1

INTRODUCTION

Groundwater provides an important source of drinking water over much of the world. It also has the fundamental importance of maintaining river and stream flows during periods without rain and also supporting wetland sites. Groundwater is under threat worldwide from over abstraction and by contamination from a wide range of human activities. In many countries, activities that may impact on groundwater are regulated by government organisations, which frequently require hydrogeological investigations to assess the risks posed by new developments.

Pumping from new wells may reduce the quantities that can be pumped from others nearby, cause local spring flows to dwindle, or dry up wetlands. The hydrogeologist will be expected to make predictions on such effects and can only do so if he or she has a proper understanding of the local groundwater system based on adequate field observations. It is equally important to evaluate groundwater quality to ensure that it is suitable for drinking and for other uses. Groundwater commonly provides the flow path that allows pollutants to be leached from industrially contaminated sites, landfills, septic tanks, chemical storage areas and many more. Hydrogeological studies are needed to define groundwater systems in order to prevent such contamination or manage its clean-up. This book is concerned with the field techniques used by hydrogeologists to evaluate groundwater systems for any or all of these purposes and with the primary or initial interpretation of the data collected in the field.

1.1 Groundwater Systems

Groundwater is an integral part of the hydrological cycle, a complex system that circulates water over the whole planet; this is illustrated in Figure 1.1. The hydrological cycle starts as energy from the sun evaporates water from the oceans to form large cloud masses that are moved by the global wind system and, when conditions are right, precipitate as rain, snow, or hail. Some of it falls onto land and collects to form streams and rivers, which eventually flow back into the sea, from where the process starts all over again. Not all rainfall contributes to surface water flow, as some is returned to the atmosphere by evaporation from lakes and rivers, from soil moisture, and as transpiration from plants. Water that percolates through the soil to reach the water table becomes groundwater. In thick aquifers, groundwater at depth is below the depth of freshwater circulation and is saline, often with a higher electrical conductivity than seawater. The same is true for groundwater down dip from the outcrop of an aquifer. Groundwater flows through the rocks to discharge into either streams or rivers. In coastal areas, groundwater discharges into the sea, and the aquifer contains seawater at depth. The volume of water percolating into the aquifers defines the groundwater resources that both support natural systems and are available for long-term water supply development. In most groundwater studies it is necessary to consider the other components of the cycle as well as the groundwater itself in order to understand the groundwater system. Consequently, hydrogeological investigations usually include a range of field measurements to assess these parameters.

Groundwater flow through saturated rock is driven by a hydraulic gradient, which, in unconfined aquifers, is the water table. Rocks that both contain groundwater and allow water to flow through

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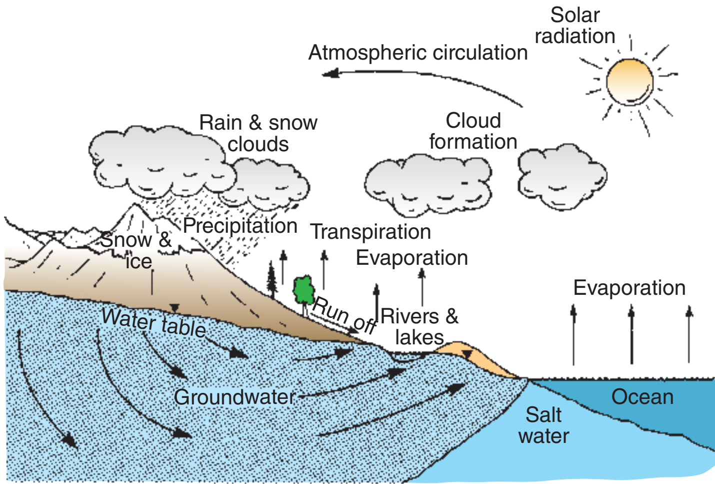

Figure 1.1 *The hydrological cycle.*

them in significant quantities are termed *aquifers*. Flow rates that are considered as significant will vary from place to place and also depend on how much water is needed. Water supplies to individual houses require small groundwater abstractions compared to wells supplying a whole town. In pollution studies, even small groundwater flow rates may transport considerable amounts of contaminant over long periods of time. A critical part of the definition is that the rock allows a flow of water, rather than simply containing groundwater. Some rocks such as clays have a relatively high water content, although water is unable to flow through them easily. Other rocks may not be saturated but still have the property to permit water to flow, and therefore should be regarded in the same way as an aquifer, a clear example being the part of an aquifer formation that lies above the water table.

