous across countries. A useful development of from these networks would be to use the power of the Internet to not only make this information available to all, but also to make it updatable - reflecting its dynamic nature, and collectable on a regional basis - reflecting its heterogeneity.

Hence, while DSTs are now widely used in contaminated land management for a number of decision making applications, there is a long way to go yet in providing robust, reproducible and accessible decision support for others. The principle areas requiring support are:

Enabling a diverse and heterogeneous range of research projects applying different decision analysis tools to holistic approaches to contaminated land decision making (this work must include an integrated assessment of all three elements of sustainable development: economic, environmental and social).

Providing a platform for the validation of decision support tools in Europe[20]. This should be related to practical decision making in the field and the measurement or estimation other wise of the performance and effects of remediation work.

Supporting the development of guidance, and perhaps ultimately some kind of support, for widening stakeholder engagement in contaminated land decision making, particularly involving "lay" stakeholders.

Supporting the provision of web based contaminated land information from the different Member States and the EC in a way that is accessible to, and can easily be found by, all who are involved in contaminated land management.

[20] The US EPA has already implemented a programme for testing DSTs: the Environmental Technology Verification Program (ETV) - Sullivan *et al*. 2000d

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Note: NATO / CCMS papers are available on: *www.nato.int/ccms/info.htm*. CLARINET papers for this review are published on its web site: *www.clarinet.at*.

GLOSSARY

This glossary is not intended to be a set of formal definitions, nor to supplant terms defined by organisations such as ISO. Rather it is intended to convey the meaning of terms as they have been used in this report.

Term	Contemporary Usage
Aftercare	Actions necessary for managing a remediated site
Analyses Used in Decision Support	Several different techniques can be employed to assist environmental decision-making. In practice, many decision support tools use several of these techniques, or mixtures of different parts of them. For example, software tools might combine risk assessment and cost-benefit analysis techniques to generate risk maps, cost comparisons between remedial options and other decision information.
Best Practical Environmental Option	The outcome of a systematic consultative and decision making procedure which emphasises the protection and conservation of the environment across land, air and water. The BPEO procedure establishes, for a given set of objectives, the option that provides the most benefit or least damage to the environment as a whole, at acceptable cost, in the long term as well as short term. (This is a UK definition[21] – other countries have similar definitions.)
Comparison of options/ options appraisal	Evaluating different alternatives (actions, strategies etc).
Core	Describes the activities and their outcomes that are a result of the core objectives and site specific factors and constraints.
Core objectives	Those remediation objectives that need to be achieved in order to enable redevelopment; to reduce risks to human health, surface and groundwater, ecosystems and construction; to reduce liabilities, or some combination of these drivers, reached after consideration of site specific factors / constraints and taking into account the views of the key stakeholders for that site.
Cost Benefit Analysis	A form of economic analysis in which costs and benefits are converted into monetary values for comparison.

[21] As defined by the 12th Report of the UK Royal Commission on Environmental Pollution

Term	Contemporary Usage
Cost Effectiveness Analysis	A simplified form of cost benefit analysis.
Decision Making Role	The decision making role describes the type of decision making being supported, e.g. for managing a single site, or for prioritising a number of sites. This deals with the overarching decision being made at the site.
Decision Support	Assistance for, substantiation and corroboration of, an act or result of deciding; typically this deciding will be a determination of an optimal or best approach.
Decision Support System	A Decision Support System is the complete decision making approach, including all of its components.
Decision Support Tool	A Decision Support Tool supports one or more components of decision making.
Decision Table / Matrix	A simplified means of presenting summary information for assisting comparisons between different options.
Environmental Impact Assessment	Remediation projects likely to have significant effects on the environment are required to have an assessment of their potential environmental effects, before any planning consent is given.
Environmental Merit	A term used in the Netherlands and other European countries which is a measure of the potential environmental influences of contamination and its remediation. It is intended to consider environmental influences other than those considered in a risk management framework.
Evaluating Wider Impacts	Assessment systems for the key elements of sustainability appraisal (economic, environmental, resource and social evaluations).
Flow charts	A diagrammatic representation of a procedure or protocol or series of procedures / protocols.
Functional Application	The functional application to contaminated land management describes whether the decision support is for risk management, remediation, monitoring and aftercare, sustainable development etc. This deals with the issues that must be addressed to support the overarching decision. In practice, a number of DSTs address multiple decision criteria.
Identification of problem sites	Spotting or distinguishing sites of potential concern.

Term	Contemporary Usage
Life Cycle	The life cycle of a product encompasses its manufacture, its use and its disposal / fate.
Life Cycle Assessment	A technique for evaluating the broad environmental impacts of producing consumer goods.
Map	A figurative illustration of decision processes, the route taken for a decision.
Model Procedures	A series of procedures setting out good practice.
Monitoring	Observation of conditions.
Multi Criteria Analysis	A structured system for ranking alternatives and making selections and decisions.
Nature of the Product	The nature of the product describes whether the tool is written guidance; a "map" of some sort, a series of procedures or a software based system.
Non-core	Describes the supplementary effects of and/or desires for a remediation project not addressed by its core objectives.
Policy	A course of action or administration recommended by a stakeholder (often Government).
Prioritisation	Listing or ranking in order of importance or urgency.
Problem Identification	Spotting or distinguishing issues of potential concern.
Procedure	Mode of conducting business, system laid down for actions / calculations etc.
Protocol	A written means of setting out a framework for action of some kind / calculation of some quality, agreed or to be negotiated by stakeholders.
Risk Assessment	The process of assessing the hazards and risks associated with a particular site or group of sites.
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.
Roadmap	A diagram showing the major steps in reaching a decision.
Site specific	Pertaining to an individual site / dependent on individual site characteristics.

Term	Contemporary Usage
Software Tools	Computer implementation of guidance, e.g. to assist in the calculations (such as, risk assessment). Software tools are also developed to assist in the decision process for computationally intensive analysis, e.g., flow and transport, geostatistical modelling, and multi criteria analysis.
Stakeholders	Stakeholders typically include any individuals or groups that may be affected by the environmental contamination. Stakeholders include federal, state, and local regulators, local businesses, citizens, citizen groups, problem holders, environmental industry, and public health officials.
Strategy development	Planning a course of action / planning an approach that will assist several courses of action in different circumstances / locations.
Sustainability Appraisal	A system intended to determine the contribution of a particular project or action to achieving sustainable development.
Sustainable Development:	Development that meets the needs of the present without compromising the ability of future generations to meet their own needs (BRUNDTLAND, 1987).
System	The meaning of system is variable: for some people "system" is synonymous with "tool" (above).For others "system" conveys the entire approach to decision making, including all its components. For them this totality is the decision support system, and something that deals with just a component part would be a "tool" rather than a "system". The second meaning is that used in this report.
Technique	A principal, or series of, operations used to assist decision making.
Tool	A document or software produced with the aim of supporting decision making, i.e. something that carries out a process in decision support.
Tree	A logical progression of decision making steps.
Wider Environmental Value	describe the wider (non-core) environmental effects of a remediation project, which may be less contentious than “environmental merit”.
Written Guidance	Procedures and information provided, often by regulatory agencies, as a means of obtaining a standardised, reproducible approach to reaching a decision.

LIST OF ABBREVIATIONS

ADEME	Agence de l’environnement et de la maîtrise de l'énergie (French Agency for the Environment and Energy Management)
ADI	Average Daily Intake
ANPA	Agenzia Nazionale per la Protezione dell Ambiente (Italian EPA)
ASTM	American Society For Testing and Materials
BAT	Best Available Technology
BATNEEC	Best Available Technology Not Entailing Excessive Costs
BNFL	British Nuclear Fuels Limited
BNL	Brookhaven National Laboratory, USA
BOSS	Het beslisondersteunend systeem ter bepaling van de beste beschikbare bodemsaneringstechnieken (=Decision Support System for the Best Available Soil Remediation Technics)
BPEO	Best Practical Environmental Option
BUWAL	Bundesamt für Umwelt, Wald und Landschaft
CARACAS	Concerted Action on Risk Assessment for Contaminated Sites in the European Union
CBA	Cost Benefit Analysis
CEN	European Committee for Standardisation
CHAINET	European Network on Chain Analysis for Environmental Decision Support
CLARINET	Contaminated Land Rehabilitation Network for Environmental Technologies in Europe
CONCAWE	The CONservation of Clean Air and Water in Europe industry network
DEFRA	Department for Environment, Food and Rural Affairs
DETR	Department for the Environment, Transport and the Regions
DGM	Directoraat General Milieubeheer
DRA	Detailed Risk Assessment
DS	Decision Support
DSS	Decision Support System
DST	Decision Support Tool
EIA	Environmental Impact Assessment

List of Abbreviations (continued)

EPA	See US EPA
ERA	Ecological Risk Assessment
ESRC	Economic and Social Research Council
ICM	Isolate-Control-Monitor
ICRCL	Interdepartmental Committee for the Redevelopment of Contaminated Land
IPPC	Integrated Pollution Prevention and Control
ISO	International Standards Organisation
LCA	Life Cycle Analysis
LCI	Life Cycle Inventories
MAT	Multi Attribute Analysis
MCA	Multi Criteria Analysis
NATO/CCMS	North Atlantic Treaty Organisation Committee on Challenges for Modern Society
NGO	Non Governmental Organisation
NICOLE	Network for Industrially Contaminated Land in Europe
NOBIS	Netherland Onderzoeksprogramma Biotechnologische In situ Sanering
OECD	Organisation for Economic Co-operation and Development
OFD	German Higher Finance Office
OVAM	Public Waste Agency of Flanders
OWD	Waste Office of Wallonia
PCCRARM	Presidential/Congressional Commission on Risk Assessment and Risk Management
PPC	Pollution Prevention and Control
RA	Risk Assessment
RBCA	Risk Based Corrective Action
RBLM	Risk Based Land Management
RBSL	Risk Based Safety Level
REC	Risk Reduction, Environmental Merit, Costs
RfD	Reference Dose
RIVM	Rijksinstituut voor Volksgezondheid & Milieu

List of Abbreviations (continued)

SFT	Statens forurensningstilsyn (Norwegian Pollution Control Authority)
SNIFFER	Scottish and Northern Ireland Forum for Environmental Research
SRA	Simplified Risk Assessment
SUS	Saneringsurgentiesystematiek (system for environmental prioritisation of clean-up)
TCB	Technical Committee on Soil Protection
UBA	Environmental Protection Agency (Germany, Austria)
USEPA	United States Environmental Protection Agency
VITO	Vlaamse Instelling voor Technologisch Onderzoek (= Flemish Institute for Technological Research).
VYH	Ympäristöhallinto (Finnish Environmental Adminstration)
WEV	Wider Environmental Value
WG	Working Group (of CLARINET)
WHO	World Health Organisation

ANNEX 1

Decision Support Survey - Findings by Country

AUSTRIA

Flow diagrams/decision support tools (DST) for management procedures of contaminated land

Austrian legislation does not provide any tools for decision making. Therefore the Austrian Standards Institute produced a sequence of guidelines to assist the management of contaminated sites (numbered OENORM S 2085 to OENORM S 2090). The OENORM S 2085 (July 1st, 1998) illustrates a tiered approach of procedures and activities for the management of contaminated sites using a flow diagram. This provides a general guide for dealing with investigation, assessment and remediation of contaminated land incorporating a number of standards dealing with subsets of the contaminated land problems. The flow diagram provides the framework for decision-making; the integration of the various steps is provided by the progressive nature outlined in the flow diagram. A general outline for risk assessments is set by OENORM S 2088 part 1 and part 2, which also define guideline values for contaminated land related to the protection of groundwater resources as well as the safe use of land.

The decision-makers, community involvement and information communication

The decision-makers and the 'actors' or 'stake holders' usually involved in decision-making are normally only the authorities, the landowner and the problem holders (typically industrial or municipal). Neighbours or neighbouring facilities are kept informed. Potentially threatened neighbours or institutions such as water supply companies are likely to be involved where a linkage is suspected. As a prerequisite for remediation projects which get public funding, the Federal Environment Agency has to perform a general risk assessment and to propose a classification for the national priority list. In parallel the KKA (Kommunalkredit Austria AG), a bank which administers the funding of remediation projects and scientific projects on behalf of the Federal Ministry for Environment, has to evaluate the economic and the ecological effectiveness of the planned solution. There is no legal requirement to involve other interested parties such as citizens, community organisations or environmental NGOs. If there is a responsible polluter it is their decision how and when to involve the interested public.

