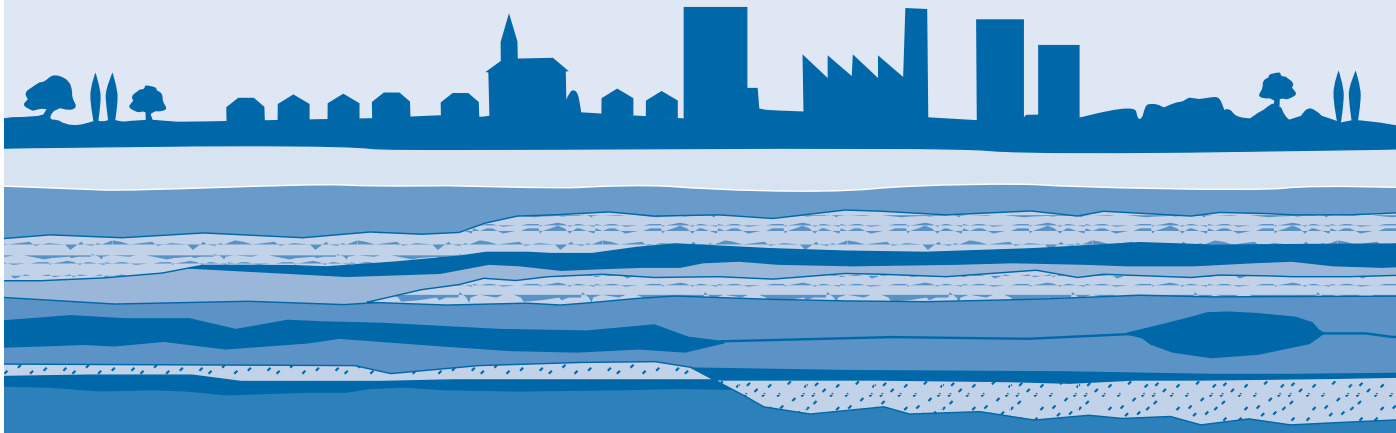
Environment Agency

underground, under threat



Groundwater protection: policy and practice

Part 3 – tools

Contents

1. INTRODUCTION 1

1.1. What are groundwater tools? 1

Conceptual understanding 3

Reviewing and forecasting 4

Screening tools 5

Site-specific tools 5

1.2. What tools are available? 6

2. SUMMARY OF AVAILABLE TOOLS 10

2.1. Tools for land-use management and risk screening 10

Groundwater vulnerability mapping 10

Source Protection Zones 11

2.2. Tools for assessing specific activities 11

Level 1 and Level 2 assessments for Groundwater Regulations authorisations 12

Hydrogeological risk assessments for landfills 12

LandSim 13

Contaminant fluxes from hydraulic containment landfills 14

Cation exchange capacity in composite landfill liners 14

Resource Assessment and Management Framework – RAM 15

IGARF (Impact of Groundwater Abstractions on River Flows) 16

2.3. Tools for assessment of land contamination 16

Remedial Targets Methodology (R&D Publication 20) 17

Monitored Natural Attenuation 18

ConSim 18

2.4. Generic tools and sources of data 19

Published maps 19

Databases 20

Other useful sources of information 21

3. REFERENCES 22

1. Introduction

1.1. What are groundwater tools?

These are the various frameworks, maps, software, and methods of numerical analysis that we use at the Environment Agency to support our management and protection of groundwater. We have developed the tools described here. However, hydrogeologists use many other tools on a daily basis. These include geological maps, proprietary models and basic groundwater flow equations. Examples of our own tools include LandSim, which calculates the likely impact of a landfill on groundwater, and IGARF, which calculates the effect of a borehole abstraction on a river.

Our tools are founded on risk-based regulation and conceptual modelling. They are supported by sound science. Figure 1.1 relates the type of tool to the risk assessment framework that we operate.