Unless groundwater is removed by pumping from wells, it will flow through an aquifer towards natural discharge points. These comprise springs, seepages into streams and rivers, and discharges directly into the sea. The property of an aquifer that allows fluids to flow through it is termed *permeability*, and this is controlled largely by geological factors. Properties of the fluid are also important, and water permeability is more correctly called *hydraulic conductivity*. Hydrogeologists often think of hydraulic conductivity on a field scale in terms of an aquifer's *transmissivity*, which is the hydraulic conductivity multiplied by the effective saturated thickness of the aquifer, often taken being the depth of local wells.

In both sedimentary rocks and unconsolidated sediments, groundwater is contained in and moves through the pore spaces between individual grains. Fracture systems in solid rocks significantly increase the hydraulic conductivity of the rock mass. Indeed, in crystalline aquifers of all types, most groundwater flow takes place through fractures, and very little, if any, moves through the body of the rock itself. Some geological materials do not transmit groundwater at significant rates, while others only permit small quantities to flow through them. Such materials are termed *aquicludes* and *aquitards*, respectively, and although they do not transmit much water, they influence the movement of water through aquifers. Very few natural materials are completely uniform and most contain aquiclude and aquitard materials.

Figure 1.2 shows how the presence of an aquiclude, such as clay, can give rise to springs and may support a perched water table above the main water table in an aquifer. The top diagram (Figure 1.2a) shows a lower confined aquifer and an upper water table aquifer. The upper aquifer includes low-permeability material that supports a perched water table. The diagram shows the rest-water levels in various wells in both aquifers. Figure 1.2b shows how both confined and unconfined conditions can occur

in the same aquifer. In zone A, the aquifer is fully confined by the overlying clay and is fully saturated. The groundwater in this part of the aquifer is at a pressure controlled by the level of water at point p, and water in wells would rise to this level above the top of the aquifer. In zone B, the overlying clay will prevent any direct recharge, although it is unconfined, like zone C. The aquifer in zone C is unconfined and receives direct recharge. Seasonal fluctuations in the water table levels will alter the lateral extent of zone B along the edge of the aquifer. It is likely to be at a minimum at the end of the winter and at its greatest extent in the autumn, before winter recharge causes groundwater levels to rise.

Where impermeable rocks overlie an aquifer, the pressure of the groundwater body can be such that the level of water in wells would rise above the base of the overlying rock (i.e. the top of the aquifer). In such instances the aquifer is said to be *confined*. Sometimes this pressure may be