However, experience has shown the practical necessity to inform concerned citizens and communities at an early stage of investigation and remediation projects. Therefore the usual procedure for public financed investigation projects is to hold three informal meetings, an initial meeting before the work starts, an interim and progress meeting to present first results and a final meeting to communicate the extent of contamination and possible risks. This is particularly important for remediation projects where *ex situ* measures are implemented. In most cases the problem-holder needs some public acceptance for various tangible and visible impacts of the remediation project, such as entering private properties, noise, or additional traffic. Large public remediation projects of regional importance are also communicated through public hearings, mail circulars, flyers or the Internet. Only these regionally important projects involve the environmental NGOs.

Use of fixed, generic and/or other limit values and the role of specific risk assessments

The standards OENORM S 2088-1 (Contaminated Sites – Risk Assessment concerning the pollution of groundwater; October 1st, 1997) and OENORM S 2088-2 (Contaminated Sites – Risk Assessment for polluted soils concerning impacts on surface environments; June 1st, 2000) define guideline values (trigger-values and limit-values). These values are generally the starting point to appraise investigation results or are also often used to define target-values for remediation projects.

These guidelines identify three qualitative target levels for remediation projects:

1. Preserving and restoring the natural state of the environment or the relevant environmental media.
2. Preserving or establishing the natural state with man-made influences, but allowing for sustainable multi-functional use.
3. Preserving or establishing an environmental state allowing for a limited use and prevention of further discharges of hazardous substances

Target-values for remediation projects can be site-specific, generally at the range of trigger-values and limit-values. Deviations or transgressions of limit-values are not excluded by principle but must be subject to intensive investigations and feasibility studies.

Legislation in Austria does not provide for different levels / stringency of risk assessment. There is no reference to risk assessment in the Federal Water Act, the major legislation with respect to contaminated sites. The Federal Act on Remediation of Contaminated Sites (ALSAG) targets landfills and industrial sites that pose a "serious" risk for the environment and mentions the necessity to perform risk assessments. However there are no legal definitions or outlines to clarify risk assessment procedures.

Current Austrian procedures for risk assessment do not refer to calculations of human uptake of pollutants site-specific or to run exposure models, although the recently published standard OENORM S 2088-2 refers to other European exposure models (which will be incorporated into Austrian procedures).

The types of soil/site/water use considered by legislation and regulation; possibility for site use to be changed if remediation is not feasible

The types of soil / site / water use that the legislation and regulation in Austria consider are:

Groundwater: 99% of drinking water is groundwater; therefore groundwater must meet drinking water requirements. The Austrian Water Act follows the precautionary principle and a 'zero-pollution-tolerance'. To deal with old contaminated sites this approach has been adopted within the OENORM S 2088-1 (Contaminated sites – Risk Assessment Procedure: Groundwater) which distinguishes two categories of groundwater resources: -

1. specially protected aquifers or aquifers with an high relevance for future water management;
2. aquifers which are not likely to be used.

Soil: There is no national legislation on soil conservation and protection, however, some provinces enacted soil laws particularly on the conservation of agricultural soils.

OENORM S 2088-2 (Soil) considers three classes of soil / land

1. Sensitive use – soil in its function for humans
2. Agricultural use – soil in its function for production.
3. Other uses – soil as a filter and as a buffer within ecosystems

Depending on the current use of land the verification of contamination can bring about restrictions on land use. Concerning an intended change of land use, the Austrian Water Act as well as the two mentioned guidelines postulate that higher risks, new releases of pollutants or an increased exposition of any receptor are not acceptable. In practice the interested party has to prove that negative impacts are unlikely to appear as a result of a project.

Spatial planning legislation is done regionally by the nine Austrian provinces and the execution is largely the responsibility of the communities. Thus, change of land use at contaminated sites may depend upon on the regional or local circumstances. Generally the regional spatial planning legislation does not consider special regulations on contaminated sites. However, in Lower Austria it is prohibited to change the land use at registered potentially contaminated sites or contaminated sites listed at the national priority list. Contaminated sites that are not remediated within five years after entry on the national priority list will be restricted to limited uses, without any compensation for the owner. Building redevelopment on potentially contaminated sites must be applied for; the developer must investigate, remediate and develop the properties within five years.

Handling, recording and use of Risk assessment results

Risk assessment results are handled, recorded and used in the following manner: if a site is assessed as seriously contaminated the results of the risk assessment are recorded in the Register of Contaminated Sites which is available to the public and also available on the Internet. Details of sites that are contaminated to a tolerable level are published in a shortened version and are available to planners and potential purchasers of a site. There are no defined procedures for approval of site remediation or of consequent use upon remediation.

Special provisions for Brownfields, water resources, diffuse contamination

Brownfields – there is no current provision for brownfield sites, although there is ongoing discussion within legislative bodies. There are intentions to tolerate higher levels of soil pollution if there are no serious offsite consequences and to give regulatory incentives for the re-use of the former industrial land.

Water resources – The precautionary principle prevails through the Austrian Water Act. Groundwater must satisfy drinking water criteria.

There are no existing provisions on diffuse contamination of soils, but the Austrian Water Act and the Austrian Groundwater Threshold Value ordinance require the prevention of diffuse pollution of groundwater. Groundwater Threshold Values are set at 60% of the allowable drinking water standards, if these are continually exceeded at 25% of the sampling sites, the provincial authorities have to initiate and co-ordinate a programme of measures to avoid the deterioration of a aquifer.

Consideration of environmental impacts of the remediation system (planning, verification and evaluation); wider environmental value; and sustainability issues of the remediation system.

There are no provisions to consider environmental impacts, wider environmental effects and sustainability issues of remediation options. In an integrated pollution control context, the environmental impacts of the remediation system during and after the works are considered in decision making and remediation planning, verification and evaluation. The best available technology must be used to ensure that the problem is not simply ‘passed on’.

The guidelines for public funding postulate an overall target of remediating contaminated sites at the maximum wider environmental effects subject to acceptable expense. Therefore it is necessary to perform a study on the remediation options and to evaluate environmental impacts and broad economic consequences. However it is done on a case by case basis without general valid provisions. As a consequence remediation goals, costs and feasibility remain the important drivers for decisions on the general solution design. Other sustainability issues like community, political, and social concerns are not considered at an operational basis.

Measurement of wider environmental effects; economic merits; community, political and social concerns; and sustainability. The experts in developing DSTs for risk management and sustainability.

The considerations of wider environmental effects, economic merits and community, political and social concerns are measured, assessed and used in decision making by funding guidelines, expert judgement, and case by case decisions. No legal instruments are involved. The development and introduction of a Decision Support Framework is a mid-term objective on the agenda of the Federal Ministry for Agriculture, Forestry, Environment and Water Management.

Support procedures in place or planned for the remedial decision-making, the role of decision support techniques; primary factors driving decision-making for risk management

All commonly used remediation technologies are described by the Austrian standard OENORM S 2089 (July 1st, 1998). These basic descriptions expand on the principle functionality, the general field of application, corresponding parameters and exclusion criteria. A corresponding table highlights site-specific features and suppositions as well as treated pollutants.

The guideline for public funding asks for the use of best available techniques and the implementation of a feasibility study listing and evaluating all possible remediation technologies. Different decision support techniques like cost-benefit analyses or decision tables are applied within feasibility studies, but there is no fixed procedure. The general requirement is a clear statement on relative advantages and disadvantages (including costs).

The primary factors driving decision making for risk management are to eliminate the danger to human health and the environment, taking into consideration costs and feasibility.

BELGIUM (FLANDERS)

Flow diagrams/decision support tools (DST) for management procedures of contaminated land

In Flanders there is a flow diagram of the procedure activities for the management of a polluted site in the regulatory framework on contaminated land. The Soil Remediation Decree (22/2/95) incorporated a flow diagram concerning the procedures of remediation including the following phases:

1. Identification study (historical investigation and soil sampling);
2. Descriptive soil study (risk analysis and limitation of the pollution);
3. Remediation project (studying alternatives for remediation following the BAT-NEEC principle);
4. Remediation works;
5. Aftercare.

In addition there are decision support systems for risk management available and/or in use. A distinction is made between Historical Soil Pollution (pre 29/10/95) and New Soil Pollution (post 28/10/95). A system of 'Active Soil Management' is being developed which will aim to provide precautionary measures and land use limitations based on risk assessment. Advice and guidance is provided on the appropriate measures when there is limited information available about a site but there are indications of a serious risk, and also where remediation is not possible.

The decision-makers, community involvement and information communication

The decision-makers and the 'actors' or 'stake holders' usually involved in decision-making are operator and owner of the site, or the government (OVAM). The Decree on Soil Remediation clearly identifies that the obligation to clean up rests with the operator and owner of the site and the final burden is for the responsible person. For New Pollution (originated before 29/10/95) there is an immediate and independent obligation to remediate. For Historical Pollution (originated after 28/10/95) the decision to clean up is a government decision based on the recommendation of the Public Waste Agency of Flanders (OVAM) which also supervises the total clean up procedure. Soil experts accredited by OVAM execute soil and site investigation, make clean up plans and supervise clean up operations.

The community, citizens and/or environmental organisations can be involved as follows. When remediation is planned the local municipal authority is informed and the intention to remediate (the soil remediation project) must be advertised, so everyone can make an appeal. The decision to remediate depends on a government decision, which can always be contested before the State Counsel.

The information is communicated to non-specialists, communities, neighbours etc. by soil experts or OVAM representatives. Public meetings are organised when large groups of people are involved.

Use of fixed, generic and/or other limit values and the role of specific risk assessments

Fixed, generic and / or other limit values play a role in decision making; soil standards are set for five different land use types (and varying with Soil Organic matter and Clay content): - a. Natural; b. Agricultural; c. Residential areas; d. Recreational Areas; and e. Industrial areas. When the limits are exceeded on a recently contaminated site (post 28 / 10 / 95) remediation is obligatory; for old sites remediation is obligatory only if the risk is not acceptable.

Legislation and regulation in Flanders do not provide for different levels / stringencies of risk assessment. Risk assessment is part of a Descriptive Soil Survey. The same level of stringency is applied in all cases. In case of uncertainty about important parameters, however, additional measurements can be demanded. According to land use (and water use) type, different scenarios for receptors are defined, resulting in different concentrations of contamination that are allowed without risk.

There are different specific risk assessments for the five land use types mentioned above: natural, agricultural, residential, recreational, and industrial. Water protection areas are not defined according to water use.

The types of soil/site/water use considered by legislation and regulation; possibility for site use to be changed if remediation is not feasible

The legislation and regulation in Flanders consider all types of potentially polluted soil and water. Future developments will consider prevention of pollution. It is not possible to change site use (and value) if remediation is not possible, but OVAM can impose land use restrictions. Land use options are based on risk assessment.

Handling, recording and use of Risk assessment results

Decisions based on risk evaluation are summarised in the Register of Contaminated Soil (maintained by OVAM). Risk assessment as part of the Descriptive Soil Survey is done by accredited soil experts. Descriptive Soil Surveys are evaluated and approved by the OVAM.

Special provisions for Brownfields, water resources, diffuse contamination

There are special provisions in place or planned (e.g. administrative, permitting, etc.) for:

a. Brownfields: the Decisions Support System in preparation will stimulate the use of Brownfield Sites.

b. Dealing with aquifers and other water resources (surface or groundwater): Groundwater vulnerability is taken into account when considering the necessity to clean up sites.

c. Diffuse as opposed to point source contamination (e.g. from Agriculture, sewage sludge re-use): different investigation strategies are prescribed.

Consideration of environmental impacts of the remediation system (planning, verification and evaluation); wider environmental value; and sustainability issues of the remediation system.

In an integrated pollution control context, the specifically environmental impacts of the remediation system during and after the works considered in decision making and remediation planning, verification and evaluation are not considered. Post remediation costs and risks are considered.

Measurement of wider environmental effects; economic merits; community, political and social concerns; and sustainability. The experts in developing DSTs for risk management and sustainability.

Cost benefit analysis is an integral part of the procedures. The wider environmental effects; economic merits; community, political and social concerns are not specifically taken into consideration. The BATNEEC principle is the only consideration for sustainability issues.

Support procedures in place or planned for the remedial decision-making, the role of decision support techniques; primary factors driving decision-making for risk management

The soil expert must provide different approaches. A Decision Support System (BOSS) has been developed to indicate all technically feasible options for specific cases. There are no new procedures being developed and planned.

The primary factors driving decision making for risk management are the risk based remediation objectives.

BELGIUM (WALLOON)

Flow diagrams/decision support tools (DST) for management procedures of contaminated land

No specific legislation about contaminated land existed at the time of the questionnaire but new legislation has been drafted which should come into force by the end of 2001. This legislation deals with soil pollution, risk assessment and rehabilitation. There was no decision support system in place at the time of the questionnaire. Polluted soil is considered as waste and managed in the context of waste legislation.