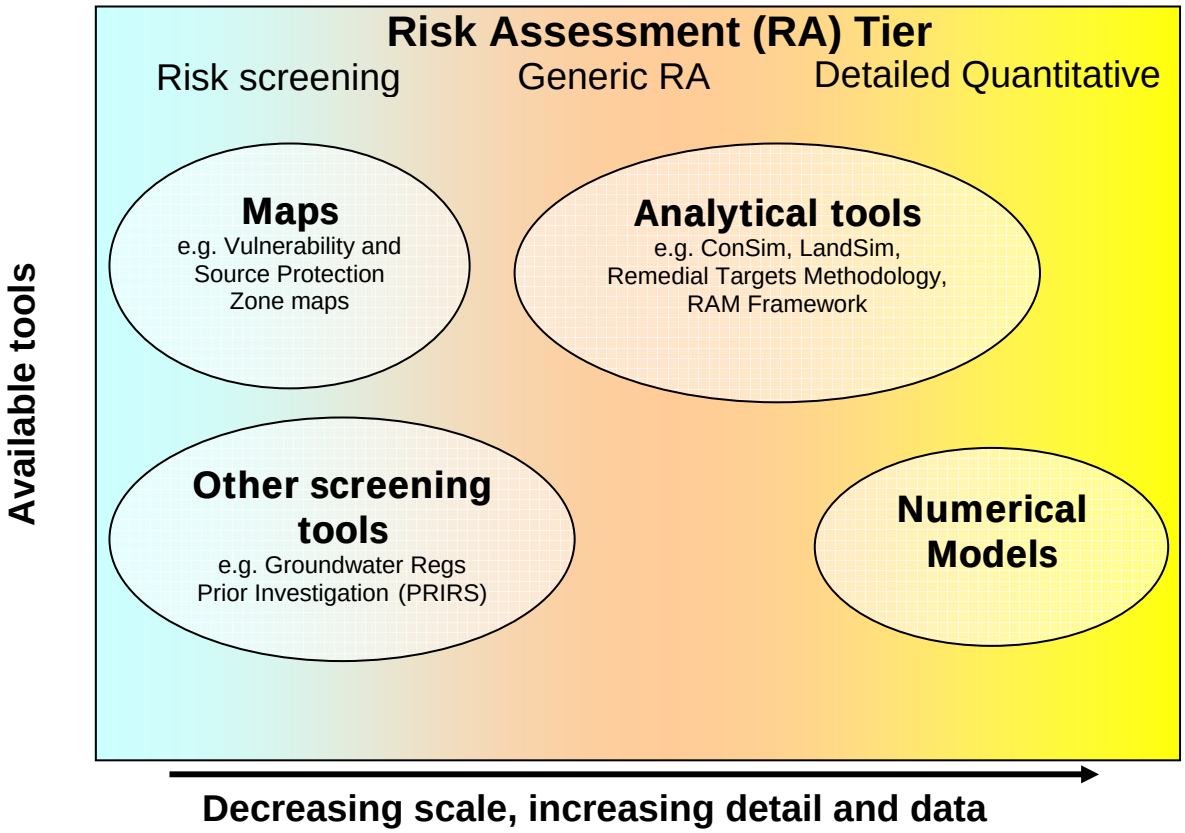


Figure 1-1 Types of groundwater assessment tools used by the Environment Agency, mapped against the different levels of risk assessment

Screening tools give an initial risk assessment of the impact on groundwater. In general, screening is used to determine which hazards or risks should be investigated in more detail. Screening is based on generic descriptions of activities and often relies on mapped properties (for example, vulnerability maps). Risk screening assesses all hazards even where there is no detailed quantitative information available.

Generic risk assessment tools tend to use a combination of generic data obtained from empirical or calculated properties in combination with some site-specific details. As the assessment moves into generic or detailed quantitative risk assessment increasing amounts of site-specific data are needed. The tools used for detailed quantitative risk assessment are often tailored to the circumstances of a particular site and may need a large amount of site-specific data. This is likely to mean intrusive investigations and analysis of on-site materials and structures.

In most cases the scale of the site reduces as the assessment process moves towards detailed quantitative risk assessment. However, numerical models may cover significant areas but nevertheless require large amounts of detailed data specific to the area being modelled.

Many of the concepts and methods employed have been generated from our own research. We have developed them into regulatory tools in response to both our own and external needs.

These tools are essentially devices to predict the impact of human activities on groundwater. This includes impacts on abstractions and on dependent waters such as rivers, springs and wetlands and their associated ecosystems. These tools support and improve our decision-making and therefore the standard of our regulatory work.

We will accept assessments that are based on tools developed by others. However, we insist that the tool and the assessment have been peer reviewed and that there is a clear audit trail for the quality assurance of any submitted results.

How do we use them?

We use different tools for particular activities. Each tool has its own method of use, underlying assumptions and limitations. It is important that users have the appropriate training and are technically competent. The necessary level of training and expertise will vary with the complexity of the tool. In all cases the user must assess objectively the limitations of the tool and the experience needed to use it. For example, if you are using Source Protection Zone maps, you require relatively little training but a good appreciation of the limitations of the maps. In contrast, a more complex tool such as ConSim requires a thorough understanding of the fate and transport mechanisms of chemicals in groundwater, chemistry and probability density functions.

The quality and availability of data are always limiting factors in the application of tools. Often a user can apply a tool in a screening mode, to establish some basic ideas and assess the quality of available information, before progressing to more detailed analysis. The screening may highlight the need to collect better information or even the need for a different approach. It is essential to use the appropriate tool and to interpret the results with a clear understanding of the applicability, accuracy, precision and relevance of the inputs and outputs.

Conceptual understanding

The first and most important step in using these tools is developing a conceptual understanding or model. This is key to assessing any site at whatever scale.

Conceptual modelling uses available information to produce a 'picture' of how the groundwater flows and interacts with the environment (for a formal definition of conceptual models, see box below). The conceptual model is then tested against reality and, if necessary, refined and tested again.

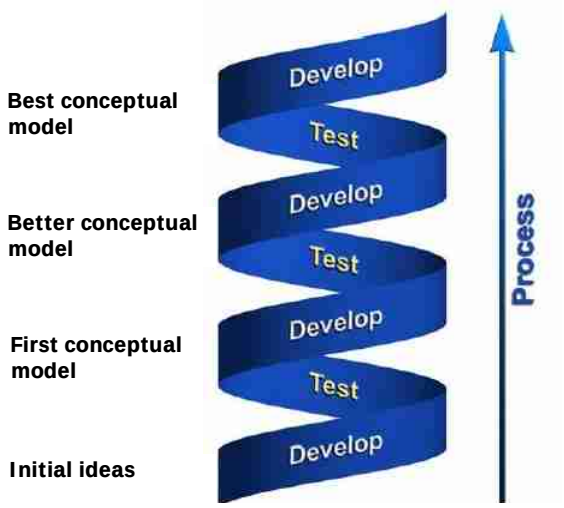


Figure 1-2 the conceptual model process

Developers of these models can continue this process until their understanding is good enough to make reasonable predictions. People using conceptual models should constantly review and refine them in the light of experience or as new data becomes available.

Definition
A *conceptual model* is a simplified representation of how the real system is thought to behave. It is based on a qualitative analysis of field data. A quantitative conceptual model includes preliminary calculations for key processes.

Conceptual models are a necessary part of all the tools we use whether they are:

- strategic – for example, maps of groundwater; or
- site-specific – such as IGARF (see Section 2.2).

Conceptual models are the basis for everything from a simple cross-section (such as Figure 1-3), to clarify the geological relationships behind a ConSim or a LandSim model, through to a detailed understanding of complex flow regimes that will support a full numerical water resources model.