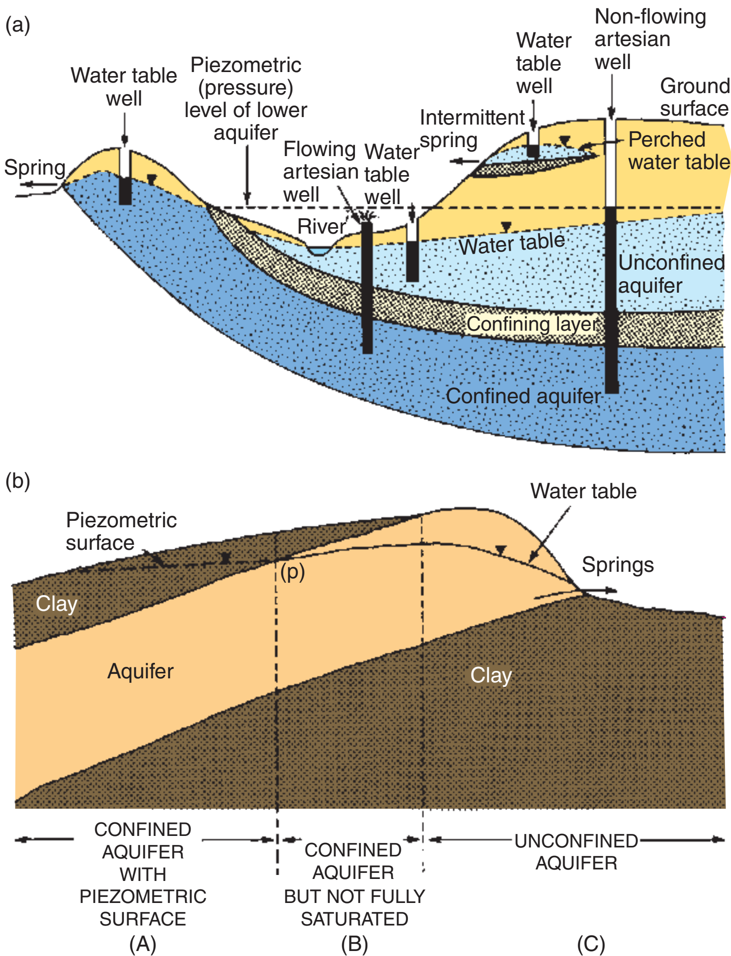

Figure 1.2 *(a) A lower confined aquifer and an upper water table aquifer that includes low-permeability material supporting a perched water table. (b) Both confined and unconfined conditions can occur in the same aquifer.*

sufficiently great that the water will rise above the ground surface and flow from wells and boreholes without pumping. This condition is termed *artesian flow*, and both the aquifer and the wells that tap it are said to be *artesian*.

A groundwater system, therefore, consists of rainfall recharge percolating into the ground down to the water table, and then flowing through rocks of varying permeabilities towards natural discharge points. The flow rates and volumes of water flowing through the system depend upon the rainfall, evaporation, the geological conditions that determine permeability, and many other factors. It is this system that a hydrogeologist is trying to understand by carrying out field measurements and interpreting the data in terms of the geology. The four key factors in achieving a successful investigation are to understand the geology; to interpret the groundwater-level data in terms of the three-dimensional (3D) distribution of heads that drive all groundwater flow systems; to remember that groundwater and surface water systems are interdependent; and to use a structured iterative approach to developing your understanding of the groundwater system you are investigating.

1.2 Conceptual Model

The foundation of all hydrogeological investigations is to gather sufficient reliable information to develop an understanding of how a particular groundwater system works. Such an understanding is usually called a *conceptual model* and comprises a quantified description encompassing all aspects of the local hydrogeology. Consequently, it is necessary for you to think about the way you will develop a conceptual model at the beginning of each project and as the basis of planning the work that is needed.

Although inexorably linked, the activities that form a hydrogeological investigation and the methodology of developing a conceptual model are not exactly the same. The actions at each step of a hydrogeological investigation are generally focused on collecting information, whereas the emphasis in developing a conceptual model is the interpretation of data as they are collected to identify additional information needed to complete the conceptual understanding. A typical hydrogeological investigation can be divided into a number of separate parts, each building on the previous one to eventually achieve an adequate understanding of the system being studied. It will always be necessary to tailor the details of an investigation to the needs of each particular study, although the majority of investigations are made up of the following phases:

- Desk study – the existing available information is assembled to provide an early opportunity to get a ‘feel’ for the groundwater system and start the conceptual modelling process.
- Walkover survey – it is important to get to know the study area at first hand, so that you can plan your fieldwork programme.
- Exploration – may include drilling boreholes, pumping tests, and geophysical investigations.
- Monitoring programme – defines the variation in groundwater levels, groundwater chemistry, rainfall, spring and stream flows, and so on, both across the area and seasonally.
- Data management – a systematic way of noting data in the field and examining it as it is collected to determine its reliability and if it represents the groundwater in your study area. It is likely that you will store the field data electronically, so do not forget to make regular back-ups.
- Water balance – quantifies the volumes of water that are passing through the groundwater system. Computer simulations may be used in this process to help define recharge and flows through the aquifer.
- Completion of the conceptual model and providing a quantified description of the groundwater system. The quantified aspect is important as it defines things like well yields, groundwater flow rates, recharge quantities and the groundwater chemistry.