The decision-makers, community involvement and information communication

The OWD (Waste Office of Wallonia) is the responsible department for waste management within the Environment Administration. The Regional Development Administration is responsible for redevelopment of brownfield sites. The Public Society for Environmental Quality Improvement (SPAQUE) will assist in the process of prioritising sites for remediation – its mission is to assess, set priorities and reclaim former waste disposal sites.

Use of fixed, generic and/or other limit values and the role of specific risk assessments

The forthcoming legislation will refer to limit values, these will be indicative values and integrated into risk assessment tools.

The types of soil/site/water use considered by legislation and regulation; possibility for site use to be changed if remediation is not feasible

The tools planned will consider all types of potentially polluted soil and water. Future developments will consider prevention of pollution.

Handling, recording and use of Risk assessment results

Risk assessment procedures are not yet defined; a soil quality database is planned.

Special provisions for Brownfields, water resources, diffuse contamination

Brownfield sites are managed by Regional Development Administration under the Regional Planning Act and Building Code; rehabilitation is considered but not contaminants. The principle is to bring derelict land back into good condition.

An environmental study is undertaken before rehabilitation involving history, soil, water and gas analysis. This information is discussed with the site owners to decide upon one of three future actions:

a. More information required;

b. Continue with current actions; or

c. Change site use.

Consideration of environmental impacts of the remediation system (planning, verification and evaluation); wider environmental value; and sustainability issues of the remediation system.

These are not considered.

Measurement of wider environmental effects; economic merits; community, political and social concerns; and sustainability. The experts in developing DSTs for risk management and sustainability.

Wider environmental impacts, economic merits; community, political and social concerns; and sustainability are not measured. The experts in developing DSTs for risk management and sustainability are the Regional Development Agency and OWD, Public Society for Environmental Quality Improvement (SPAQuE), Institut Scientifique de Service Public (ISSeP).

Support procedures in place or planned for the remedial decision-making, the role of decision support techniques; primary factors driving decision-making for risk management.

Future legislation will consider protection of the surrounding population and other natural resources (e.g. groundwater); feasibility will be important in making the final decision.

DENMARK

Flow diagrams/decision support tools (DST) for management procedures of contaminated land

The Danish EPA guidelines no. 6/1998 'Remediation of Contaminated Sites', provide a step by step description in the form of a flow diagram. Decision support is provided on how to conduct a risk assessment. The procedures are PC based using Microsoft Excel.

The decision-makers, community involvement and information communication

Municipalities and Regional Councils are the responsible bodies for decision-making. The Danish Environment Protection Agency deals with complaints of parties that have received orders from local or regional authorities to carry out investigation or remediation of contamination. Property owners and other interested parties are frequently involved. Interested parties may submit opinions. Information is distributed as widely as possible through letters, citizens' meetings etc.

Use of fixed, generic and/or other limit values and the role of specific risk assessments

Generic values are used, if they are exceeded it is considered that there may be a risk. There are different levels of stringency and risk assessment, for example particularly valuable water resources versus areas with limited groundwater resource; or sensitive land use (gardens) versus less sensitive land use (industrial).

There are two levels of criteria in the Danish guidance on remediation - Soil Quality Criteria and Cut-off Values. Soil quality criteria are toxicologically based criteria; the cut-off values are about tenfold the soil quality criteria values (but where the contaminant has an acute toxicological effect the values are identical). Measures must be taken to prevent people living on land with soil above the cut-off values from coming into contact with the soil; advice is given to those living on land with levels below the cut-off levels but above the soil quality criteria levels (Ad Hoc Working Group on Contaminated Land 1999).

The types of soil/site/water use considered by legislation and regulation; possibility for site use to be changed if remediation is not feasible

Soil, air, ground and surface water recipients are considered. It is possible to change to a less sensitive land use if remediation is not feasible (this will seldom happen); risk assessment would be part of the policy in deciding if change can be allowed.

Handling, recording and use of Risk assessment results

There is no systematic record kept centrally as Danish legislation has a decentralised structure. The decision-making power lies with local authorities.

Special provisions for Brownfields, water resources, diffuse contamination

The Soil Contamination Act came into force on January 1st 2000. This new legislation considers all types of contamination irrespective of how and when contamination took place. Diffuse and point source contamination are not differentiated – they are considered to be end members of a continuum. There are three priority areas in the Soil Contamination Act:

1. Groundwater within defined areas of particular value;
2. Groundwater within catchment areas for larger water supplies;
3. Human health - People in areas with housing, childcare centres or public playing grounds.

(Soil affected the agricultural spreading of sewage, manure and pesticides is considered elsewhere under Danish law.)

Consideration of environmental impacts of the remediation system (planning, verification and evaluation); wider environmental value; and sustainability issues of the remediation system.

Environmental impacts are not systematically recorded. The aim of the policy is to use contaminated land if it does not pose a danger to people and/or environment. It is not possible to quantify relative importance of these issues.

Measurement of wider environmental effects; economic merits; community, political and social concerns; and sustainability. The experts in developing DSTs for risk management and sustainability.

These are not measured systematically. (Although attempts have been made in some projects to measure the wider effects of the remedial approach).

Support procedures in place or planned for the remedial decision-making, the role of decision support techniques; primary factors driving decision-making for risk management

A Decision Support tool is used. The primary factor driving decision-making is protection of people and the environment whilst assessing the costs.

FINLAND

Flow diagrams/decision support tools (DST) for management procedures of contaminated land

A Council of State Decision is under preparation (based on the Environmental Protection Act, 2000) which identifies that either guideline values or risk assessment can be used in the management of contaminated sites. No specific flow diagram or equivalent is provided.

There are no official decision support systems. An earlier guide to risk assessment of contaminated soils presented a simple conceptual decision model. This model has essentially the same elements as those followed by the US EPA and ASTM.

The decision-makers, community involvement and information communication

The decision-makers are normally authorities from the regional environmental centres and the municipality of Helsinki. Stakeholders can include landowners, polluters and insurance companies. Each remediation activity is subject to a separate permit. The permit is processed in the order set out by the Environmental Protection Act. The application for permits is sent to all neighbours and is notified to the public. Consequently, all stakeholders have the right to present their opinion. In cases where the permit can be granted according to notification procedures (e.g. contaminated soil material disposed or processed where a Waste Permit is held, environmental remediation) there is no community or citizen involvement. In some cases environmental impact assessment procedures (EIA) are required, for which there is separate legislation. In this Act on Environmental Impact Assessment general guidelines of communication are given.

Stakeholders (e.g. inhabitants) are normally informed directly in special meetings. They can also view the documents held by the appropriate authorities. Depending upon the significance of the case, information can be distributed through local or national newspapers, radio TV, etc.

Use of fixed, generic and/or other limit values and the role of specific risk assessments

The Environmental Protection Act, which regulates the treatment of contaminated soils, does not include any specific mention of risk assessment. In the Council of State Decision, which is in preparation and expected to be in force at the end of 2001, risk assessment is presented as a risk management tool together with generic guideline values. The level or contents of risk assessment procedures are not defined in the Decision.

To date risk management decisions have been based on fixed generic guideline values. Even if a site specific risk assessment has been executed, remediation target levels are mostly based on generic target values. In the few cases where quantitative health risk assessment procedures have been adopted, ADI, RfD or equivalent values given by US and Danish EPA, WHO etc. have been used to calculate site-specific target levels. Occasionally, threshold values given in other countries (e.g. Canada, USA) and based on ecological risks (e.g. PRGs, RBSLs etc.) have been proposed for remediation target levels.

The types of soil/site/water use considered by legislation and regulation; possibility for site use to be changed if remediation is not feasible

Soil protection is regulated by the Environmental Protection Act. Some distinction is made according to land use, and regulations cover all types of land use. However, if the possibility of water pollution is involved, ground water protection and permits for wastewater discharge are handled according to the Environmental Protection Act. For groundwater for domestic use, there exists an absolute prohibition of pollution and the drinking water requirements (e.g. substance specific guidelines) must be met. For emission to surface waters there are no generic guideline values. The permits for discharges are granted on a case-by-case basis by the Regional authorities or, in certain circumstances, by the local environmental authorities.

The legislation does not mention the possibility of changing land use, but in practice this is possible.

Handling, recording and use of risk assessment results

Risk assessment results are not registered or recorded systematically and the reports are normally prepared solely for the decision-makers. However, the regional government centres record all remediation permits issued according to the former Waste Management Act (1994) for contamination occurring before 1993, or the present Environmental Protection Act. (Sections of the Waste Management Act referring to soil contamination were repealed in 2000 with the new Environmental Protection Act). The Finnish Environment Institute (FEI) also collects this information for a nationwide register. No special attention is paid to risk assessment. In practice, risk assessment results are used to estimate the possibility of deviating from the generic guideline values (e.g. to define site specific target levels) and being able to identify hot-spots or significant exposure routes on which to focus risk management measures. Risk management decisions might be made by land owners or regional or municipal authorities. The authorities in the regional environmental centre give the final authorisation for risk management measures.

There is no specific procedure for approval of risk assessment results. The former Waste Management Act and the current Environmental Protection Act stipulate that for reclamation to be approved, a permit has to be applied for from the regional environmental centre of, in certain circumstances, the regional environmental authorities. Approval of the permit is linked to the risk assessment. Before final decision-making, local authorities may request official statements from several expert organisations. These requests may be restricted to risk assessments.

Special provisions for Brownfields, water resources, diffuse contamination

There are no special provisions for brownfields in Finland as there are few areas that can be so classified.

Stricter discharge limits than usual may be applied for some protected watercourses. The authorities can make the recommendations in the protection plans for groundwater.

For the re-use of sewage sludge there is a separate Council of State Decision which gives general guidelines and maximum permissible concentrations of some heavy metals according to the use of the sludge (agriculture, gardening, landscaping). This decision is currently being updated. Concerning the use of mineral wastes (ash, slag, waste concrete, contaminated soil, etc.) in land construction, a Code of Practice and Guideline Values (permissible concentrations and maximum permissible solubility values) to assess the environmental acceptability are given until the end of 1999. These guidelines are intended to be used as a basis for the preparation of Council of State Decisions with which some wastes can be removed from the waste permit Process. For the year 2000 a project is planned in order to give environmental criteria and guidelines for recycling of slightly contaminated or processed (stabilisation or equivalent) contaminated soil.

Consideration of environmental impacts of the remediation system (planning, verification and evaluation); wider environmental value; and sustainability issues of the remediation system.

In the application of the permit for remedial activity (Environmental permit or notification) measures for the protection of remediation workers as well as plans for the post-remediation site monitoring have to be presented. If the authority considers these measures to be inadequate, specific requirements can be set in the final permit. Remediation is considered to be completed only after a supervisor has stated this in a separate decision.

The main objective of the generic target values given for soil is to maintain the multi-functionality of the site. In this sense, sustainability is considered in soil protection. Target values can be exceeded if the risk assessment process demonstrates that there is no significant risk to humans or the environment (animals, plants, cultural environment, countryside). Sustainability is a general aspect of decision making so that only solutions that are acceptable in the long run are normally accepted. Economic aspects play an important role, especially in residential areas. Community, political and social concerns are taken into account as well as the BATNEEC principle.

Measurement of wider environmental effects; economic merits; community, political and social concerns; and sustainability. The experts in developing DSTs for risk management and sustainability.

These criteria are not measured.

Support procedures in place or planned for the remedial decision-making, the role of decision support techniques; primary factors driving decision-making for risk management

There are no specific support procedures. The BAT principle is the starting point and the main criterion in the selection of remedial actions has been cost effectiveness. In case EIA procedure is demanded, an alternative ‘no action’ approach has to be considered.

Cost effectiveness is evaluated only qualitatively, no specific cost-benefit methods or procedures, decision tables etc. are applied.

National guidelines for content and quality assurance of remedial plans are in preparation and expected to be finished during the year 2000. These will include guidelines for documentation.

The primary factor driving decision-making for risk management seems to be cost. However, long term performance and reliability as well as environmental benefits are also important factors.

FRANCE

Flow diagrams/decision support tools (DST) for management procedures of contaminated land

The approach to dealing with polluted sites is derived from the legislation on environmental management of industrial installations, and to a lesser degree, to the legislation on waste management. There is no specific legislation regarding soil protection or polluted sites. Four key policy documents define the principles for contaminated land remediation - The Ministerial Directives of 3.12.93, 3.04.96, 31.03.98 and 10.12.99, which relate to the management and remediation of contaminated sites (they are linked to a law on environmental protection of 19.7.76).

The approach involves three steps:

a. The Inventory phase involves a systematic search for polluted sites - either active or historical.

b. The Selection phase involves an initial characterisation of any site that the state or any responsible party wants to study based on a simplified evaluation of risk. This results in a threefold classification.

Class 1 sites requiring further investigation and detailed risk assessment;

Class 2 sites requiring monitoring and possible restriction on use; and

Class 3 sites may be used for specific purposes with no further investigation or treatment.