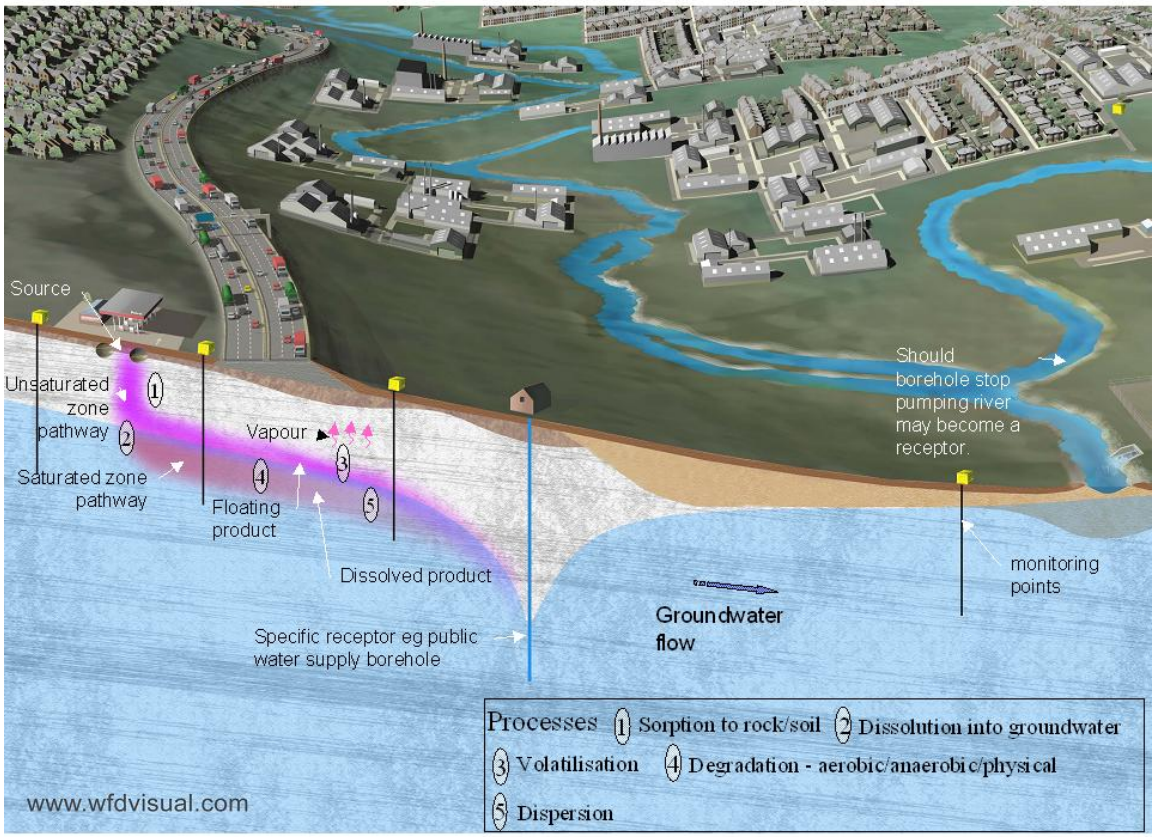


Figure 1-3 Example of a conceptual model – cross-section showing Source (leaking storage tank), Pathway (ground between the source and the water table) and Receptor (the groundwater, which is also a pathway, and a water supply borehole) (Sniffer (2005) www.wfdvisual.com)

Reviewing and forecasting

Hydrogeologists use many assessment tools for both forecasting and hindcasting. *Hindcasting* assesses the impact of current or past activities using actual monitoring data. We use *forecasting* to predict the potential impact of an activity or development. Forecasts will often use a combination of monitoring/sampling data and our best estimates of those parameters which we cannot monitor in advance. We frequently adopt a probabilistic approach to such assessments using Monte Carlo techniques – see overleaf. (The Monte Carlo technique is used in the ConSim and LandSim models.)

The Monte Carlo simulation technique.

Software using this technique randomly selects a value for each parameter used in a model's calculations. The values are chosen from a pre-defined range of possible input values called 'probability density functions'. The computer then calculates a result. This process is repeated many times to give a range of results. The collected results from the calculations are generally presented as a probability curve. This shows the likelihood of a contaminant exceeding a particular concentration at an assessment point. Models using this technique can usually display other information such as time of arrival of a substance at a point. The properties of rocks and groundwater are very variable. Using this technique allows us to see the likely range of results for a given situation. Knowing what could and is most likely to happen enables us to make better decisions.

Screening tools

We use screening tools with conceptual models, to give an initial indication if an activity is acceptable at a given location. These tools are based on generic or mapped data and their use is more qualitative than quantitative. They may indicate the level of protection needed at a site, or that a more detailed assessment is needed. The screening stage should quickly show that some activities are unacceptable; some are acceptable subject to conditions and safeguards to protect groundwater; and others require little regulation.

These types of tool focus on screening risk. They are widely used in the initial assessment of development proposals and in development control (planning) consultations. Vulnerability maps and SPZs are clear examples of screening tools. They are often linked to policies that give more information on the types of acceptable activities and likely restrictions at a particular location. This type of information is found in Part 4 of this Groundwater Protection: Policy and Practice (GP3) document. The GP3 as a whole could be regarded as a qualitative screening tool, as it provides information on which initial assessments can be based.

Many problems can be dealt with at the risk-screening level and do not need more detailed assessment. This could be because the risks are low and the activities have been previously well-characterised and assessed. At the other extreme, the risks could be well-known and very high. Then it is obvious that significant environmental damage would result if the activity took place. Where there is doubt, or if generic data are inapplicable and the problem merits more detailed assessment, the assessor will probably need to use site-specific tools and data.

Site-specific tools

At the Environment Agency, we have developed a range of methods and software packages that support site-specific assessments. We have often developed these in partnership with others. These methods and software are applicable at either a generic or detailed quantitative level. We use many of them at more than one level of assessment. This is done through combinations of site-specific data and default values. It is important that the person using the tool clearly understands the level of assessment and how this applies to the problem. This must also be communicated to everyone who sees the results.

Tools which assess specific threats to groundwater rely on the source-pathway-receptor relationships in the underlying conceptual model. The key information required includes:

- ***Sources***: these include the distribution, physical and chemical properties of the source material or effluent, and the rate of contaminant discharge or the recharge to groundwater.
- ***Pathways***: these include the geological and hydrogeological characteristics of the natural ground and any overlying engineered containment; the depth and distribution of groundwater and its direction and rates of flow; and the attenuating properties of the soil and aquifer materials.
- ***Receptors***: this may be the groundwater directly beneath the site or another agreed location at some point downstream in the groundwater flow, such as a monitoring borehole or abstraction. Receptors also include natural discharges, baseflow to rivers or wetlands.