A framework for developing a conceptual model as a series of steps was proposed by Brassington and Younger (2010) and is illustrated in Figure 1.3. The steps follow the logical sequence taken in

developing a conceptual model that defines the information sources, activities, and review process required along the way, including an audit trail to record all the information that relates to your project. The repetition in the review process is an essential element that ensures the data collection and field work programme are sufficient to enable you to draw meaningful conclusions from your work. The steps summarised in Figure 1.3 are explained in more detail below, with details of how to collect and interpret the data given in subsequent chapters of this book.

1.2.1 Step 1 – defining the objectives

You should define the purpose of each investigation before starting it, so that you focus on all the key questions that need answering as you design the field investigations to provide all the necessary

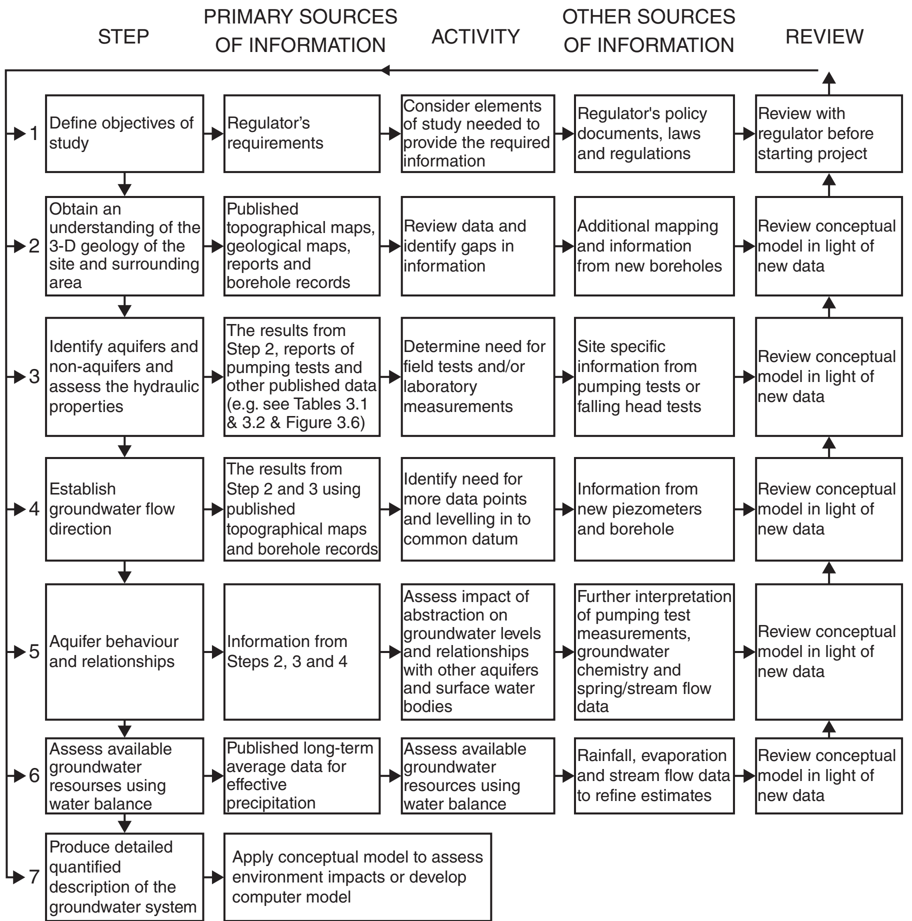

Figure 1.3 *How a conceptual model is developed from existing information and then gradually improved as field evidence is collected. Figure adapted from Brassington and Younger (2010) with permission of CIWEM.*

data. In most cases the objectives should be set out in writing and agreed with your boss, the client, the regulator, or any other people with interests in the outcomes of the project. If you work as a consultant, part of this objective setting may be contained in the proposal that you sent to the client before you were appointed to undertake the project.

1.2.2 Step 2 – defining the geology

The geology of an area controls its hydrogeology and so it is essential to understand the types of rocks present in the area of interest, their lithologies, and their structural relationships. The information can be derived from existing geological maps and reports, although sometimes more information may be needed, possibly involving additional field mapping, drilling exploratory boreholes, or geophysical surveys. Such additional field work should be planned using the results of the desk study, with each element of the new work testing specific aspects of the developing conceptual model.