In addition, Class 1 sites are investigated for the feasibility of treatment.

c. The Treatment phase is guided by a flow diagram and is highly site-specific giving detailed evaluation of risks to humans and the environment, guidance on treatment options and remedial objectives.

No decision support system is currently available for risk management. The approach is normally on a case by case basis. Administrative decisions will normally involve all participants in the risk assessment process.

The decision-makers, community involvement and information communication

The decision-makers are the Prefects (administrative representatives) of the French Government in the 99 Departments and the inspectors. The inspectors within these Departments are members of the Directions Régionales de l'Industrie, de la Recherche et de l'Environment (DRIRE). Owners of the site will also be involved. The remediation of orphan sites (sites where the responsible party is not able to pay) is funded by public financial support. Since January 1999 a general tax on polluting activities (TGAP) has been introduced to replace a complex range of previous taxes. The tax is now collected directly by the State (previous taxes were collected by ADEME on behalf of the State). The State allocates the funding (or part of the funding) to ADEME, which is in charge of conducting investigations and remediation measures (protection of environment, security and health of the public) requested by the Prefect and the Ministry of the Environment.

A key element in the French policy is the participation of the full range of stakeholders involved in dealing with contaminated land including the local population. There is specific guidance describes how to keep Municipalities and the population fully informed of the state of play at a contaminated site and actively involved in the decision making process.

According to the perception of problems associated with the site, the Prefect can decide to inform representatives of the population (for example, the Mayor, environmental organisations and residents associations) through special meetings called CLIS (Commission of Local Information and Monitoring) during the whole of the investigation and / or at the treatment steps. The information should be presented so that is will be widely understood.

Use of fixed, generic and/or other limit values and the role of specific risk assessments

French policy is characterised by two successive steps of assessment, a simplified risk assessment (SRA) and a detailed risk assessment (DRA). Generic and / or limit values are used in SRA to score the level of expected impact as a function of future land use. National guideline values have been defined for two end uses (sensitive (residential) and non-sensitive (industrial) uses). Guidelines are calculated from the main exposure pathways (soil ingestion and soil contact and by vegetable ingestion for sensitive use).

The approach is a case by case approach based on the structure outlined above (Inventory; Selection; Treatment). In the first step of the risk assessment (SRA), only risk for humans and water resources are considered-. If a site is found to be in Class 1, a second step is then needed. At this level a quantitative assessment is conducted, taking into account specific receptors, for example human health, water supplies, ecosystems and buildings can be considered according to the site.

The types of soil/site/water use considered by legislation and regulation; possibility for site use to be changed if remediation is not feasible

In the first stage (SRA) water and soil are considered as receptors. Three types of water use can be distinguished (drinking water supplies, other uses, and future resources) from two different origins (surface water and groundwater). The site is graded for each receptor based on these uses.

Limit values are used to score the level of impact. These limit values are derived from national or European limit values for water. Limit values for soil for a range of substances and two types of end-use have been developed. They are already available for two types of land use (residential use with vegetable gardens and industrial use).

If the results of Detailed Risk Assessment conclude that the risk of the current or proposed use is unacceptable, then either the site use has to be changed or remedial action is required. Whatever the decision the objectives or tolerable risk must be both technically and economically realistic.

Handling, recording and use of Risk assessment results

The persons responsible for the site (industrial operator, owner or ADEME in the case of orphan sites) must present the risk study to the administrative authorities. However, because of the complexity and uncertainty inherent in the methods used, and the absence of a recognised tool to quantify the risk there can be conflicts between decision-makers and those responsible for the sites. In an attempt to resolve, and to avoid, these conflicts the French Ministry of the Environment has appointed INERIS (Institut National de l'Environnement Industriel et des Risques) and BRGM (Bureau de Recherches Géologiques et Minières) to act as independent experts in the consideration of risk assessment results. The Prefect of the Department makes the final decision, which must be followed, or, if the site use is restricted then the decision is recorded and archived. There are recent national initiatives to address the management of risk assessment results. If a site is to be sold, the seller is obliged to inform the buyer of the potential risks. There is now a move to make all information about soil pollution easily accessible, especially when a development project is planned. The results of any risk assessment must be systematically presented to the mayor, and sometimes public meetings (CLIS) may be organised to inform the representatives of the public.

The Prefect of the Departments approves decisions about use of sites and remediation actions.

Special provisions for Brownfields, water resources, diffuse contamination

According to the polluting activities concerned there are special regulations to monitor the practices and avoid pollution. For example waste discharges by factories are monitored and must not exceed threshold values. In agriculture spreading of sewage sludge and liquid manures is also regulated.

There are funds available to assist those responsible for site remediation.

Orphan sites are managed by ADEME with funds derived from the 'pollution tax' (TGAP).

For sites representing a risk to water resources, funds may be obtained from some water agencies.

For Brownfield sites there may be regional support.

Consideration of environmental impacts, wider environmental value, and sustainability issues of the remediation system

The responsible party (site owner, site operator or in the case of orphan sites ADEME) must check the remediation during and after the operation. There are two options to check on the efficacy of a treatment for soil. Either an independent laboratory samples and analyses the treated soil, or the site operator samples and analyses and their results are cross-checked by an independent laboratory. ADEME usually uses the second option. For example, the results from 8-hourly sampling at the operator's on site laboratory (at a site with soil contaminated with chlorinated solvents) were validated each week by an independent laboratory. The site laboratory results were correlated with the independent laboratory results before comparison with the remedial targets for each pollutant. Validation of each batch of results is dependent upon this checking.

Sustainability and environmental merit have not featured directly in decision making. This has been recognised and discussions are in progress to incorporate these ideas into future activities. Psycho-sociological impacts are an increasingly important consideration.

Measurement of wider environmental effects; economic merits; community, political and social concerns; and sustainability. The experts in developing DSTs for risk management and sustainability.

These are not currently measured.

Support procedures in place or planned for the remedial decision-making, the role of decision support techniques; primary factors driving decision-making for risk management

There is no national procedure to support the choice, planning and/or design of remedial approaches to polluted sites in France. ADEME is developing an approach for contaminated sites based on a multi-criteria analysis (ELECTRE) which was developed for decision-making on environmental problems. This is at the preliminary stage, having been tested only on selected orphan sites. The method involves five main steps:

1. An inventory of potential scenarios;
2. Selection of criteria by an expert panel based upon a. Technique (feasibility and reliability), b. Economics, c. Psycho-sociology and d. Administrative details;
3. Grading of criteria (only economic criteria are quantitative, other criteria are scaled in a quasi-numerical manner);
4. Weighting of criteria (according to site use);
5. Multi-criteria analysis (summarising the information from the previous stages).

The approach involves pair-wise comparisons.

GERMANY

Flow diagrams/decision support tools (DST) for management procedures of contaminated land

The flow diagram used in Germany involves three steps:

1. Identification and Historical data collection
2. Investigation and Risk Assessment
3. Remediation and Monitoring

There is no explicit decision support system for risk management. Trigger values and the method for their derivation provide the framework for risk management. The trigger levels for the "direct contact" pathway are based on the worst case scenario. It is necessary to make the decision whether these worst case conditions prevail at a particular site or whether the conditions are less severe. A similar approach is taken for the "soil – plant" pathway, but no method is available yet for the "soil – groundwater" pathway.

The decision-makers, community involvement and information communication

The local authorities are normally the decision-makers; polluters and land owners are also involved. The individuals or institutions who may be affected by any remedial actions must be informed under the Federal Soil Protection Act, and they may demand consultation and involvement in all stages of the decision-making process.

The documents required to estimate the potential pollution at the site and those relating to remedial measures proposed are available for public consultation. Where commercial / confidential information is included, full summaries must be provided as alternatives to the original documents.

Use of fixed, generic and/or other limit values and the role of specific risk assessments

The Soil Protection Act specifies that the federal government is authorised to issue ordinances that specify limit values, which if exceeded shall necessitate action. Exceeding the action values requires remedial action; exceeding the trigger values requires further investigations and a specific risk assessment to decide whether remedial action is necessary. These values include consideration of the relevant soil use; but they do not consider soil use if the threat for the groundwater is assessed.

The trigger values are based on:

- Toxicological reference data (e.g. Tolerable Daily Intake);
- A lifetime cancer risk of 10^{-5} is considered tolerable for carcinogenic substances;

- Exposure model based on soil ingestion is used for sensitive areas (e.g. residential);
- Exposure model based on soil inhalation is used for industrial areas;
- Substance specific considerations.

The list of trigger values for the “direct contact” includes 13 substances and four categories according to sensitivity of use.

Human health risks and land use risks are considered in the context of pathway models. For example, the “direct contact” pathway considers different approaches with respect to land use; a. play grounds for children; b. residential areas; c. parks, recreation areas; d. industrial areas. For the “soil-plant” pathway there are differences concerning soil use; a. agriculture; b. gardening; c. green land (non-cultivated). No different approaches have been developed for the “soil-groundwater” pathway.

The types of soil/site/water use considered by legislation and regulation; possibility for site use to be changed if remediation is not feasible

The site use is considered in the “direct contact” and “soil-plant” approaches. Differences have not been developed for the “soil-groundwater” pathway.

The site use can be changed if decontamination measures and measures to contain contamination are not possible, or if they cannot be reasonably required; in that case other protection and containment methods such as the change of site use may be applied.

Handling, recording and use of risk assessment results

There is no handling or recording of risk assessment results at the federal level. If risk assessments have been made the results will usually form part of the regional registers of (potentially) contaminated land. There is no procedure for approval and consequent use.

Special provisions for Brownfields, water resources, diffuse contamination

There are no special provisions for Brownfield sites. Groundwater that is contaminated by polluted soil has to be remediated. There are 27 substances considered in the “soil-groundwater” pathway and the trigger values are based mainly on drinking water standards. The differences between diffuse and point source pollution are principally in terms of sampling and assessment.

Consideration of environmental impacts of the remediation system (planning, verification and evaluation); wider environmental value; and sustainability issues of the remediation system.

The Federal Soil Protection Ordinance requires the assessment of environmental impacts. It is not specified how these must be undertaken. Sustainability issues are not mentioned specifically.

Measurement of wider environmental effects; economic merits; community, political and social concerns; and sustainability. The experts in developing DSTs for risk management and sustainability.

The Federal Soil Protection Ordinance requires from studies in connection with remediation investigations:

- the suitability of methods with respect to pollutants, soil, material and location;
- the technical feasibility;
- the time requirement;
- the effectiveness with regard to the remediation objective;
- a cost estimate as well as the proportion of costs and effectiveness;
- the impacts on the parties concerned as well as on the environment;
- the requirement of licences;
- the generation, recovery and disposal of waste;
- industrial safety;
- duration of the effect of the measures and possibilities for monitoring them;
- aftercare requirements; and
- possibilities for subsequent improvement.

The Federal Soil Protection Act identifies the need to specify experts in the various fields of dealing with contaminated sites. The Länder have recently issued the criteria for those experts.

Support procedures in place or planned for the remedial decision-making, the role of decision support techniques; primary factors driving decision-making for risk management

The Federal Soil Protection Ordinance identifies the requirements for support procedures in place or planned for the remedial decision-making and the role of decision support techniques. Cost efficiency assessments are included.

Risks for the soil functions (both natural and soil use functions) are the primary driving factors in decision-making.

GREECE

Flow diagrams/decision support tools (DST) for management procedures of contaminated land

There is no specific legislation dealing with contaminated land and thus there are no flow diagrams for the procedures dealing with contaminated land. There are more clearly specified procedures in respect of municipal and hazardous wastes management, aspects of which are closely related to contaminated land. To date there is no decision support system for risk management.

The decision-makers, community involvement and information communication

The decision-makers are the government, together with regional, prefectural and local authorities. Other participants in the procedures, mainly regarding the development of legislation and the planning of environmental management programmes are: environmental organisations; industry; interested private bodies and associations; NGOs; prefectural councils and citizens.

Use of fixed, generic and/or other limit values and the role of specific risk assessments

A site specific risk assessment is generally used in decision-making. The risk assessment uses criteria defined by the USEPA or European governments or agencies. Where appropriate CEN methods are used and also OECD guideline/screening values.

The Greek legislation does not provide for different levels of risk assessment.

The types of soil/site/water use considered by legislation and regulation; possibility for site use to be changed if remediation is not feasible

"The Framework of specifications and general programmes for solid waste management" lists the following post-remediation site uses:

- reintegration in the natural environment
- areas for public use
- forest districts
- grazing land
- recreational areas

There are guidelines as part of the legislative programme that define guideline values for drinking water, swimming, fish farming etc. (They are based on EU directives.) Matters related to soil use are specific to agricultural uses of soil.