The source-pathway-receptor relationship is part of the conceptual understanding of a site.

We group the tools based on their primary purpose and use. Some aid decision-makers who are controlling activities or substances that affect the land. Others support developers and planners when they decide how to construct or clean up a particular site.

1.2. What tools are available?

Table 1 lists all the Environment Agency's groundwater tools that are currently available. Some are suitable for a quick risk-screening exercise, i.e. to see if a proposal is intrinsically acceptable. Others are complex and provide detailed information on the risks to groundwater. We are developing others and you can find information on these on our web site.

Table 1 Environment Agency Tools and related guidance

Tool name	Purpose	Type
Groundwater Protection: Policy and Practice (GP3)	This sets out our own position on groundwater management and protection, including land use and development. It provides the framework for the application of legislation and our approach to its use. It also supports our approach to modern regulation, namely that our work should be clear to all and based on risk.	S
Guide to good practice for the development of conceptual models	Guidelines on the development of conceptual hydrogeological models. Conceptual models are the necessary first step in any assessment of risks to groundwater. The process is repeated, as results from the first assessment are used to refine the concepts initially used.	G
Groundwater vulnerability maps	Maps that indicate the intrinsic vulnerability of groundwater. They provide a screening tool to help in the initial assessment of the risks posed by a surface-based activity (on the land/soil) to groundwater. The maps are used with the GP3. You can obtain maps by contacting our National Customer Contact Centre on 08708 506506.	M
Groundwater Source Protection Zone maps	These maps show the location of Source Protection Zones for major abstractions of groundwater used for potable purposes. Zones indicate the level of pollution risk at different distances from the abstraction. Activities on the surface in zones closer to the abstraction generally have a greater chance of polluting the water source. A leaflet (800kB, PDF) is available that gives some more information.	M
Hydrogeological Risk Assessment for Landfills	Guidance on groundwater risk assessment for landfills and the setting of groundwater control and trigger levels. This discusses the complexity of assessment required for differing hydrogeological situations and landfill configurations.	G
LandSim	This probabilistic software package uses Monte Carlo techniques to assess the risk of groundwater pollution from a landfill. It determines the range of values, and how likely that particular value is to occur for a specific substance at a defined point in the groundwater outside the landfill. There is a leaflet available [PDF 285kB] giving some more background information and you can download Chapter 1 of the manual [PDF 66kB] 'An introduction to LandSim' from the LandSim web site. See also ConSim.	A

Tool name	Purpose	Type
Contaminant fluxes from hydraulic containment landfills and accompanying worksheet	This assesses the impact on groundwater of substances diffusing out of a landfill which is below the water table. It looks at a number of common configurations for landfill liners. With these configurations, a user can calculate the diffusive flux from the waste into the groundwater of a range of substances.	A
Cation Exchange Capacity (CEC) in landfill liners and accompanying Worksheet	This is guidance and a spreadsheet solution. The results will show how much a substance is attenuated by cation exchange as it passes through the mineral liner of a landfill. It is useful for risk assessments on proposed and existing landfills where mineral layers form part of the landfill liner.	A, G
Level 1 and 2 assessments for groundwater authorisations and accompanying worksheets.	These tools are for simple initial ('prior') investigations to assess Groundwater Authorisation applications for disposal to land. Level 1 is a screening tool based on a scoring protocol. Level 2 is a generic quantitative assessment. Both have supporting spreadsheets. These assessments help us to decide if an application is acceptable. If an application is acceptable, the assessments help us to set conditions on the authorisation which will protect groundwater.	S, A
RAM – Resources Assessment Methodology – and worksheet.	This sets the resource availability status for river reaches and associated groundwater. It generates flow duration curves for a river catchment and uses some simple tests to assess whether the balance between recharge and abstraction is being maintained. We use this information to set the resource availability status for surface and groundwater management units. This is then used in our Catchment Abstraction Management Strategies.	A
IGARF Methodology and accompanying worksheet.	This evaluates the effects of groundwater abstraction on surface water at a scoping level. It uses largely analytical solutions that can be applied to a variety of typical river/aquifer scenarios. It can be used to scope the range of plausible parameter values.	A

Tool name	Purpose	Type
Remedial Targets Methodology (P20) and accompanying worksheet	This methodology is used to set targets for cleaning up soil and groundwater to protect water resources. The technique is usually applied to contaminants in the ground and informs the decisions on the level of clean-up on the site. It introduces the tiered approach to groundwater risk assessment and discusses the data needed for each tier.	A, G
Guidance on Monitored Natural Attenuation (MNA): R&D Publication 95	This is guidance on assessing the viability of natural attenuation processes as a method of cleaning up contamination. It introduces the framework for the detailed monitoring of groundwater to ensure that natural processes are reducing the risk of pollution.	A, G
ConSim	This probabilistic software package uses Monte Carlo techniques to assess the risk to groundwater from contamination in the ground. ConSim allows us to consider the uncertainty and natural variability relating to the source-pathway-receptor system in the risk assessment. It uses ranges of data to show the probable concentration of substances in the ground should they reach a specified location. See also LandSim.	A

Type key - A = Analytical tool, G = General guidance, M = Map tool, N = Numerical model, S = Screening Tool

Note. Before you select any of the assessment models or tools described here, you need a sound conceptual model of the site. You should be satisfied that the tool you select to model the site is appropriate, ie that it represents the conceptual model and performs analyses appropriate to the quality of the input data.

2. Summary of available tools

This section provides a brief description of the tools that we have developed to protect and manage groundwater. The tools are grouped according to their potential uses.

2.1. Tools for land-use management and risk screening

These generally operate on a large scale and are based on data sets with national coverage. People can use them to quickly evaluate the groundwater risk from an activity and decide if it requires more study. Typically, groundwater is 'out of sight' and therefore 'out of mind' when decisions on land-use management are made. These tools help to overcome this problem by raising awareness of the presence and distribution of groundwater.

The primary tool in any assessment of groundwater, including risk screening or considering the impact of land use management, is a conceptual model. They can range in scope from qualitative to quantitative and can be complex. Conceptual models are more fully described in Section 1 above.