1.2.3 Step 3 – defining the aquifer framework and boundaries

The aquifer or aquifers being studied exist as 3D bodies and consequently the aquifer boundaries need to be defined on the top, bottom, and all sides. This information is often most easily understood as a series of maps and cross-sections. The geological information derived from Step 2 should be used to identify the aquifers and to estimate the possible values for the aquifer properties, as discussed in Chapter 3. Pumping tests are often required to provide field data from which the hydraulic properties can be calculated. Pumping test methods are described in Chapter 6, along with methods for analysing the data. Copies of the field results and details of these calculations should be kept as part of the audit trail. It is likely that the desk study phase of your investigation that is described in Chapter 2 will include the initial appraisal of the data used in Steps 1–3 of the conceptual modelling process.

1.2.4 Step 4 – defining groundwater flow directions

Groundwater flow directions are best defined using rest groundwater levels measured in non-pumping boreholes that are interpreted using the geological information and information on the aquifers taken from Step 3. Information taken from topographical maps on the location and elevation of springs and surface watercourses is also used, as described in more detail in Chapter 4.

1.2.5 Step 5 – defining the aquifer relationships

This step follows naturally from Steps 3 and 4 and involves considering the flow rates and volumes of groundwater flowing through the system from one part of an aquifer to another, between aquifers and between the groundwater and the surface water systems. Such flow should be quantified and will usually involve calculations based on the Darcy equation (see Chapters 3 and 4). This is the point to decide on the need for a numerical model to assist in the development of the conceptual understanding and/or to make predictions on aspects of the groundwater system when part of it is stressed, such as by new or increased abstraction.

Groundwater systems are usually closely linked to surface water catchments and in order to understand the hydrogeology of an area you should consider both the surface and groundwater catchment areas. Key surface water features such as streams and rivers, springs and ponds, and wetland areas should be identified, initially using topographical maps and later from site visits. The contour information on topographical maps will allow you to define the surface water catchment areas.

New data are likely to be gathered during this step which you should compare with your existing data sets by repeating earlier steps of the framework. The new data may confirm your existing ideas, expand on your developing concepts or even challenge them. This is also the point in the process

where you should critically evaluate your understanding of the system to identify any gaps in the available evidence which could be addressed by field investigations. As financial budgets are always important, cost–benefit analysis needs to be taken into account before any decisions are made on this additional work.

1.2.6 Step 6 – water balance

A water balance involves the calculation of the volume of water both entering and leaving the aquifer system being studied, and it is an important factor in all groundwater assessments as it defines the resources available to support abstractions, maintain river flows and wetlands, and provide dilution factors in contamination studies. Where numerical models are being developed, a water balance may be used to gauge the accuracy of the model in replicating the hydrogeological processes involved. The process of undertaking a water balance is described in Chapter 8.

1.2.7 Step 7 – describing the conceptual model

The repeated reviews of the available information and the subsequent collection of the data identified to fill any gaps will eventually result in the development of a conceptual model that is adequate for the purposes set out in the objectives (Step 1). When that point is reached the conceptual model should be set out in your report of the investigation as described in Section 1.4, which will include your answers to the questions originally posed in the objectives. In small-scale studies the description of the conceptual model is likely to be brief and may be simply presented as the conclusions of the report. In larger projects it is likely to be a separate section of the report.

1.2.8 Audit trail

An essential feature of developing all conceptual models, ranging from simple desk studies to complex regional studies, is that they should be auditable. This is not at all sinister! Simply put, it means that someone else can pick up your report and the data sets you have collected and use them to understand how you have arrived at your conclusions. The audit trail merely consists of copies of the correspondence relating to the project, a list of all the information sources you have used, and the records of field measurements. These records include, for example, downloads from data loggers and the certificates of analysis for all the samples you sent to the laboratory. The report for a small-scale study should contain this information as a list of reports and maps used, including the key assumptions made and their justifications, perhaps summarised in a table if there are a lot. Larger studies may involve meetings to discuss progress, at which aspects of the hydrogeological interpretation may be discussed and agreed, with notes kept as part of the audit trail. Very large projects may include small associated studies to review particular aspects of the hydrogeological system, with the reports on such studies forming part of the audit trail. Where a numerical model is developed it is standard practice to keep a record of all model runs, including the aspects of the system being tested by that run and the conclusions drawn from the exercise. These records should form part of the project reports, although they are often kept as reference documents and are not part of either the main report or its appendices.