Handling, recording and use of Risk assessment results

Risk assessment is site specific and uses USEPA or European approaches. Where appropriate procedures identified for handling municipal and hazardous wastes will be used.

Special provisions for Brownfields, water resources, diffuse contamination

There are a number of legislative items that refer to water resources, contamination from agricultural use (including sewage sludge). Most are derived from EU directives.

Consideration of environmental impacts of the remediation system (planning, verification and evaluation); wider environmental value; and sustainability issues of the remediation system.

There is a legislative framework to consider the environmental impacts during and after the remediation works. This is built into the planning, evaluation and decision making process.

Measurement of wider environmental effects; economic merits; community, political and social concerns; and sustainability. The experts in developing DSTs for risk management and sustainability.

The government co-operates with experts from Greek Universities, national Institutes and scientific Chambers and Associations, together with some private environmental consultancies with significant relevant experience.

Support procedures in place or planned for the remedial decision-making, the role of decision support techniques; primary factors driving decision-making for risk management

Risk based remediation objectives, cost and feasibility are all considered as primary factors in decision making.

IRELAND

Flow diagrams/decision support tools (DST) for management procedures of contaminated land

Ireland does not have legislation dealing specifically with contaminated land. A risk-based approach is used in the assessment of contaminated land, but it is not part of the legislative framework.

The decision-makers, community involvement and information communication

Those involved in the decision-making process include: the local planning authorities, the Department of the Environment and Local Government, the Environment Protection Agency and site developers.

Citizens are invited to make submissions when an application is submitted and can raise objections if permission is granted. Citizens may view any EPA licences that have been granted. If an Environmental Impact Assessment is required the public are involved during the EIA process.

All information is available to the public.

Use of fixed, generic and/or other limit values and the role of specific risk assessments

Fixed, generic or limit values are not used, although this is currently under review. In some cases approaches from other countries are used (e.g. Dutch intervention values, UK ICRCL values). The EPA has published documents which are under discussion on environmental quality standards for surface water, and plans are in place to produce discussion documents for soils and groundwater. There is no legislation on risk assessment.

The types of soil/site/water use considered by legislation and regulation; possibility for site use to be changed if remediation is not feasible

There is no specific legislation on soil/site use – there is legislation in relation to surface water use (e.g., fit to drink, suitable for salmon). If groundwater is used to supply drinking water for human consumption then the national drinking water standards apply.

It is possible to change from high quality use of the soil to a lower quality use, if a more suitable use can be determined by undertaking a site specific risk assessment.

Handling, recording and use of Risk assessment results

Where a risk assessment has been carried as part of an Integrated Pollution Control Licence or as a Waste Licence it would be assessed by the Environment Protection Agency. Licence conditions may be based on the risk assessment.

No formal procedures have been developed for recording and using the results of the risk assessment but where an application for Integrated Pollution Control Licence or Waste Licence is accompanied by a risk assessment, the results would be used in setting conditions for the licence.

Special provisions for Brownfields, water resources, diffuse contamination

The Department of the Environment and Local Government (DELG) has developed an Urban Renewal Scheme (1998) which gives financial incentives for the development of brownfield sites in urban areas. The DELG, the EPA and the Geological Survey of Ireland have developed a methodology for the preparation of groundwater protection schemes and have also prepared response matrices for potentially polluting activities such as the landspreading of organic wastes, landfills and waste water management. Surface water quality management plans are dealt with under the 1977 Water Pollution Act.

The 1977-90 Water Pollution Acts deals with agricultural diffuse pollution. Nutrient management plans for schemes involving fertilisers, organic wastes, silage effluent etc. may be required. The EPA licenses the application of organic wastes from intensive agricultural enterprises such as pig and poultry units under IPC licensing and the disposal of organic wastes to land which are not exempted under the Waste Management Act of 1996.

Consideration of environmental impacts of the remediation system (planning, verification and evaluation); wider environmental value; and sustainability issues of the remediation system.

The environmental impacts are dealt with by ongoing monitoring as agreed between the authorities and developers and are specified in the licence conditions for a particular site. There are no formal procedures in place, however consideration is given to the above during site specific analysis.

Measurement of wider environmental effects; economic merits; community, political and social concerns; and sustainability. The experts in developing DSTs for risk management and sustainability.

These are not considered.

Support procedures in place or planned for the remedial decision-making, the role of decision support techniques; primary factors driving decision-making for risk management

BATNEEC and BAT principles are used on a site-specific basis.

ITALY

Flow diagrams/decision support tools (DST) for management procedures of contaminated land

The national 'Regulation for Remediation of Contaminated Sites' (DM 471/99) does not include a flow diagram. There are no decision support systems specifically indicated in the legislation. Risk assessment models (RBCA Tool Kit, ROME, Giuditta, etc.) are used to support decision strategies.

The decision-makers, community involvement and information communication

Regional administrations provide guidelines for remediation and inventories of contaminated sites; municipal administrations authorise site investigation and remediation projects; and provincial administrations certify that remedial actions have met remedial goals. Site owners and liable parties undertake remedial procedures and risk assessment. In the case of sites of national interest, the Ministry for the Environment together with other public institutions, local authorities and the ANPA (Italian Environmental Protection Agency) authorise remediation projects together with other interested parties such as trade unions and environmental non-governmental organisations.

There is no formal process of communication or community involvement. Citizens are informed through public debates and the media.

Use of fixed, generic and/or other limit values and the role of specific risk assessments

The remedial process is linked to legal generic concentration limits in soil and groundwater: if these are exceeded the contaminated site must be cleaned up to at least the legal limits.

Whenever, according to BATNEEC considerations, this is not achievable, higher site-specific levels may be accepted as target remediation values, subject to 'safety measures' and a site specific risk assessment. As compared to the ASTM/RBCA scheme this corresponds to Tier 2 risk assessment. Tier 1 risk assessment for screening purposes is seldom carried out, but rather the legal non risk-based limits are used.

The types of soil/site/water use considered by legislation and regulation; possibility for site use to be changed if remediation is not feasible

Two categories of land use are envisaged by the present legislation and two sets of limits for soil in residential or recreational sites, and commercial or industrial sites are listed. No particular end uses for groundwater are identified.

A change of land use is only allowed in the case of 'remediation with safety measures' - whenever remediation cannot reach the generic legal set of limits. A risk assessment may support the change to a less sensitive land use.

Handling, recording and use of Risk assessment results

The Municipal Authority evaluates the results of the risk analysis within the remediation project authorisation. Risk assessments reports are kept with the local land planning records. For sites of national interest, government authorities co-ordinate the projects and keep the records of risk assessment results. Risk assessment results are approved within the remediation project authorisation process by the responsible local or national authority.

Special provisions for Brownfields, water resources, diffuse contamination

There are no special provisions for brownfields now or in the foreseeable future, although a specific law on sites of national interest highlights the importance of regeneration of unused areas within large industrial sites, some of which are included in the urban territory. Groundwater protection and remediation (for drinking water or other uses) is considered within the site remediation legislation, which does not consider diffuse pollution problems and agricultural land-uses.

Consideration of environmental impacts of the remediation system (planning, verification and evaluation); wider environmental value; and sustainability issues of the remediation system.

A specific environmental impact authorisation is foreseen for the type of treatment plants listed in the EIA legislation. There are no clear or specific references to EIA or IPPC in other cases. Sustainability issues and environmental merit are not considered under present legislation, but these issues are promoted by following BATNEEC principles and by stated limitations on landfill use. However practice may contradict these principles, as compliance with fixed limit values appears to prevail over promotion of sustainable and risk-based solutions.

Measurement of wider environmental effects; economic merits; community, political and social concerns; and sustainability. The experts in developing DSTs for risk management and sustainability.

These effects are not directly measured, but BATNEEC principles are referred to, with respect to the need for reducing waste transportation and production.

ANPA developed a specific national approach for risk assessments (1997) following RBCA and CONCAWE schemes, and developed a specific software tool to assist the process.

Support procedures in place or planned for the remedial decision-making, the role of decision support techniques; primary factors driving decision-making for risk management

No decision support procedures are available yet from public agencies, but consideration of BATNEEC principles, limitation of 'dig and dump' practices and careful assessment of environmental impacts from remedial actions, are stated. No specific cost-benefit analysis guidelines are available so far.

The primary factors driving decision-making for risk management are risks to human health and the environment, and compliance with legal limit values.

NETHERLANDS

Flow diagrams/decision support tools (DST) for management procedures of contaminated land

There is a complex set of flow diagrams available for a variety of questions relating to contaminated land management, but these have common threads:

- Is the site a potential risk?
- Is remediation urgent? – based human toxicology, ecotoxicology or rate of dispersal of material

Remedial objectives

Current approaches are driven by risk assessment rather than by the need to remove contaminated material (which characterised some earlier approaches).

A range of decision support tools are available commercially such as REC (see Section 5.4) and SUS (Saneringsurgentiesystematiek - system for environmental prioritisation of clean-up)

The decision-makers, community involvement and information communication

The major decision-makers are the party forced to remediate a site and the competent authorities (i.e., the Provinces plus the four largest cities). Responsibility for remediation lies in the following sequence:

Polluter > Owner > Party making profit on the site > Provincial Government.

Other party involvement is encouraged if relevant. Residential remediation will involve the residents; they are provided with funds to optimise their involvement.

Use of fixed, generic and/or other limit values and the role of specific risk assessments

Generic values are only used at the first stage of contaminated land assessment. Specific risk assessment is used to assess the urgency of the remediation and involves a number of 'conservative' values. Different levels/stringencies of risk assessment are provided for depending on the problem and end use.

The types of soil/site/water use considered by legislation and regulation; possibility for site use to be changed if remediation is not feasible

The situation is exceedingly complex in the Netherlands. For example, there are three kinds of quality objectives for each medium of soil, air and water, as well as three different risk levels. The end use of a site may be changed if soil contamination cannot be completely remediated.

Handling, recording and use of Risk assessment results

Consultants are hired to undertake the assessments by the party required to remediate the site. The Province must approve the risk assessment and the proposed solution.

Special provisions for Brownfields, water resources, diffuse contamination

It is only permitted to remediate pre-1987 contamination to a specific land use. New pollution must be completely remediated. The remediation of aquifers / surface waters is covered by the Preventative Soil Protection Regulations.

Consideration of environmental impacts of the remediation system (planning, verification and evaluation); wider environmental value; and sustainability issues of the remediation system.

These issues form part of environmental licensing. According to the traditional policy that prevailed in the Netherlands, there was a need for remediation if the intervention values were exceeded. The timetable for remediation was determined by the nature of the actual risks of the present or future use of the site. Sustainability was addressed only in terms of the 'costs' of remediation and specifically with respect to the choice of remediation procedure. The remediation procedure involved two approaches; the total remediation and return of multifunctionality; alternatively an ICM (Isolate-Control-Monitor) approach. The ICM approach was allowed if the total remediation would result in environmental problems, was technically not feasible, or was too costly. Following recent changes the policy allows more flexibility and will consider the relative environmental merits of the remediation procedures and the remediated site, allowing for a lower degree of remediation if the impact of the remediation procedures will be 'environmentally costly'. Applications of current and future versions of REC will increase; in addition political considerations may be important.

Urban developments and land use planning are the main driving forces in remediation projects. If land use does not change and there are no actual (only potential) risks, then there will be no remediation.

Measurement of wider environmental effects; economic merits; community, political and social concerns; and sustainability. The experts in developing DSTs for risk management and sustainability.

There is no uniform approach in measurement of these effects. Where the Isolate-Control-Monitor (ICM) approach has been chosen on the basis of technical or environmental problems a translation in financial terms would be made, but mostly the approach has been to make qualitative evaluations and rely upon the common sense of the competent authorities. There is a formula approach to cost the restoration of site to multifunctionality. If the costs of full restoration were twice the costs of ICM then the restoration to multifunctionality is considered to be too expensive. This will change under the new policy.

There are a large number of experts, but here are no plans for the development at a national level of a formal decision support system.

Support procedures in place or planned for the remedial decision-making, the role of decision support techniques; primary factors driving decision-making for risk management

The REC model will be developed. The primary factors in driving decision-making are the benefits in terms of fitness for current or future use. Environmental benefit (less aftercare, less environmental impact), cost and technical feasibility are factors which are also considered.

NORWAY

Flow diagrams/decision support tools (DST) for management procedures of contaminated land

A flow diagram summarises contaminated land management processes. Its steps are as follows:

1. Problem Description;
2. Investigation and Risk Analysis;
3. Implementation of remedial measures; and
4. Terminating the Case.

Between each of these steps there is a control and decision-making phase which determines whether it is possible to progress through to the following step. There are decision support systems available in Norwegian.

