Common Implementation Strategy for the Water Framework Directive (2000/60/EC)

Groundwater risk assessment

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Technical report on groundwater risk assessment issues as discussed at the workshop of 28th January 2004

12 October 2004[1]

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[1] This document has been developed on the basis of the Guidance Document No. 3 on the Analysis of Pressures and Impacts and contributions from the participants of the Groundwater Risk Assessment workshop of 28th January 2004

Foreword

The EU Member States, Norway and the European Commission have jointly developed a common strategy for supporting the implementation of the Directive 2000/60/EC establishing a framework for Community action in the field of water policy (hereafter referred to as Common Implementation Strategy (CIS) for the Water Framework Directive (WFD)). The main aim of this strategy is to allow a coherent and harmonious implementation of this Directive. Focus is on methodological questions related to a common understanding of the technical and scientific implications of the Water Framework Directive.

In this framework, a working group on Groundwater Body Characterisation and Monitoring has been established, with the aim - during the period 2003–2004 - to exchange information/experience on groundwater issues covered by the WFD (e.g. characterisation, risk assessment, monitoring, chemical status and trends) in the form of workshops and technical reports gathering the participant's experience. The workshop of 28th January 2004 on Groundwater Risk Assessment is the second one of the series of this CIS working group activity. The technical report summarises important aspects of groundwater risk assessment as they are already discussed in the relevant CIS guidance documents, and includes examples of practices presented at the national, regional or Pilot River Basin levels by the participants.

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1 Introduction

1.1 Background – The Common Implementation Strategy of the WFD

The Water Framework Directive (2000/60/EC)[2] is a comprehensive piece of legislation that sets out, *inter alia*, clear quality objectives for all waters in Europe. The Directive provides for a sustainable and integrated management of river basins including binding objectives, clear deadlines, comprehensive programme of measures based on scientific, technical and economic analysis including public information and consultation. Soon after the WFD adoption, it has become clear that the successful implementation of the Directive will be, at the least, equally as challenging and ambitious for all countries, institutions and stakeholders involved. Therefore, a strategic document establishing a Common Implementation Strategy (CIS) for the Water Framework Directive (WFD) was developed and finally agreed under the Swedish Presidency in the meeting held in Sweden on 2–4 May 2001. Despite the fact that it was recognised that implementing the WFD is the full responsibility of the individual Member State, there was a broad consensus amongst the Water Directors of the Member States, Norway and the Commission that the European joint partnership is necessary in order to:

- ✓ develop a common understanding and approaches;
- ✓ elaborate informal technical guidance including best practice examples;
- ✓ share experiences and resources;
- ✓ avoid duplication of efforts;
- ✓ limit the risk of bad application.

Furthermore, the Water Directors stressed the necessity to involve stakeholders, NGOs and the research community in this joint process as well as to enable the participation of Candidate Countries in order to facilitate their cohesion process. Following the decision of the Water Directors, a comprehensive and ambitious work programme was started of which the first phase, including ten Working Groups and three Expert Advisory Fora, was completed at the end of 2003[3] and led to the availability of thirteen Guidance Documents which are publicly available[4]. The second phase of the Common Implementation Strategy (CIS) now involves four working groups, namely on Ecological Status (WG 2A), Integrated River Basin Management (WG 2B), Groundwater (WG 2C) and Reporting (WG 2D). The present workshop has been held under the auspices of the WG 2C of which the mandate is described in a separate document[5].

1.2 The Commission proposal on new Groundwater Directive

In parallel of the drafting activities of CIS Guidance documents, an Expert Advisory Forum (EAF) on Groundwater has contributed to the development of the draft proposal of Groundwater Directive, which has been adopted by the Commission in its final form on 19th September 2003[6]. In the period between the adoption of the proposal and the adoption of the future groundwater directive by the

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[2] European Parliament and Council Directive 2000/60/EC of 23 October 2000 establishing a framework for Community action in the field of water policy (OJ L 327, 22/12/2000, p. 1) as amended by European Parliament and Council Decision 2455/2001/EC (OJ L 331, 15/12/2001, p.1)

[3] Common Implementation Strategy for the Water Framework Directive, European Communities, ISBN 92-894-2040-5, 2003

[4] Final CIS document available under: http://europa.eu.int/comm/environment/water/water-framework/implementation.html

[5] Mandate of the CIS Working Group 2C on "Groundwater"

[6] COM(2003)550

European Parliament and the Council, it has been decided to organise regular workshops to exchange information and experiences among the newly formed Working Group 2C on "Groundwater". In this framework, a workshop on groundwater risk assessment has been held in Brussels on 28th January 2004, gathering more than 80 participants from both the WG 2C and the WG 2B.