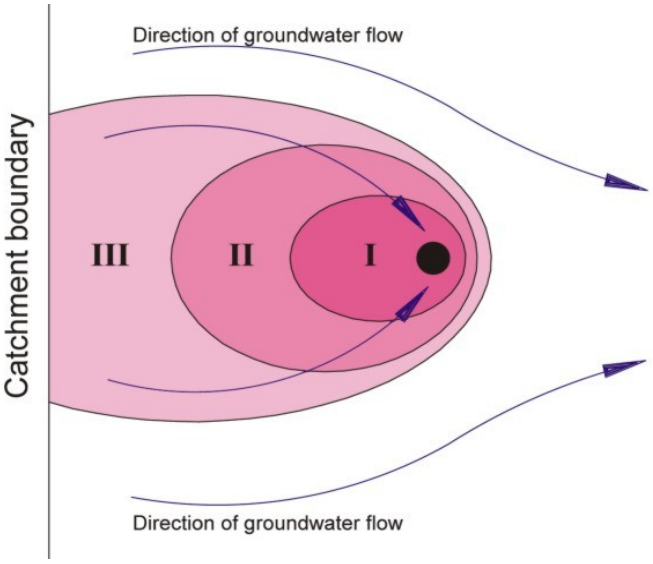
Groundwater vulnerability mapping

The Groundwater Vulnerability maps are produced at 1:100,000 scale. They show, by means of colour coding, those areas of the country where water-bearing rocks (aquifers) are present. They also show the vulnerability of groundwater to pollution. The aquifers are classified into major, minor and non-aquifers according to their physical properties and their consequent value as a resource. The classification of the land surface reflects the ability of contaminants to leach through the covering soils and pose a potential risk to groundwater at depth. The maps also indicate areas where the presence of low permeability drift may provide additional groundwater protection.

These maps can therefore be used for an initial screening assessment of the vulnerability of groundwater to contaminants applied to the surface of the ground. They do not provide all information relevant to the determination of vulnerability, such as the depth to water table or nature of the drift deposits. Site-specific information would always be needed for a detailed assessment of vulnerability at a given location.

The original groundwater vulnerability maps were produced some time ago. They are becoming incompatible with the regulatory regime that the Water Framework Directive is bringing into force. This regime will be fully up and running by 2012. As a result, we are developing a new framework for assessing groundwater vulnerability. In the meantime, the interim up-to-date maps are only available in digital format from our National Customer Contact Centre on 08708 506506.

Source Protection Zones



Source Protection Zones (SPZs) indicate the risk to groundwater supplies from potentially polluting activities and accidental releases of pollutants. Zones have been defined for more than 2,000 groundwater sources. These are wells, boreholes and springs used for major potable uses, in particular public drinking water supply. We usually define three zones: an inner, outer and total catchment. Occasionally we define a fourth zone, called a zone of special interest. You will find more detail on the definition and application of SPZs in GP3 Part 2: Technical Framework.

A Source Protection Zone is a signal that there are likely to be particular risks due to the use of the abstracted groundwater. If the quality of abstracted groundwater is affected by activities that take place nearby there may be serious consequences for the users of the water. The zones are defined at the water table and do not consider the effect of the unsaturated zone. SPZs and Groundwater Vulnerability Maps provide an initial screening for assessing the impact of specific activities. SPZs can also help to target measures against pollution in those areas most at risk. SPZs are available for direct download from our website and are free of charge.

2.2. Tools for assessing specific activities

These tools are for use in assessing groundwater impacts at individual sites, or at a catchment scale (eg RAM framework), such as to assess landfill and contaminated land developments, or individual groundwater abstractions.

When used at the catchment level such tools can provide strategic assessment of activities. This mostly applies to water resources assessments where the combined resources for an area need to be analysed to optimise use whilst protecting the environment. Catchment wide study is also needed for some large abstractions, or abstraction in a sensitive location. The emphasis is on forecasting the impact on groundwater and linked environments from the activity in question. The tools are also useful in hindcasting, to understand the effect an activity is having and the possible result of any proposed changes.

Tools for assessing groundwater abstraction support our licensing decisions and the management of resources. We use them internally in assessing proposals for new or varied abstraction. They are also valuable to external organisations such as water companies, consultants and companies providing private water supplies.

Our tools to design and assess landfill sites help us to formulate responses to consultations and determine permit applications. We have developed these tools in-house and in partnership with external organisations. They are also helpful to a wide range of practitioners, including consultants and site owners. Due to the long-term pollution risk from landfill, our own tools do not just consider the comparatively short operational phase of a landfill, but look at the whole life cycle of the landfill – until it poses no further hazard to human health or the environment.

Level 1 and Level 2 assessments for Groundwater Regulations authorisations

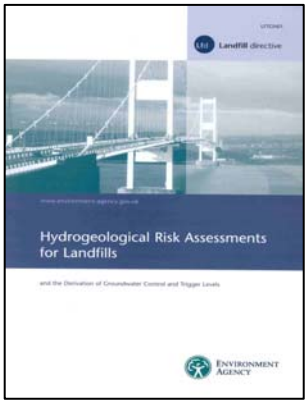
If you want to dispose of certain agricultural wastes (such as pesticide washings and waste sheep dip) by spreading them on to land, you will need us to issue you with a Groundwater Authorisation. The Groundwater Regulations 1998 specify that there must be a prior investigation before we grant authorisation. We can only grant an authorisation if the investigation and our subsequent assessment demonstrate that there will be no unacceptable discharge to groundwater.

The first stage is the Level 1 assessment. This initial screening uses the applicant's submission and other information readily available to us. A simple and conservative scoring table considers key factors such as the nature and volume of the effluent, the hydrogeology and the general site setting. This indicates whether sites are acceptable, unacceptable or require further consideration.