The decision-makers, community involvement and information communication

The polluter is considered responsible for remediation with the owner next in line. The decision-makers are the environmental authorities at national or regional level.

The official procedure implies that various stakeholders are entitled to comment on remediation plans and have legal rights to present alternative solutions and documentation to the authorities.

Plans are published in at least two local papers and as much as possible is 'translated' into a language which should be easily understood (this does not apply to risk assessment information which is not always fully communicated). Public hearings are occasionally carried out.

Use of fixed, generic and/or other limit values and the role of specific risk assessments

Generic values (e.g. Dutch) are only used at the first stage assessment of contaminated sites. Operative limit values with respect to the extent of remediation are derived on a case by case basis. This is coupled with enhanced use of site specific risk assessment. Differing levels/stringencies of risk assessment are not directly considered in the Norwegian legislation, but according to guidelines it may be appropriate to use various levels of site specific risk assessment.

The types of soil/site/water use considered by legislation and regulation; possibility for site use to be changed if remediation is not feasible

There is no limit on the aspects which are to be considered. All relevant negative impacts that a contaminated site may pose to a soil, land or water must be described, identified and assessed in all cases. There are also various characterisations of land use, in accordance with national planning and building legislation. It is possible to change land use after consideration of risks involved.

Handling, recording and use of Risk assessment results

Risk assessment is the basis for decisions and they are filed as general data on a site. There are no detailed procedures.

Special provisions for Brownfields, water resources, diffuse contamination

There are no specific provisions for brownfields. Surface waters are considered under the national environmental targets. Diffuse contamination is not specifically considered.

Consideration of environmental impacts of the remediation system (planning, verification and evaluation); wider environmental value; and sustainability issues of the remediation system.

Monitoring during and after remediation is essential for verification of environmental impacts. In general it is considered to be more sustainable to manage re-use of contaminated land rather than developing new greenfield sites. Cost beneficial approaches are preferred. Remediation should be compatible with local planning, but must not lead to an excessive cost.

Measurement of wider environmental effects; economic merits; community, political and social concerns; and sustainability. The experts in developing DSTs for risk management and sustainability.

These aspects are not measured, but are included in the remediation projects, both by the polluters and not at least by the authorities.

Support procedures in place or planned for the remedial decision-making, the role of decision support techniques; primary factors driving decision-making for risk management

Support procedures are currently under review following a pilot study. Legislation is the driving force for decision-making.

PORTUGAL

Flow diagrams/decision support tools (DST) for management procedures of contaminated land

There is no specific legislation on contaminated land. However, there is a programme to produce legislation on contaminated land towards the end of 2001. There is no risk assessment decision support system. When necessary the criteria employed in the Canadian and USEPA systems are used.

The decision-makers, community involvement and information communication

The environmental and economic Ministries are the decision-makers, with universities, municipalities, Regional Directorates of Environment, government institutions and industries as the stakeholders.

Local inhabitants are informed and invited to contribute to the discussions. Environmental organisations usually participate in the public debate. There are newspaper articles, conferences and public debates to communicate information.

Use of fixed, generic and/or other limit values and the role of specific risk assessments

When necessary the criteria employed in the Canadian and USEPA systems are used.

The types of soil/site/water use considered by legislation and regulation; possibility for site use to be changed if remediation is not feasible

In water legislation limits are established for human consumption and agricultural use. In agricultural practices the use of sewage sludge is regulated by law.

Handling, recording and use of Risk assessment results

There are no specific procedures at present.

Special provisions for Brownfields, water resources, diffuse contamination

Brownfields – this is a new concept in Portugal. The industrial waste plans include a proposal to create a fund (similar to ‘Superfund’) to rehabilitate the identified sites.

There is specific legislation to protect surface and groundwater resources.

Portugal has a code for the best agricultural practices; legislation regulates the use of sludges.

Consideration of environmental impacts of the remediation system (planning, verification and evaluation); wider environmental value; and sustainability issues of the remediation system.

At the outset an Environmental Impact Assessment is performed and the report of this study is submitted to a public discussion and technical analysis before final approval. During and after the execution period the process is monitored following a legal framework.

There are no defined criteria to consider environmental impacts.

Measurement of wider environmental effects; economic merits; community, political and social concerns; and sustainability. The experts in developing DSTs for risk management and sustainability.

Currently there is no information available.

Support procedures in place or planned for the remedial decision-making, the role of decision support techniques; primary factors driving decision-making for risk management

In some cases the BATNEEC criterion is used. Cost, feasibility and future use are the primary factors driving decision-making.

SPAIN

Flow diagrams/decision support tools (DST) for management procedures of contaminated land

There is legislation on waste (Waste Act, April 1998) that includes a chapter for contaminated soil. This legislation states the framework policy providing the basis for soil contamination management in Spain. At the moment this legislation is being developed in more detail. The flow diagram and the decision support tools will be developed in near future.

The decision-makers, community involvement and information communication

The polluter is considered responsible for remediation with the owner next in line. The decision-makers are the environmental authorities at regional level.

According to soil legislation, regional authority has to develop an inventory of contaminated sites and its priority list. Regional authority has to certify the site remediation, carried out by the responsible, in order to take it out of the inventory.

Local authorities are also involved and the participation of the community is promoted if required.

Use of fixed, generic and/or other limit values and the role of specific risk assessments

Limit values are currently under development.

The types of soil/site/water use considered by legislation and regulation; possibility for site use to be changed if remediation is not feasible

The reference values are in development and will include different values for different soil uses. Site use changes are not specifically defined.

Handling, recording and use of risk assessment results

No specific risk analysis procedure is currently available, but consultants normally use risk assessment and risk management. The approach is on a case by case basis.

Special provisions for Brownfields, water resources, diffuse contamination

There are not yet any special provisions for brownfields, but the legislation provides for the possibility of agreement between the parties responsible for soil remediation and the authorities. There are no special provisions for diffuse contamination.

Consideration of environmental impacts of the remediation system (planning, verification and evaluation); wider environmental value; and sustainability issues of the remediation system.

Environmental impacts of a remediation system are considered in order to choose the most appropriate remediation technology, but in practice there are no defined criteria to evaluate these impacts.

Measurement of wider environmental effects; economic merits; community, political and social concerns; and sustainability. The experts in developing DSTs for risk management and sustainability.

There are no formal guidelines for measurement.

Support procedures in place or planned for the remedial decision-making, the role of decision support techniques; primary factors driving decision-making for risk management

There are no decision support procedures available yet.

The primary factor driving decision-making is protection of human health and the environment.

SPAIN (CATALUNYA)

In Spain the waste management legislation provides the basis for soil contamination management for the whole country. However, each Autonomous Community (the regions) is responsible for developing its own criteria for soil contamination management within its territory. Catalunya, the Basque Country, Valencia, Andalucia and Galicia have already established these criteria. This section describes the situation in Catalunya.

Flow diagrams/decision support tools (DST) for management procedures of contaminated land

There is legislation on waste (the Catalan Waste Act, July 1993) which defines the responsibilities for soil remediation, but the management of contaminated soil was not specifically regulated. A flow diagram has been developed as a technical guideline; it summarises the process of dealing with contaminated land and involves five steps:

1. potentially affected sites;
2. soil suspected of contamination;
3. affected sites;
4. contaminated sites;
5. remediated site and monitoring of sites.

In each of these steps there is an assessment and a tool to help with the decision-making process to determine whether it is necessary to progress through to the subsequent step.

STEP	**ASSESSMENT**	**DST**
potentially affected site	Initial identification of the problem	simplified risk assessment
soil suspected of contamination	Investigation to identify the problem	soil quality criteria
affected site	Detailed investigation and detailed risk assessment	risk analysis
contaminated site	Selection of remedial measures and definition of remediation goals	
Remediated site and monitoring	Implementation of the remediation and monitoring following remediation	

Simplified Risk assessment. This is qualitative approach to identify source-pathway-receptors. It identifies the probability of risk at the first stages of the investigation where no analytical data are available.

Soil Quality Criteria. Generic values have been defined in Catalunya to compare analytical data from the investigations.

The decision-makers, community involvement and information communication

The responsible party for soil remediation is the polluter with the owner next in line.

The Catalan regional authority is the decision-maker, and in some cases the local authority. The stakeholders involved include all parties responsible or interested in the remediation: Polluters, owners, consultants, developers. Participation of the community is promoted depending on its implication in the case and neighbours are informed if they are affected.

Use of fixed, generic and/or other limit values and the role of specific risk assessments

In Catalunya provisional soil quality values have been fixed (Soil Quality Criteria) both for industrial and non-industrial use. These values will be reviewed for imminent legislation. If these values are exceeded, soil is defined as an ‘affected’ soil and a more detailed investigation including a detailed risk assessment is required. If the risk assessment identifies unacceptable risk, the soil is defined as a contaminated and remediation is obligatory.

The types of soil/site/water use considered by legislation and regulation; possibility for site use to be changed if remediation is not feasible

The reference values for soil and site use include industrial use and residential use. Water is considered as drinking water if appropriate. In some cases the possibility for site use to be changed is considered, if remediation is not feasible.

Handling, recording and use of risk assessment results

There are no specific risk analysis procedures at present. Risk assessment is normally carried out by consultants on a case by case basis. The results of the risk assessment are taken into consideration in defining the remedial objectives.

15.6 Special provisions for Brownfields, water resources, diffuse contamination

Brownfields are a new concept and there are currently no special provisions for brownfields. This is a problem that needs to be approached. Water resources are considered under national legislation. Diffuse pollution is not specifically considered.

Consideration of environmental impacts of the remediation system (planning, verification and evaluation); wider environmental value; and sustainability issues of the remediation system.

Environmental merit and economic merit are a key part of the decision-making process for the remediation activity. There are no guidelines for ranking.

Measurement of wider environmental effects; economic merits; community, political and social concerns; and sustainability. The experts in developing DSTs for risk management and sustainability.

There are no guidelines for measurement.

Support procedures in place or planned for the remedial decision-making, the role of decision support techniques; primary factors driving decision-making for risk management

There are no support procedures, although a cost-benefit analysis is undertaken. The primary factors driving decision making for risk management are risk based remediation objectives – cost, feasibility, planned site use.

SWEDEN

This section contains observations concerning the situation in Sweden based on an analysis of the information presented on the Swedish EPA's web site (*www.environ.se*) and supplemented with information from Martin *et al.* (1997).

Flow diagrams/decision support tools (DST) for management procedures of contaminated land

Forms are provided to assist in systematically collecting data and performing a risk assessment. The information is plotted diagrammatically to ease interpretation and decision making. There is not a flow diagram as such.

A broad decision support system exists which addresses health risks and environmental risks. This involves information on:

- hazards of the pollutants;
- concentrations of the pollutants in question;
- the migration potential of the pollutants (related to such factors as soil characteristics and groundwater circulation);
- the site's sensitivity (risk of human exposure to pollutants); and
- protective value (the presence of valuable natural features in the surrounding area).

The decision-makers, community involvement and information communication

The following stakeholders are involved in decision-making:

- National (Ministry of the Environment, Environmental Protection Agency) government;
- Regional government (responsible for heavy industry);
- Local government (responsible for small-scale industry and planning);
- Site operator;
- Land owner (possibly).

Use of fixed, generic and/or other limit values and the role of specific risk assessments

Guideline values are given for a wide range of potential metal, other inorganic and organic pollutants in polluted soils, groundwaters at polluted petrol stations and polluted surface waters. The guideline values establish limits that cannot be exceeded without risk to human health and the environment. The further over the limit value, the greater the risk.

In addition, reference values are given for polluted soils, polluted groundwaters, polluted surface waters, polluted sediments and polluted marine sediments. The reference values are used to derive estimates of the pollution levels that would have existed if the area being studied had not been polluted from a point source. These reference values reflect the natural levels of the relevant substances, plus any additions resulting from the large-scale spread of pollution.

These values are linked to hazard and risk assessments.

There are three phases of risk assessment (risk classification, simplified risk assessment, and detailed risk assessment) which consider transport and migration of contaminants, exposure and impact on human health and the environment. Sites are then classed from Class 1 (very high risk) to Class 4 (low risk).

The types of soil/site/water use considered by legislation and regulation; possibility for site use to be changed if remediation is not feasible

Two types of land use are considered – 'sensitive' (housing, any general soil use) and 'less sensitive' (traffic installations and industrial areas).

Handling, recording and use of risk assessment results

There is no information available.

Special provisions for Brownfields, water resources, diffuse contamination

There is no information available.

Consideration of environmental impacts of the remediation system (planning, verification and evaluation); wider environmental value; and sustainability issues of the remediation system.

There is no information available.

Measurement of wider environmental effects; economic merits; community, political and social concerns; and sustainability. The experts in developing DSTs for risk management and sustainability.

There is no information available.