1.3 Aim of the workshop

The aim of the workshop was to share national and regional experiences on groundwater risk assessment, taking into account the CIS guidance. The present workshop report summarises key elements of the general approach on the analysis of pressures and impacts and tools to assist as they are summarised in the IMPRESS guidance document[7] as well as key elements of groundwater risk assessment like aquifer pollution vulnerability and contamination risks, reports on assessment approaches in the light of the WFD, either at the national level (Hungary, the Netherlands, Sweden and the United Kingdom) at the regional level (Lower Saxony in Germany, Piemonte region in Italy) or within Pilot River Basins (Shannon and Tevere) and reports on on-going research on groundwater risk assessment.

2 Common understanding

2.1 Requirements of the Water Framework Directive

Article 5 of the Water Framework Directive requires that, by 22 December 2004, characteristics of the river basin districts be analysed and a review of the environmental impact of human activity, as well as an economic analysis of water use, be undertaken.

It should be clear that the identification of groundwater bodies as the fist step is, first and foremost, based on geographical and hydrological determinants. However, the identification and subsequent classification of water bodies must provide for a sufficiently accurate description of this defined geographic area to enable an unambiguous comparison to objectives of the Directive. This is because the environmental objectives of the Directive, and the measures needed to achieve them, apply to "water bodies". A key descriptor in this context is the "status" of those bodies. If water bodies are identified that do not permit an accurate description of their status, Member States will be unable to apply the Directive's objectives correctly.

A specification for the impact review for groundwaters is contained in WFD Annex II Section 2 and includes five parts. All parts of this process are addressed by the IMPRESS guidance document[8]:

1. Initial characterisation, including identification of pressures and risk of failing to achieve objectives;
2. Further characterisation for at risk groundwater bodies;
3. Review of the impact of human activity on groundwaters for transboundary and at risk groundwater bodies;
4. Review of the impact of changes in groundwater levels for groundwater bodies for which lower objectives are to be set according to Article 4.5; and,
5. Review of the impact of pollution on groundwater quality for which lower objectives are to be set.

[7] Analysis of Pressures and Impacts. Common implementation strategy for the Water Framework Directive (2000/60/EC). Guidance document No. 3

[8] Guidance Document No 3. Analysis of Pressures and Impacts. ISBN 92-894-5123-8.

The main elements of the identification, the initial characterisation and the further characterisation of groundwater bodies have been already focused on and discussed in detail during the workshop of 13th October 2003 on groundwater body characterisation of CIS WG 2C[9].

Regarding the groundwater risk assessment the WFD requires within the ***initial characterisation*** of all groundwater bodies (Annex II.2.1) to assess their uses and the degree to which they are at risk of failing to meet the objectives of Article 4 of the WFD, namely the achievement of good (quantitative and chemical) status of groundwater at the latest by the end of the year 2015. Groundwater bodies may be grouped for the purposes of this initial characterisation. The pressures to which the groundwater bodies are liable to be subject to shall be identified including point sources of pollution, diffuse sources of pollution and changes in water levels and flow caused by abstraction or recharge.

Following this initial characterisation, ***a further characterisation*** has to be carried out for those groundwater bodies or groups of bodies which have been identified as being at risk in order to establish a more precise assessment of the significance of such risk and identify any measures to be required under Article 11 of the WFD. Accordingly, this characterisation shall include relevant information on the impact of human activity. Specific provisions concern those bodies of groundwater which cross the boundary between two or more Member States, focusing mainly on quantitative aspects.

Connected to this further characterisation, the WFD also requires as a review of impacts of changes in groundwater levels the identification of those bodies of groundwater for which lower objectives are to be specified under Article 4 including as a result of consideration of the effects of the status of the body on (Annex II.2.4 of WFD): 1. Surface water and associated terrestrial ecosystems; 2. Water regulation, flood protection and land drainage, and 3. Human development.

Finally, Member States have to identify those bodies of groundwater for which lower objectives are to be specified under Article 4(5) of the WFD where, as a result of the impact of human activity, and as determined in accordance with the analysis of pressures and impacts under Article 5(1), the body of groundwater is so polluted that achieving good groundwater chemical status is infeasible or disproportionately expensive (Annex II.2.5 of WFD).

The review of pressures and impacts is only one element of the planning process, with other elements feeding into the review, or dependent on its outcome (Figure 1).