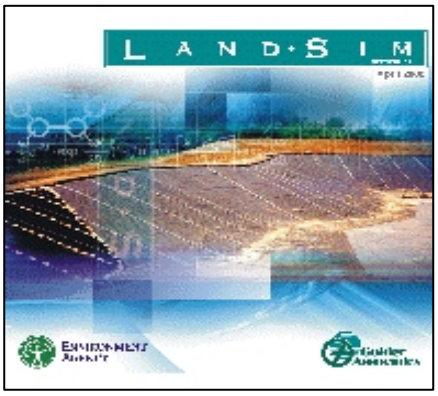
Sites that warrant further consideration may progress to a Level 2 assessment. This takes a more quantitative approach and looks at the migration of contaminants through the soil zones. Simple spreadsheets support the methodology.

Hydrogeological risk assessments for landfills

This document provides guidance on the requirements for the assessment of the risk to groundwater from landfills. It is also used to set groundwater control and trigger levels in the PPC permit process. This guidance considers the underlying requirements of the Groundwater Regulations and Landfill Regulations. It sets a baseline both for us and for landfill developers and their consultants. The guidance describes a tiered approach, from initial risk screening through to simple and complex risk assessments. There are several appendices that provide useful supporting information on leachates and water quality. There is also a checklist to support the appraisal of risk assessments.



LandSim



LandSim was developed by the Environment Agency to assess the risk to groundwater from a landfill site.

Since 1995 it has been used to evaluate:

- leakage of leachate from landfills;
- attenuation in the unsaturated zone;
- dilution and contaminant transport in the saturated zone.

LandSim allows landfill operators and regulators to consider the environmental performance of the geological barrier, artificial sealing liner and leachate collection systems. It can also take into account the large variety of geological and hydrogeological regimes and site-management scenarios. At the Environment Agency, it is our preferred tool for assessing the risks to groundwater from landfill sites. It is part of our assessment process for determining Pollution, Prevention and Control (PPC) permits for landfill sites.

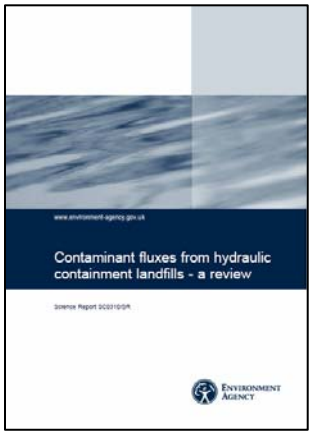
LandSim uses the Monte Carlo simulation technique (see The Monte Carlo simulation technique box (page 5), as does ConSim (page 18). The Monte Carlo technique is suited to assessing landfill because of the range and uncertainty of the parameters used in calculating a site's impact. The probabilistic input extends to the performance of specific landfill lining systems and leachate chemistry.

Program outline

LandSim enables groundwater risk assessments to be carried out by experienced professionals with a good background in landfill engineering, hydrogeology and risk assessment. An in-depth knowledge of programming is not needed. A cartoon guides you along the path of contaminant transport, from the engineered landfill to a groundwater receptor. Parameters are assigned to the model using pop-up dialogue boxes.

LandSim assumes the landfill is above a simple unidirectional groundwater flow field. Other modelling techniques may be required for sub-water table landfills or for more complex groundwater situations.

Contaminant fluxes from hydraulic containment landfills



Hydraulic containment is the practice of operating a landfill below the water table with a lower leachate level than the external groundwater head. This document is not a design manual for landfills and does not advocate the construction of such sites.

The report contains information on diffusion across the low permeability materials used in basal and side-wall liners and barriers in landfills. It will help decision-making for risk assessments at landfill sites using hydraulic containment. To accompany the report we have developed a spreadsheet tool that helps to assess the impact on groundwater of landfills operated under hydraulic containment. The spreadsheet model is a scoping tool that calculates diffusive contaminant fluxes from hydraulic containment landfills, and also their concentrations in groundwater (or pore water at the outer edge of the liner for List I substances). The spreadsheet model is pre-configured to use landfill designs that comply with the three scenarios described in the report. A user manual accompanies the spreadsheet. This explains how to use the spreadsheet model, and how to interpret the results.

Cation exchange capacity in composite landfill liners

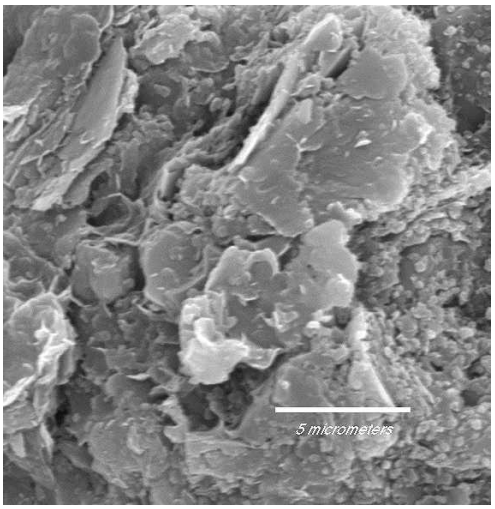


Figure 2-1 Scanning electron microscope picture of clay minerals (from www.geol.lsu.edu)

At the Environment Agency, we have developed a spreadsheet solution and user manual on cation exchange. This is to help assessors to determine the potential for the attenuation of cations within the mineral layer of a composite landfill. This potential is determined by the cation exchange capacity of the mineral layer (CEC). Cations are positively charged atoms or molecules, usually metals.

The spreadsheet model (version 1.0) calculates solutions to equations developed by Appelo and Postma (Ref 2). This worksheet may be used for groundwater risk assessments at existing or proposed landfill sites using a composite landfill liner. It may be used with a LandSim assessment, or to support other groundwater risk assessment tools used at the application stage for planning/waste management permits. It may help to indicate whether a landfill can be engineered to comply with the Groundwater Regulations.

Resource Assessment and Management Framework – RAM

This tool is used to implement Catchment Abstraction Management Strategies (CAMS). It builds on our accumulated knowledge and experience, existing best practice and recent work in the fields of water resources management and hydro-ecology.

We use the RAM framework to set resource availability status. This status is based on an estimate of naturalised river flows, the actual or potential impact of artificial influences (water abstractions and discharges) and the ecological assessment of the river reach. When it is possible or feasible to do so, we look at groundwater resources in relation to the surface water catchment divisions. Where this is not appropriate, the RAM framework can be supported by the results of other groundwater resource assessments. We can derive resource information from the construction of regional-scale groundwater flow models, for example. Based on experience gained over the past 30 years, we have produced a national technical framework, together with guidance notes, for the development of these models.