Support procedures in place or planned for the remedial decision-making, the role of decision support techniques; primary factors driving decision-making for risk management

Health and environmental risk are the primary factors driving decision-making for risk management.

SWITZERLAND

Flow diagrams/decision support tools (DST) for management procedures of contaminated land

There are four main stages in contaminated site management:

1. Registering of sites;
2. Preliminary investigation (does the site need remediation? A basic risk evaluation);
3. Detailed investigation (detailed risk assessment, definition of remediation goals, definition of delays to be expected); and
4. Planning and realisation of remediation including monitoring of the site.

There is a computer based decision support system for the registration of sites and to support the initial decision on the necessity of an initial investigation. Development work is underway for later stages in the process, involving considerably more detailed information. This focuses in particular on the link between soil and land as a source of pollution through the unsaturated zone into groundwater. The model will follow the broad outline of the SISIM model produced by Germany.

The decision-makers, community involvement and information communication

Federal authorities set general quality standards and / or target values etc. The Cantons (local authorities) take most decisions on specific cases within the given limits set at the Federal level. Communities and citizens are involved if they are directly concerned with a specific case. Environmental organisations are not usually involved. The register of polluted sites, which also includes information about investigative and remedial actions taken on registered sites, is open to the public. Communication is important between concerned parties. Appropriate information and communication is indispensable in dealing with contaminated sites.

Use of fixed, generic and/or other limit values and the role of specific risk assessments

There are limit values (for groundwater surface water, leachates, soil, and air) that indicate the necessity to monitor or remediate a site. If a given value is exceeded the site must be remediated and / or monitored. It is acknowledged that specific risk assessments are needed at all stages, including preliminary and detailed investigations.

There are different levels of stringency. A preliminary investigation would have few input data. A detailed investigation would have much input data, and involve the development of a detailed study in order to determine the urgency and extent of further measures required (including definition of remediation goals). A worst case estimate would involve a decision on the necessity to take action.

The types of soil/site/water use considered by legislation and regulation; possibility for site use to be changed if remediation is not feasible

Agricultural use, gardens, and children's playgrounds are considered for soil use, and drinking water is considered for water use. Site use can be changed with respect to soil contamination but not with respect to groundwater use. Soil protection legislation gives a set of guidance / test / remediation values that need to be considered when decisions are to be made on whether the nature of the soil at a site is still acceptable for a particular use.

Handling, recording and use of Risk assessment results

Local authorities (cantons) use the results on a case by case basis. There is no requirement to keep records. After remediation of a particular site the remediation measures performed and the remaining risks at a site have to be communicated to the cantons by those responsible for the remediation. The decision on the use of the results lies with the cantons. The cantons have to notify the Federal Agency of the remediated sites and of the measures ordered.

Special provisions for Brownfields, water resources, diffuse contamination

There are no specific provisions for brownfields. There are federal laws dealing with water protection; and there are guideline directives on diffuse pollution (included in the federal ordinance on air pollution control) - in agriculture there is a code of good practice, as well as limit values and codes of practice on the use of sewage sludge.

Consideration of environmental impacts of the remediation system (planning, verification and evaluation); wider environmental value; and sustainability issues of the remediation system.

These are standard actions of any remediation programme. The existing remediation directive accounts for these effects. The remediation measures, geared to the individual case – ecologically sound, technically possible and financially bearable - are to be worked out within the remediation project. The remediation project provides the authorities with an instrument with which to assess the proposed measures and to definitively establish in consultation with the affected parties the remediation objectives and measures.

Sustainability is generically mentioned in the ordinance on contaminated sites in various ways. Long-term effective and sustainable remediation means that after no more than one or two generations, the remediated site can be safely left to posterity without any further measures. Similar requirements apply for containment procedures. In establishing securing measures for sites, attention must additionally be paid to long-term maintenance, monitoring, overhauling and seizure of the requisite financial means. Negative environmental impact at polluted sites that have been secured can only be prevented as long as the securing measures function.

If the remediation efforts to achieve the remediation goals would result in more harm to the environment then alternative remediation approaches would be considered. Wider economic merits such as effects on the regional economic redevelopment are only rarely driving forces.

Community, political and social concerns do not feature greatly in decision-making.

Measurement of wider environmental effects; economic merits; community, political and social concerns; and sustainability. The experts in developing DSTs for risk management and sustainability.

The approach is based on Life Cycle Analysis in which environmental burden and environmental merit are quantified based on mass and energy flows yielding and overall environmental merit. The Swiss Agency for the Environment, Forests and Landscape leads the consideration of sustainability for the remediation of contaminated sites.

There are relatively few commercial organisations with expertise in dealing with the identification and remediation of contaminated sites.

Support procedures in place or planned for the remedial decision-making, the role of decision support techniques; primary factors driving decision-making for risk management

No particular procedures are used or are available to stakeholders. Generally a remediation project is presented on behalf of the problem holder by consultants. It must deliver complete and understandable decision bases for the definitive establishment of remediation objectives and deadlines. The regulatory authority must approve these proposals. The minimum requirements are set in environmental legislation, there is a great deal of flexibility on how and over what timescales for remediation above these minimum standards, taking account of costs and acceptable environmental impacts.

Cost–benefit analysis plays a significant role. Other techniques may also be used depending upon size, significance and cost implications for a given site.

The current directive on remediation projects highlights the issues and evaluations that have to be dealt with in the remedial design project prior to approval by the competent authority.

The primary factors driving decision-making for risk management are:

- Risk based remediation objectives;
- Cost effectiveness;

- Environmental merit / sustainability;
- Planned redevelopment; v. feasibility;
- Time required and time available;
- Space and other site-specific constraints.

UNITED KINGDOM

Flow Diagrams/Decision Support Tools (DSTs)

UK legislation on contaminated land is contained primarily in the

Section 57 of the Environment Act 1995 which introduced a new Part IIA into the Environmental Protection Act 1990, and the

Town and Country Planning Act.

These are supplemented by statutory and non-statutory guidance, notably the DETR Circular 02/2000, and Planning Policy guidance No. 23, and equivalents for Scotland and Wales.

Part IIA was implemented in April 2000 in England, in July 2000 in Scotland and July 2001 in Wales. It will be implemented separately in Northern Ireland. For England its operations are outlined in a statutory guidance document Circular 02/2000 (DETR 2000). Local authorities are the primary regulator under Part IIA, while the environment agencies provide technical advice (particularly on aspects of water pollution), and in regulating 'special sites'. The Environment Agency of England and Wales has published a guide to regulatory procedures for implementation of Part IIA (Environment Agency 2000).

The implementation of Part IIA is being accompanied by a raft of technical guidance publications and training, being published by the Department for Environment, Food and Rural Affairs (DEFRA), the regulatory agencies, and other bodies such as CIRIA (The Construction Industry Research and Information Association).

The 'Model Procedures for the Management of Contaminated land' is in preparation by the Department for Environment Food and Rural Affairs and the Environment Agency. The *model procedures* will set out good practice for the overall process for managing contaminated land. They combine the tasks carried out when dealing with land which is, or may be, contaminated into a sequence of steps incorporating risk assessment and management. This framework incorporates existing good technical practice for assessing and managing the risks associated with contaminated land into a systematic process for identifying, making decisions about and taking appropriate action to deal with the contamination in a way that is consistent with UK legislation. The three primary model procedures are:

- Risk assessment;
- Evaluation and selection of remedial measures;
- Implementation of risk management actions.

These primary procedures are at the top of a hierarchy of documents, which increases in complexity and technical detail at each decreasing tier. They are to be supported by supporting secondary model procedures (e.g. for *verification of remedial treatments for contaminated land*) and technical guidance/reports. Taken together this comprehensive package of guidance will constitute a complete decision support system, linking individual decision support tools. Procedures will be summarised in a series of flow diagrams within these publications.

The majority of procedures have not been translated into software applications. However, copies of guidance are often available on the web, via*: www.environment-agency.gov.uk*.

The *model procedures* will neither be mandatory, nor a substitute for appropriate specialist experience. The procedures assist in the integration of both technical and non-technical issues to optimise the management of land.

The decision-makers, community involvement and information communication

Stakeholders involved in the decision making process include all parties with an interest in land contamination including; land owners, occupiers, developers, regulators, practitioners, financiers, insurers, environmental groups and local community groups.

Involvement of the local community in the decision making process from the earliest stages of the implementation of risk management is strongly encouraged (SNIFFER, 1999).

An agreed strategy presented in non-technical language is necessary for genuine communication with all concerned parties in order to gain public and stakeholder confidence in the approach adopted. A recent publication from the Environment Agency entitled 'Consensus Building for Sustainable Development' (Sustainable Development Series Publication SD12) provides guidance on how this is done.

Use of limit values and specific risk assessments

Fixed, generic and/or other limit values should not be used as mandated remedial objectives (clean-up standards) in the UK, but they do have a role in identifying land and/or waters where the concentration of contaminants warrants further investigation and assessment. The regulators are encouraging movement towards a risk assessment approach – however, some developers still prefer to use limit values without reference to site-specific considerations. Risk Assessments are generally used for historic contamination only. The approach is based on the Source-Pathway-Receptor principle and the need to establish the relationships between these three components. The nature of these relationships controls the degree of risks and decisions on whether the risk is sufficiently serious to warrant action. Remedial actions should be directed at controlling, modifying or destroying those Source-Pathway-Receptor relationships that present unacceptable risks. More stringent criteria would be applied to a risk assessment for a breach of a licence condition (for example, pollution caused by failure to comply with a condition in a PPC permit).

A wide variety of different criteria may be applicable in assessing the actual or potential risks associated with land contamination to health and the environment. The UK has chosen to develop guideline values rather than standards, for the assessment of risks to human health within the overall policy context of ensuring that land is 'suitable' for its actual or intended use. This allows the incorporation of qualified professional judgement in the interpretation of assessment findings, and for consideration of the nature and magnitude of the risks, technical uncertainty and the practicality and costs of dealing with contamination, when deciding upon the 'acceptability' of risk or of risk estimates in individual cases. The approach to water is more site-specific and described in "Methodology for the derivation of Remedial Targets for soil and groundwater to protect water resources" (Environment Agency, 1999) and ConSim (EA, 1999). A cautionary note is that any interpretation of risk assessment should take account of the assumed conditions in development of generic risk assessments and the departures from these conditions in individual cases. The implications of departures from these assumed conditions must be considered.

The types of soil/site/water use considered by legislation and regulation

Part IIA of the 1990 Environmental Protection Act, as introduced by Section 57 of the 1995 Environment Act, specifically defines contaminated land as '….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

a) significant harm is being caused or there is a significant possibility of such harm being caused, or,

b) pollution of controlled water is being or likely to be caused.

In this context '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.' Controlled waters include groundwaters as well as surface waters such as rivers and lakes.

The guiding principle in the United Kingdom is 'fit for purpose'. The planning and development control system will consider the intended future use of a development together with the wider environmental questions.

In practice, most remediation is secured voluntarily or through the Town and Country Planning system. Specific conditions may be attached to planning approval to require the implementation of an remedial design or construction measures necessary, either to ensure that the planned development and surroundings are safe in terms of any risks presented by land contamination, and / or, to prevent the development itself from causing unacceptable risks (for example by introducing a susceptible receptor, or a pathway linking an existing source with a receptor).

Risk assessment

Risk assessment plays a role in deciding if change can be allowed. Private practitioners normally carry out risk assessments in discrete project phases, with each phase building on the findings from the previous one, although in some situations it may be carried out as a single project. The nature of the risk assessment data will vary depending upon the practitioner and the intended future use. The boundaries placed upon the data collection should be identified and documented at the outset.

The procedures are applied to the approval of risk assessments and their consequent use for the decision making about the site remediation are variable. Risk assessments are considered on a site-specific basis by:

the development control system, where planning approval may involve specific conditions to ensure that the planned development and surroundings are safe.

stakeholders, including landowners, occupiers, developers, regulators, practitioners, financiers, insurers, environmental groups and local community groups.

Special provisions for Brownfields, water resources, diffuse contamination

There are special provisions in place or planned (e.g. administrative, permitting, etc.) for:

Brownfields: Current regulations and permitting systems do not specifically refer to 'brownfield' sites, however, discussions are in progress to establish a single land regeneration permitting system.

Aquifers and other water resources (surface or groundwater): Protection of controlled waters (surface and groundwater) is regulated through the Water Resources Act (1991), Environmental Protection Act (1990) and the Groundwater Regulations (1998). Abstraction of water requires an abstraction licence, and discharges into the water environment require a discharge consent.

Diffuse pollution controls are achieved through;

specific regulations and code of practice on spreading sewage sludge on agricultural land.