1.2.9 Quality control

It is important to ensure that the field measurements are made in such a way that the data are as reliable as possible and also that making the measurement has had the minimum possible effect on the data. This means following standard protocols, and is usually best if these are written down and ideally part of widely accepted standards. This approach of formal quality management is used by

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individual organisations in most countries and includes specifications for performing key activities and for making and maintaining records. In hydrogeological work these may include such tasks as taking groundwater samples, recording data during a pumping test, checking that field equipment is working properly before (and sometimes, after) you have used it in the field, examining data sets to decide that they reflect the conditions in the aquifer, and getting someone to check your report. Of course, having a written method describing how these activities should be carried out does not guarantee that they will be done properly. Neither does it mean that these checks were not a part of routine hydrogeological work before the modern concept of quality control was introduced.

Defining a comprehensive quality control system is beyond the scope of this book. However, the basic checks on equipment are discussed in the appropriate chapters, as well as methods for checking that field readings are taken and recorded properly. If your employer has a formal system, you must ensure that you follow it. Where no formal system is in place, ensure that your personal professional standards include taking proper care in your work and that you ask others to review or audit your work when appropriate. For example, have a colleague read your reports before they are sent out. Use appropriate national standards or codes of practice that are published by bodies such as the British Standards Institution in the UK or the American National Standards Institute in the USA.

There are a number of ways that simply taking field measurements can affect the value you obtain. How to take specific measurements such as a groundwater level in a borehole or piezometer or to collect a groundwater sample are discussed later in this book, where each activity is described. However, there are a few general points that are worth bearing in mind both as you plan your fieldwork programme and when you are out taking the measurements. In hydrogeology a large proportion of field data is collected from boreholes and it is possible that just the presence of the borehole itself changes the groundwater system you want to study. The borehole may connect different aquifers, thereby allowing flow between them along the borehole, potentially affecting both the groundwater level in the borehole and the groundwater chemistry. The direction of flow will depend on the relative heads in each aquifer penetrated by the borehole. Less obviously, a borehole will also provide a flow path when it only penetrates a single aquifer, with the flow driven by the vertical component of the 3D distribution of heads that drive groundwater flow. In recharge areas the flow will be downwards and in discharge areas such as river valleys the flow will be upwards. The reasons for this phenomenon are discussed in more detail in Section 4.7.

1.3 Groundwater Computer Modelling

Computer-based mathematical models are used to make predictions of impacts caused by groundwater abstraction or the movement of pollutants, and may be seen as the end point of a groundwater project. However, the most valuable application of such modelling to groundwater studies is to test aspects of the conceptual model as it is being developed.

Groundwater mathematical models are computer programs based on the groundwater flow equations and a water balance within the aquifer. The aquifer is divided into a large number of segments or nodes that are taken to be representative of a small local area. Values for aquifer properties are assigned to each node, together with values of the recharge from rainfall and other sources and the potential for outflows as abstraction from wells or discharges into the surface water system. The nodes may be of equal size or defined so that some areas of the model are examined in more detail. The water balance equations are solved for each node and the movement of groundwater from each node is calculated. Such flows affect the groundwater levels in neighbouring nodes, requiring the process to be iterative to take account of the water movements through the aquifer. The output is usually in terms of changes in groundwater levels and a statement of the water balance components.

Groundwater models are calibrated using field data. The model-predicted groundwater levels and discharges to surface water are compared with the available field records. Where there is poor correlation between predicted and measured data, the parameters in the model are adjusted and new model runs made repeatedly and compared with the field data until a close fit is obtained.

A number of standard programs (or modelling packages) are commercially available. MODFLOW was originally developed by the United States Geological Survey in 1984 (McDonald and Harbaugh, 1988). It is a 3D finite-difference groundwater model originally conceived solely to simulate groundwater flow. It has a modular structure that has allowed many additional features to be added to simulate coupled groundwater/surface-water systems, solute transport, variable-density and unsaturated-zone flow, aquifer-system compaction and land subsidence, parameter estimation, and groundwater management.