We also make a number of separate checks, as part of the groundwater resource assessment, to ensure that an adequate balance between recharge and abstraction is maintained. We then bring together the results in order to set the resource availability status for each river reach and groundwater management unit. There are four classes of resource availability status. These are shown in Table 2.1.

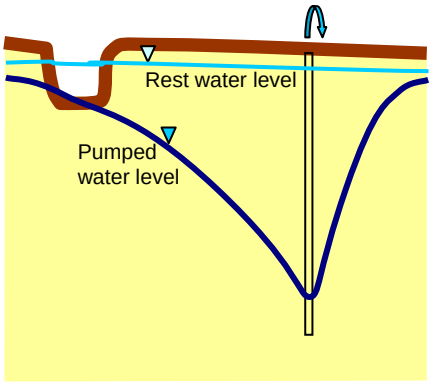
We use the resource availability status to draw up an overall strategy for managing the catchment. This is all fed back into the CAMS sustainability appraisal and consultation process. Once this is finalised, we have a framework for the management of that catchment's resources. This framework will last for six years, and will then be reviewed.

Table 2.1 Resource availability status categories

Resource availability status	Definition
Water available	Water is likely to be available at all flows including low flows. Restrictions may apply.
No water available	No water available for further licensing at low flows. Water may be available at higher flows with appropriate restrictions.
Over-licensed	Current actual abstraction is such that no water is available at low flows. If existing licences were used to their full allocation they could cause unacceptable environmental damage at low flows. Water may be available at high flows, with appropriate restrictions.
Over-abstracted	Existing abstraction is causing unacceptable damage to the environment at low flows. Water may still be available at high flows, with appropriate restrictions.

IGARF (Impact of Groundwater Abstractions on River Flows)

We have developed this tool to evaluate the effects of groundwater abstraction on surface water flows. It comprises a user manual and spreadsheet for processing data. It uses a tiered risk-based approach to evaluate the impacts. Our staff uses the output from the spreadsheet and user manual to assist in the process of determining and reviewing abstraction licences.



The IGARF methodology has three specific uses:

1. To evaluate the impact of periodic abstractions, such as spray irrigation.
2. To evaluate the impact of steady abstractions, for example, public water supply.
3. To design tests to gather information to assess both periodic and continuous abstractions.

This tool can also be used to scope the benefits of pumping groundwater directly into a river to augment surface flows.

The methodology is based on current practice in use across the Environment Agency. It uses common analytical solutions that are applicable to a wide variety of hydrogeological conditions. These analytical models provide only simplified idealisations of real environmental situations. However, we can deploy them quickly, cheaply and with only limited information. They are also useful in directing further data collection.

IGARF is useful for assessors to scope the range of possible impacts, but suitably qualified and experienced hydrogeologists must make the final decision.

2.3. Tools for assessment of land contamination

We have developed a number of site-specific tools to help assess the risks of pollution to the water environment from contaminated sites and set appropriate criteria for clean-up operations. These tools are especially useful where potential point-source contamination is suspected.

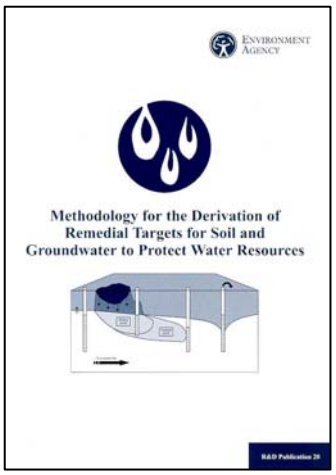
The need for site assessment due to potential contamination may arise for example during discussions with site owners or developers. However it can also arise as part of a more formal process, such as a response to a planning application or through the application of the Part IIA contaminated land regime. Typical instances would include:

- sites with known problems – i.e. a site investigation has already been undertaken which highlights the nature/extent of contamination;
- sites at which a new process has the potential to pollute groundwater or the wider water environment – for example, a proposed new development on the site of a closed landfill.

All such assessments need a well-founded conceptual model of the site.

As with many of the tools described in this document, methods for cleaning up pollution are under continual development. You may well find that there are also other tools available. We will do our best to include all relevant items and update this document as necessary. However, do not treat this document as a comprehensive list. Additional information is in the 'Model procedures for the management of land contamination (CLR11)'.

Remedial Targets Methodology (R&D Publication 20)



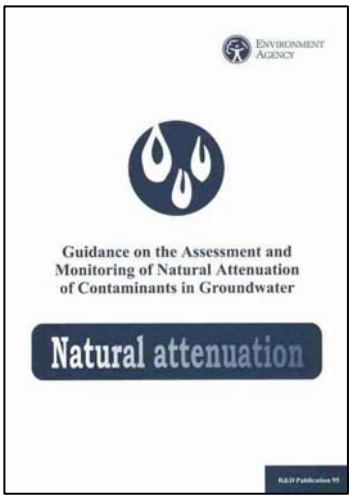
This tool provides a standardised, practical approach to determining what needs to be done to clean up soil and groundwater in order to protect water resources. The methodology can be applied on a site-by-site basis and is consistent with current legislation and guidance. This approach is detailed in the report *Methodology for the derivation of Remedial Targets for Soil and Groundwater to Protect Water Resources* (R&D Publication 20). It is commonly referred to as the P20 report.

The P20 report is part of the overall process to evaluate the risks that contaminated soil and groundwater pose for health and the environment. Its methodology is based on a tiered risk assessment, with the level of analysis and detail increasing at each stage. A source-pathway-receptor analysis produces criteria for remediation that are specific to that site. These criteria are based on an assessment of the potential impact at the identified receptor.

The methodology produces a remedial target at each tier. This is likely to be less demanding at each consecutive tier. This is because each stage of assessment – tier – looks at more of the processes that affect contaminant concentrations along a pathway. Examples of such processes are dilution and attenuation. At each stage, the data requirements and the sophistication of the analysis also increase, so users gain a better understanding of the source-pathway-receptor relationship. The user can then have more confidence in the predicted impact. This tiered approach enables low-risk sites to be screened out, and allows regulators and developers to focus their attention where risks are greatest.