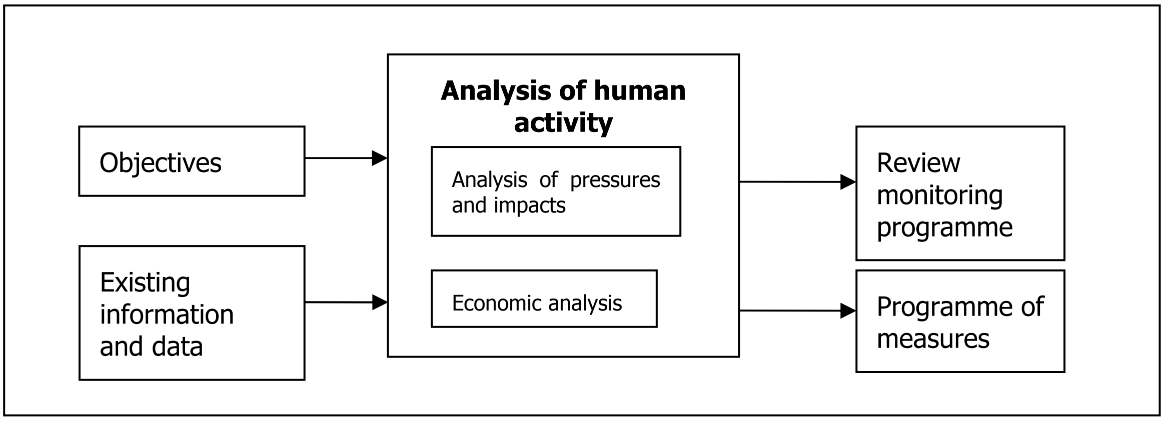


Figure 1: Elements of the planning process.

[9] Groundwater Body Characterisation. Technical report on groundwater body characterisation issues as discussed at the workshop of 13th October 2003. http://forum.europa.eu.int/Public/irc/env/wfd/library?l=/framework_directive/groundwater_working&vm=detailed&sb=Title

2.1.1 Objectives

The WFD requires the achievement of its principal objectives; good groundwater status, by the end of 2015 at the latest, unless Articles 4.3–4.7 are applicable. Accordingly, the analyses of pressures and impacts must consider how pressures would be likely to develop prior to 2015 in ways that would place water bodies at risk of failing to achieve good status if appropriate programmes of measures were not designed and implemented. This will require consideration of the effects of existing legislation and forecasts of how the key economic factors that influence water uses will evolve over time and how these changes may affect the pressures on the water environment. Such forecasts should be provided by the economic analyses of water use required under Article 5. The pressures and impacts analyses will also need to identify which of the risks to the WFDs' objectives are expected to be addressed by the implementation of measures specified under other Community legislation. This information will enable the economic analyses to assess, and provide advice on, the most cost-effective combinations of measures that can be used to address the other risks to the achievement of the WFDs' objectives.

One of the most fundamental elements of this larger process is the setting of the environmental objectives (Article 4). The objectives depend on both the overall objective to achieve good status by 2015, and possibly additional specific objectives that apply to *protected areas* as defined from other legislation. The objectives may also depend on the current status of the water body, since Member States must, in general, prevent any deterioration in the status.

For groundwaters the objectives are essentially:

1. To implement measures to prevent or limit the input of pollutants into groundwater and to prevent the deterioration of the status of the groundwater body (groundwater status consists of two parts; quantitative status and chemical status and the overall status of groundwater is taken to be the poorer of the two);
2. To protect, enhance and restore all bodies of groundwater, and ensure a balance between abstraction and recharge of groundwater, with the aim of achieving good groundwater status by 2015 in accordance with the provisions laid down in Annex V;
3. To reverse any significant and sustained upward trend in the concentration of any pollutant resulting from the impact of human activity in order to progressively reduce pollution of groundwater.

If a groundwater body currently has good status but it is thought that pressures may cause its status to be rendered poor by 2015, then the body is "at risk" and will require further characterisation. It should be noted that a body currently determined to have poor status will automatically be "at risk".

Article 17 of the WFD requires the Commission to propose a Daughter Directive on groundwater, which is expected to establish criteria for the identification of significant and sustained upward trends in pollutant concentrations [Article 4.1(b)(iii)], and additional criteria for defining good groundwater chemical status. Until these criteria have been established, Member States will need to decide what constitutes a significant and sustained upward trend according to their own criteria. The Daughter Directive will also clarify the meaning of the requirement to "prevent or limit the input of pollutants into groundwater" (1 above). The WFDs' objective of preventing or limiting inputs of pollutants into groundwater [Article 4.1(b)(i)] does not specify which pollutants should be prevented from entry and to what extent others should be limited. It is therefore not clear how to assess the risks of failing to achieve this objective until clarification of its purposes is provided.

In addition, it is required that objectives **for protected areas** established under Community legislation should also be met. For example, if a water body falls within a Nitrate Vulnerable Zone then the objectives of the Nitrates Directive (91/676/EEC) must be met. Article 7 of WFD requires Member States to establish protected areas for all bodies of water providing more than 10 m^3 drinking water a day as an average or serving more than 50 persons, or bodies intended for that use in the future. The objective for these areas is to avoid deterioration in quality in order to reduce the level of purification treatment required.