MODFLOW is probably the most commonly used groundwater modelling software in the world. Having had a very large number of users means that most of the errors (bugs) in the program have now been discovered. Versions that run on your laptop are available from several companies, each having front- and back-end packages that format the input data and outputs to suit your needs. It is common for these models to be used at an early stage in an investigation, even on site, as a tool for evaluating field data as they are collected and to assist in the development of the conceptual understanding, as described above. This aspect of modelling may be the most important.

Standard hydrogeological software is also available for pumping test analysis, such as AquiferWin32, for examining water quality data (AquaChem) and to help make impact assessments such as LandSim (used to assess landfill sites) and ConSim (used in contaminated land work). Environmental regulators generally prefer the use of standard software, as it means that the predictions based on the output have the same reliability. Several have assessed the different types of commercially available software and recommend preferred systems. I always try to use the same system as the regulator to minimise disagreements over the interpretation of the results.

Finally, do not be seduced into the trap of thinking that computer modelling is what hydrogeology is really about. The models are only tools to aid understanding and should never be thought of as more than that. High quality computer graphics may look convincing and the models may involve complex and impressive mathematics, but their real value depends on the level of understanding that the hydrogeologist has in terms of the rocks and their influence on groundwater flow. Such an understanding must be based on sound and adequate fieldwork. Do not let anyone ever convince you otherwise!

1.4 Hydrogeological Report Writing

A description of your investigation, the conclusions that you have drawn and the recommendations that follow from them is as important as any other part of the work. After all, a report is likely to be the only tangible thing that is produced by your efforts. Most hydrogeological studies are intended to answer specific questions such as ‘Will a new well on my property produce enough water for my needs?’ or ‘What environmental impact will my new quarry have on water resources?’ and so the report should be written to answer the relevant question. It should have a logical structure and be consistent with the objectives of the study. It should be written in a clear, straightforward way that the reader will be able to understand.

All reports should consist of three parts, namely a beginning, a middle, and an end: in other words, an introduction, setting out the objectives of the study; the main body of the report, which may extend to several chapters; and the conclusions and recommendations. Make sure that you always include these three elements. Table 1.1 sets out a possible structure for a report that provides a logical sequence for you to develop the description of the groundwater system you have been studying.

1.5 Expert Witness

Sometimes a hydrogeologist is asked to be an expert witness and to give evidence to the court or a public inquiry, and to understand what is required we first need to sort out a few definitions. An *expert* is someone with experience in a particular field or discipline beyond that expected of a

Table 1.1 Template for planning the contents of a report.

Section	Content
Summary	Must be written last when the rest of the report is complete and cover the main points contained in the body of the report. It is important as many recipients of your report will only read the summary. Do not include material or ideas that do not appear in the body of the report.
Introduction	Explains the objectives for the study and provides the basic logic to the report structure.
Topography and drainage	A description of the topography and surface water systems will help to define the aquifer boundaries and quantify the available water resources.
Geology	The description of the geology should be in sufficient detail to identify the main aquifers and factors influencing the groundwater system. Maps and cross-sections are very good ways of explaining the geology and help non-geologists to understand your arguments.
Hydrogeology	Describe the aquifers and their hydraulic properties and whether the flow is intergranular or through fractures. Define flow directions and discharge points.
Groundwater chemistry	Use the chemistry to characterise different aquifers. Piper, Schoeller and other graphical representations will help explain your arguments.
Water resources	Define the available resources and how much is needed both to support wetlands and surface water flows and to supply existing abstractors.
Risk assessment	Use a systematic approach to quantify the risk of a new activity having a serious impact. Vulnerable features are identified and the potential risk considered for each one. Pollution studies use the Source–Pathway–Receptor model.
Conclusions and recommendations	Conclusions should be based on and supported by the information described in the main part of the report. The recommendations should match the objectives set out in the introduction.
Appendices	Appendices are best used for those parts of your work that do not easily fit into the main text, such as calculations or data lists.
Tables and diagrams	A picture is worth a thousand words and so are tables. Both provide excellent ways of summarising information and presenting your arguments.

layman. An *expert witness* is an expert who makes this knowledge and experience available to a court or other judicial or quasi-judicial bodies, such as a parliamentary committee or a public inquiry, to help it understand the issues in a case, so that it can reach a sound and just decision. An expert witness is paid for the time it takes to form an opinion and, where necessary, support that opinion during the course of litigation.