The P20 report is not intended to provide a prescriptive approach. Rather it identifies the key factors for deciding on remedial targets. This decision process will generally require a high level of technical expertise, particularly at the higher tiers of assessment (Tiers 3 and 4). It will also require a detailed knowledge of both hydrogeological and geochemical processes, and expertise in the application of models.

Monitored Natural Attenuation



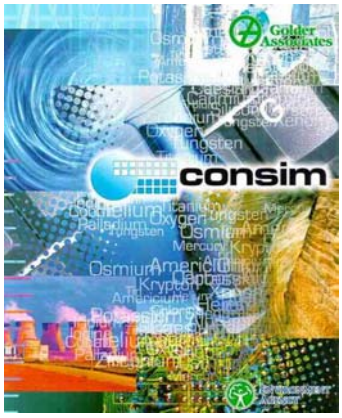
Monitored natural attenuation (MNA) is increasingly accepted as a viable, cost-effective option for managing the risks of contaminated groundwater. This is mainly because evidence shows that, under certain environmental conditions, naturally occurring processes in the subsurface can reduce the mass, toxicity, mobility, volume or concentration of organic and inorganic contaminants. These reductions are due to the following mechanisms acting alone or together on contaminants:

- destructive mechanisms, including biodegradation, abiotic oxidation and hydrolysis;
- non-destructive mechanisms such as sorption, dispersion, chemical or biological stabilisation, and volatilisation.

The term MNA refers to the monitoring of groundwater to confirm that natural attenuation processes are acting at a rate that will leave the wider environment unaffected and ensure the achievement of remedial objectives within a reasonable time scale.

At the Environment Agency, we recognise that environmental risks and regulatory control mechanisms will vary between sites. The guidance given on MNA is a generic framework, rather than prescriptive requirements. Our aim is to encourage best and consistent practice in the design, evaluation and implementation of natural attenuation strategies within a risk-based context. In developing MNA schemes, the people responsible for the clean up should always consider the requirements and constraints of the applicable regulatory framework(s).

ConSim



ConSim is used to assess the risk to groundwater from contaminated sites. It can also help in considering the impact of contaminated groundwater on other receptors. We developed ConSim for use by our own staff and by those concerned with the management of land contamination. The software has been developed in accordance with the guidelines set out in P20.

The software models the mobilisation and transport of contaminants. It can use commonly available site investigation data to calculate the probability of groundwater being polluted. Large amounts of common data are available in the software. ConSim uses the Monte Carlo simulation technique (see The Monte Carlo simulation technique box on page 5) for more information.

ConSim may be used:

- to help to establish whether a site could have a significant pollutant linkage that could pollute controlled waters;
- to assess whether or not one needs to collect additional site investigation data in order to quantify the risk to groundwater from land contamination;
- to determine how much remediation is required to reduce the risk of polluting controlled waters to an acceptable level;
- to compare the viability of various remedial techniques to see which is most likely to reduce the risk of contaminating controlled waters to an acceptable level.

ConSim adopts a tiered approach similar to that described in P20. The tiered structure consists of:

- Level 1 – Contaminant Source Assessment;
- Level 2 – Unsaturated Zone Transport, Aquifer Dilution;
- Level 3 – Saturated Zone Transport.

At each level, one can compare the calculated contaminant concentrations with appropriately selected water quality standards or site-specific assessment criteria. This will show the size of the possible effect on groundwater.

Program outline

ConSim uses cartoon representations, pop-up dialogue boxes and drop-down menus. ConSim is a probabilistic model that uses the Monte Carlo simulation technique. You have to select an appropriate probability density function (PDF) for each input parameter from a drop-down menu. The results can be printed out in graphical or statistical form.

2.4. Generic tools and sources of data

We also rely on generic tools and data sources to do our job. These are often the fundamental building blocks of groundwater management and protection. Below, we list some of the most important generic tools. The list is not exhaustive, as there are many of these available.

Published maps

In our day-to-day work, the tools and data sources that we most commonly use are published maps and their associated literature. We use a number of maps when we assess the risk to groundwater. These are listed in Table 2.2.

Table 2.2 Relevant maps and literature used as tools and data sources

Map	Description	Source
Geological maps and associated memoirs	These show geological strata and are available at different scales. Some show drift or unconsolidated strata alone or in combination with the underlying bedrock (solid geology). Others may show only solid geology. The memoirs document the detail of the geology for the map area.	British Geological Survey
Soil Maps and associated booklets	These give the soil cover for England and Wales. The cover is broken down into different soil classes. Detailed descriptions of the soils are provided in associated booklets.	National Soils Research Institute
Hydrogeological Maps	There are national summary maps. Limited areas of the UK also have maps with information on groundwater flow and chemistry. These are available at 1:125,000 scale.	British Geological Survey
Thematic Maps	Geological maps dealing with specific issues such as risk of land-slip.	British Geological Survey
Baseline Reports (To see available reports follow link above and search for 'Baseline')	Information on the expected 'natural' quality of the groundwater in a large number of aquifer blocks in England and Wales.	Environment Agency/ British Geological Survey
CAMS Reports	These show the results of our assessments of available water resources in designated catchments. Based on this the policy for resource management in that catchment is set out	Environment Agency

Databases

At the Environment Agency, we hold information on water levels, river gauging, abstractions, discharges, water quality and more. The public does not have direct access to much of this information. However, some is available (generally in summary form) on our web site or through public registers, or by request. We may sometimes make a charge in order to cover our costs.

Other useful sources of information

Other useful information sources include:

- Reports on aquifer properties – these cover the hydrogeological properties of most of the important aquifers in England and Wales. We produce them jointly with the British Geological Survey.
- Hydrogeological Reports – produced by the British Geological Survey and give additional information on certain aquifers and activities.
- British Geological Survey Geochemical Atlases – this provides map-based information on the geochemical characteristics of the rocks of the UK. It is produced by the British Geological Survey.

This list is by no means exhaustive.

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