Waste Management Licensing Regulations (1994), Groundwater Regulations (1998) and PPC Regulations (2000) which deal with the placement of wastes and other materials on land

IPC / IPPC regulations control airborne diffuse pollution.

Groundwater Regulations (1998) and Nitrate Vulnerable Zone (NVZ) controls.

Consideration of environmental impacts, environmental merit, and sustainability issues of the remediation system

The environmental impact of remediation processes on site and post-remediation conditions are controlled through the Waste Management Licensing Regulations (1994) if the operations constitute waste management operations covered by the EU Waste Framework Directive. The majority of on-site remediation processes are required to be operated under a Mobile Plant Licence, which sets out general controls on the plant/process, which are applicable under all circumstances. In addition for each site to which the process is applied, there is a requirement to provide and have approved a Working Plan for the site which covers site specific factors such as bunding of sensitive areas of the site or plant, testing during the works, validation testing and long term monitoring. Some exclusions and exceptions exist for very specific circumstances. The current use of licensing in remediation projects has been set out in an Environment Agency publication (Environment Agency, 2001). However, a new licensing regime specifically for remediation projects is envisaged, and a position paper exploring possible ways forward is soon to be published by DEFRA.

New Integrated Pollution Prevention and Control regulations, implementing the EU's IPPC directive have been recently implemented, focused on operational sites rather than brownfield development.

Remediation is closely linked to the planning regime, and this context is likely to incorporate attention to sustainability issues. Local Plans provide a range of acceptable land uses, and these will constrain how a particular piece of land will be used. It is possible to challenge the constraints on use through public inquiries etc.

It should be recognised that the private sector drive and fund the majority of development and remediation, and consequently they will have a major influence on how land is re-used and the form of the remediation. In recent years large plc's have incorporated sustainability issues is their overall policy brief under their environmental policies. In most cases however the community and social concerns are introduced by Planning Authorities seeking benefits for the communities in exchange for agreement to some form of wider development that is proposed by the private sector. This planning gain is an important feature of redevelopment programmes.

The Environment Agency has a policy that promotes the use of sustainable remediation solutions. Where the Agency is in a position to influence the choice of solution, it will seek to promote treatment technologies above disposal options, provided that the solution is effective, practicable and economically viable.

The relative importance of environmental merit, economic merits and community, political and social concerns vary according to viewpoint. From a developers standpoint, cost, time-scales, feasibility and fundability are the primary concerns. From a Planning Authority viewpoint the primary concerns are appropriate land use, remediation goals and planning gain. From a funding standpoint, remediation goals, long-term effectiveness of the solution and regulatory acceptance are the primary concerns.

Measurement of environmental merit, economic merits and community, political and social concerns; and sustainability

Measurement of sustainability issues can only be done subjectively unless they have an actual cost implication for development i.e. there is an agreement to build social housing on a part of a housing site which otherwise might have received a more profitable form of housing. Other than measurement of direct financial cost, there is no formal method of measuring environmental or community benefit that is widely used in the UK.

There is no approved list of experts/companies developing decision support for risk management and national approaches to considering 'sustainability', but reference to the Environment Agency Research Contract summaries will provide evidence for organisations currently undertaking research for the Environment Agency.

Support procedures for the remedial approach

The Model Procedure for the Management of Contaminated Land in preparation will provide recommended approaches and procedures to support selection, planning and/or designing remedial approaches for polluted sites. These procedures are not expected to be mandatory, and will include flexibility to allow for expert judgement and future technical developments.

Decision support tools have a role to play in each stage of the risk assessment and risk management process. Costs and benefits will be considered at the stage of evaluating one or more remedial treatments for a given site.

A number of research projects to provide additional technical information supportive of the three primary model procedures have been initiated through the Environment Agency's R&D programme. The technical outputs of these projects may be transcribed into model procedures (e.g. costs and benefits of remediating contaminated land and groundwater; validation of remedial treatments).

Primary factors driving decision-making

Whether a particular type of remedial action or combination of remedial measures, is appropriate and cost effective for the circumstances under consideration will depend upon a number of factors including:

- The requirements for risk management – the identified risks and objectives;
- The site conditions (e.g. the physical and technical constraints);
- costs and benefits (e.g. capital and operational costs);
- local and wider environmental consequences (e.g. noise, dusts, emissions);
- regulations;

- social and political factors;
- timescales.

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ANNEX 2

"Phyto-DSS"

"PHYTO-DSS"

A Decision Support System to assess the potential of phytoremediation in the management of heavy metal polluted soils and sediments.

Phyto-DSS is presently being developed to meet the main objective of the EU-supported project PhytoDec (contract number EVK1-CT-1999-0024), that is carried out by scientific institutes in The Netherlands, Italy, France, Spain and Poland. The project continues until August 2004. Project objectives and work plan can be downloaded from the PhytoDec website that will be installed in October 2001 (*www.phytodec.nl*).

Phyto-DSS will enable the user to estimate the costs of heavy metal phytoremediation schemes in relation to its environmental and economic benefits and comparing phytoremediation with alternative remediation or soil management schemes. Phytoremediation schemes are focusing at the removal of the heavy metals from the soil after crop uptake (phyto-extraction, potentially applicable at moderately polluted sites) and at the physical and chemical stabilisation of heavy metal through direct and indirect root action (phytostabilisation, potentially applicable at heavily polluted sites).

The first phase of the construction of Phyto-DSS (to be ready in spring 2002) concentrates on phyto-extraction of heavy metals (including arsenic) from soils and dredged sediments. Moreover, major emphasis in this first phase is given to normal, non hyper-accumulating, plants and non-treated soils (i.e. no use of additives used intended to increase bio-availability in the soil). The key factor for the estimation of costs under these conditions is the phyto-extraction duration.

The basic structure of Phyto-DSS for the phyto-extraction of heavy metals is shown In Figure 19.

The duration of phyto-extraction can be estimated on the basis of:

- The pollution levels in the soil;
- Soil parameters; and
- Environmental targets (i.e. the desired final pollution level to obey to soil quality standards);
- Pollution levels (both actual levels and target levels) are defined as potentially available heavy metal pools (quantified through specific soil extraction procedures).

Transfer functions then are used to estimate the heavy metal concentration in the soil solution, both the total dissolved concentration and the ionic activity. Transfer functions are empirical formulas that are derived from a statistical analysis of extensive analytical data on the composition of soils and adhering soil solutions.

The *total concentration* of heavy metals in the soil solution, together with the average annual rain surplus, is used to estimate the leaching rate from the upper soil layer. The estimated ionic activity of heavy metals in the soil solution, together with a crop uptake factor, is used to estimate annual uptake by the crop. The crop uptake factor may or may not be a constant over a broad range of soil solution ionic activities. This is investigated in other work packages of the PhytoDec project. Crop uptake and leaching together determine the net change in heavy metal concentrations in the soil, considering estimates of additional annual inputs (fertilisers, atmospheric deposition) as well. Knowing the net amount that is removed in the first year, the residual amount can be calculated and introduced as input for the second year and so on. This way it can be calculated how many years (or harvests) it takes to reach environmental targets, thus determining the phyto-extraction duration.

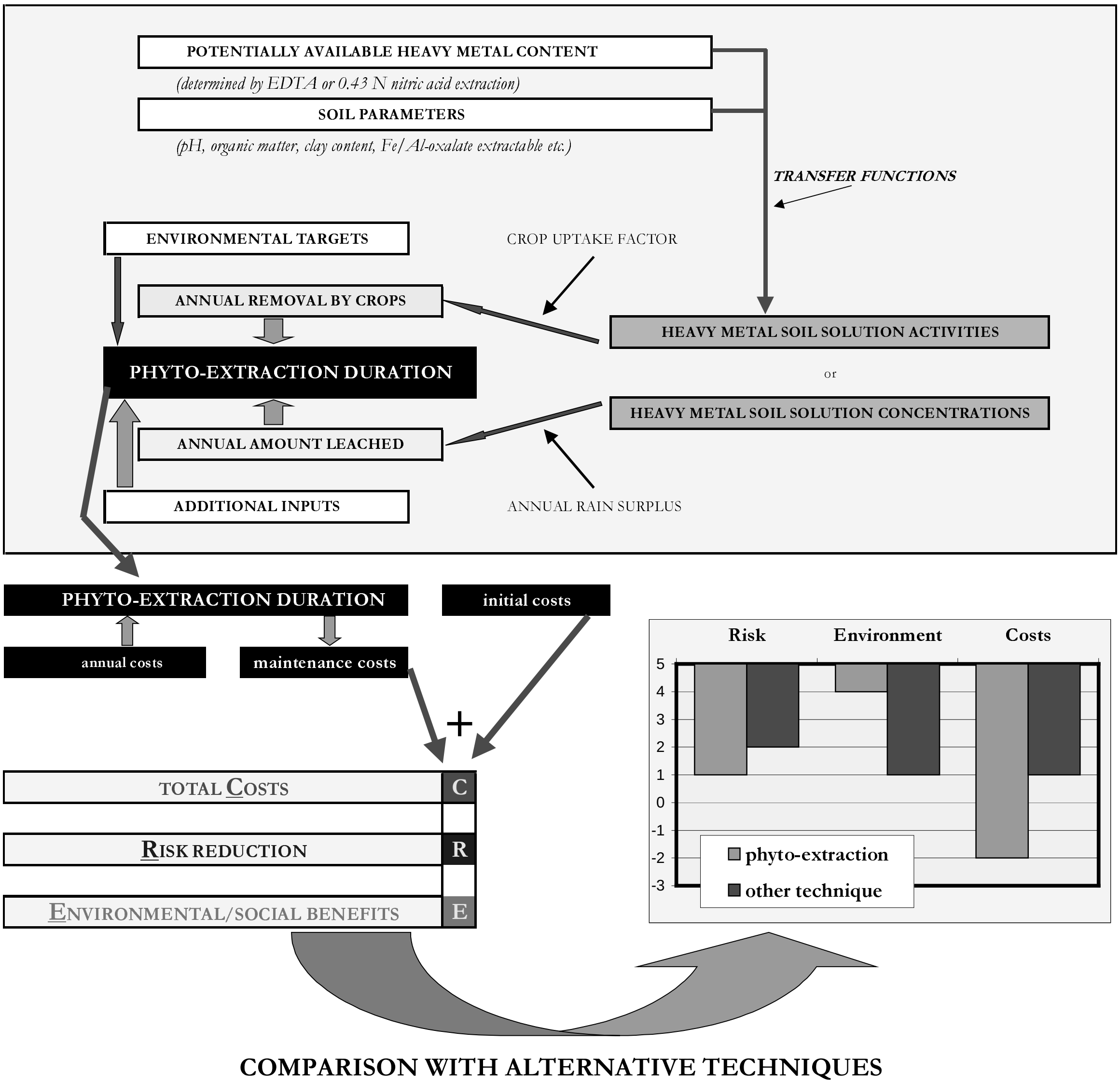

Figure 19: Phyto-DSS Structure

When the phyto-extraction duration is defined, total soil remediation costs can be estimated on the basis of *annual costs and initial costs*. Annual costs include among others depreciation of capital, monetary inflation, site fertilisation and monitoring costs to check risk reduction rates. Initial costs include fencing, initial soil tillage, preliminary experiments etc.

The whole procedure leads to a quantification of risk reduction, environmental/social benefits and costs, each factor using its own units. A similar evaluation can be done for other common soil remediation techniques, so that a comparison can be made for all relevant evaluation areas: risk reduction (**R**), environmental and social benefits (**E**) and remediation costs (**C**).

In 2001-2002 Phyto-DSS will be extended to cover phyto-extraction by hyperaccumulators. The system will be made suitable as well for the description of phyto-extraction using soil additives that enhance bio-availability (EDTA, acids etc.).

Finally, in 2003-2004 Phyto-DSS-construction will focus on phytostabilisation techniques.

To broaden the potential of its practical use, it will be discussed whether it is technically viable to link Phyto-DSS as a subroutine to a more general environmental risk-DSS like the REC-model, developed in the Netherlands. This will be done during a workshop in Pisa in November 2001.

Review of Decision Support Tools for Contaminated Land Management, and their Use in Europe

Further CLARINET publications in this series:

Sustainable Management of Contaminated Land: An Overview

Brownfields and Redevelopment of Urban Areas

Contaminated Land and its Impact on Water Resources

Remediation of Contaminated Land Technology Implementation in Europe, State of the Art

An Analysis of National and EU RTD Programmes related to sustainable Land and Groundwater Management

Clarinet Final Conference, Proceedings; 21/22 June 2001, Vienna, Austria

Prepared by Working Group "Decision Support" of the Concerted Action Contaminated Land Rehabilitation Network for Environmental Technologies (CLARINET) funded by the European Commission, DG Research, under the Environment and Climate Programme and coordinated by the Austrian Federal Environment Agency