An expert witness is not paid either for the opinion given or for the assistance that opinion gives to the client's case – that is different to being paid for the time taken to form your opinion. It is very important to keep these definitions clear because if you stray from acting as an expert witness into advising the client you become an *expert advisor* and your immunity from prosecution will be removed. You must remain aware of the distinction at all times, and only move into the role of expert advisor in full knowledge of the legal consequences.

An expert might take on a number of roles. An expert instructed by just one party in a claim, and whose opinion is to be put before the court, is a proper expert witness. When advising a party, without any intention of putting the expert's opinions before the court, the expert is known as an expert advisor or shadow expert. In this case he or she may attend the court to advise the lawyers who ask the questions

during cross-examination but will not speak to the court. If the expert witness is instructed by all the parties in a claim, then he/she acts as a Single Joint Expert. This latter case is preferred by the courts particularly in small cases as it reduces the costs and also focuses on the main issues more easily.

The fundamental characteristic of expert evidence is that it is opinion evidence. Generally speaking, lay witnesses may give only one form of evidence, namely evidence of fact. They may not say, for example, that a vehicle was being driven recklessly, only that it ended up in the ditch. In this example, it is the task of the expert witness to assist the court in reaching its decision with technical analysis and opinion inferred from factual evidence of, for example, skid marks.

To be of practical assistance to a court, however, expert evidence must also provide as much detail as is necessary to allow the court to determine whether the expert's opinions are well founded. It will often include factual evidence supplied in the expert's instructions which requires expertise in its interpretation and presentation; other factual evidence which, while it may not require expertise for its comprehension, is linked inextricably to evidence that does; explanations of technical terms or topics; and hearsay evidence of a specialist nature, such as the consensus of medical opinion on the causation of particular symptoms or conditions, as well as opinions based on facts put forward in the case.

Expert evidence is most obviously needed when the evaluation of the issues require technical or scientific knowledge only an expert in the field is likely to possess. However, there is nothing to prevent reports for court use being commissioned on any factual matter, technical or otherwise, providing that it is deemed likely to be outside the knowledge and experience of those trying the case, and the court agrees to the evidence being called.

In all cases, you will be expected to prepare a report and send it to the court or to provide it as evidence on which you will be examined at a public inquiry. It is important to make your report as simple as possible so that it is easily understood by all those who read it, which is often done by defining all the technical terms that you use the first time you use them. It is very important to take your time in preparing the report and to get someone else to read it for you. If you work in a consultancy practice you may well have a quality control system that takes care of such things. However, the people who read the report will also use the same language as you and so it may be advisable to have additional people read it that do not have the technical language to have that extra check on clarity. What seems like everyday language to you may well be difficult to understand by a layperson.

You may not always be called to give evidence, for several reasons. The parties may be negotiating over a claim, say, and the report may be used as a bargaining tool. In other instances, although your report has been accepted by the court, there are no aspects of it that require further discussion. This has happened to me where I showed in a report that several water samples had the same chemistry using Piper and Schoeller diagrams and that was all the court needed to make a decision without me being called to give evidence.

If you do attend court or a public inquiry, make sure that you wear a suit (and a tie if you are a man) and make sure that you are polite and do not allow yourself to get emotional. Giving evidence is under an adversarial system, which can be off-putting to most people, especially the first time that you do it. The lawyers for the 'other side' may ask you questions on what in normal circumstances you may regard as offensive; do not be put off, that is what they are trying to do. Not all situations are like that. For example, in some situations where there are not many people likely to want to attend, a hearing may be held where an inspector and the representatives of all sides sit round a table. In most cases, however, an inquiry is likely to be held in a larger hall near the site in question, with each side taking up its own space. Court hearings are always heard in a court.

One of the most important things you need to do is to visit the site just before you give evidence so that you can answer questions on its present condition. I have heard of experts not doing that and suffering the embarrassment of looking foolish when cross-examined. Seeing the site will avoid that problem, will bring it all to mind and will help you to keep calm and collected!