2.1.2 Time table

Article 15 specifies the reporting requirements of the review undertaken under Article 5. Member States are required to provide summary reports of the reviews within three months of their completion (i.e. by March 2005 at the latest for the first review). Subsequently, reporting on these reviews will be contained in the RBMPs, which must be published first in 2009, and thereafter every six years (2015, 2021…). Therefore, from 2009 a schedule with a six-year cycle shall be established, with the review of pressures and impacts occurring two years prior to the publishing of the RBMP.

The review of the pressures and impacts is required in the design of monitoring programmes which must be operational by 2006 (Article 8), and also to help develop programmes of measures which must be established by 2009, and made operational by 2012 (Article11).

Article 6 requires that a register of *protected areas* is established by 2004, but this information is required at an earlier date to enable the review of pressures and impacts. The timescales and associated links are summarised in Table 1.

Table 1: Actions and dates by which they must be achieved (note that in practice many actions must be completed within a fixed period of the completion of a prerequisite task).

Action	Date
Impact review completed by Member States (Article 5, Article 15, Annex II)	2004
Register of protected areas established (Article 6)	2004
Summary reporting of impact review to Commission (Article 15)	2005
Monitoring programme operational (Article 8)	2006
First River Basin Management Plan completed (Article 15)	2009
Programme of measures established (Article 11)	2009
Programme of measures operational (Article 11)	2012

2.1.3 Input from public participation

Article 14 encourages the active involvement of all interested parties in the implementation of the WFD and requires Member States to *inform and consult the public*. This Article specifically requires public consultation in the production of the RBMP, to which the pressures and impacts analysis makes a significant contribution. The Guidance Document on "Public Participation" provides further information about these forms of participation[10] and chapter 0 gives an indication how key stakeholders could be involved in the analysis of pressures and impacts.

2.2 Key terms - Definitions

While it is clear from the WFD that the impacts are the result of pressures, neither term is explicitly defined. For this reason a common understanding of the terms and the most effective approach had to be developed within the IMPRESS working group. The widely-used Driver, Pressure, State, Impact, Response (DPSIR) analytical framework has been adopted with definitions as in Table 2.

[10] Guidance Document No 8. Public Participation in relation to the Water Framework Directive. ISBN 92-894-5128-9

Table 2: The DPSIR framework as used in the pressures and impacts analysis.

Term	Definition
Driver	An anthropogenic activity that may have an environmental effect (e.g. agriculture, industry)
Pressure	The direct effect of the driver (for example, an effect that causes a change in flow or a change in the water chemistry)
State	The condition of the water body resulting from both natural and anthropogenic factors (i.e. physical and chemical characteristics)
Impact	The environmental effect of the pressure (e.g. ecosystem modified)
Response	The measures taken to improve the state of the water body (e.g. restricting abstraction, limiting point source discharges, developing best practice guidance for agriculture)

It is clear from these definitions that in the analysis of *pressures* and *impacts,* it is necessary to include information on *drivers*, and changes in the *state*, but that *responses* need not be considered. The distinction made here between state and impact separates effects that are sometimes combined, or confused. One reason for this is that because many of the impacts are not easily measurable, state is often used as an indicator of, or surrogate for, impact.

It is worth noting in the context of the DPSIR framework as described above, that objectives defined by the WFD relate to both the state and the impact, since, standards from other European water quality objective legislation relate to the concentration of pollutants in the water body (i.e. its state), while the biological elements of the WFD clearly indicate impacts.

Despite this problem of nomenclature, the meaning of the WFD is clear. If the water body fails to meet its objective, or is at risk of failing to meet its objective, then the cause of this failure (i.e. the pressure or combination of pressures) must be investigated. Thus *when the Directive states that significant pressures must be identified, this can be taken to mean any pressure that on its own, or in combination with other pressures, may lead to a failure to achieve the specified objective*. Such an interpretation introduces a scale dependence, which is considered in Section 2.3.1. It is also worth noting that the actual criterion used to assess significant pressures for groundwater is that they are *at risk of failing* to meet objectives. The process of analysing pressures and their impacts is a "risk assessment" process but in this report is always referred to as a pressures and impacts analysis.

2.2.1 Groundwater pollution risk

In the case-specific sense of EIAs, the term 'groundwater pollution risk' means the actual/potential consequence on the health of a specific **receptor** (water-user community of groundwater supply or an aquatic groundwater-dependent ecosystem) of pollution arising from a specific point **source** via a defined subsurface **pathway** (indicated by background of Figure 7). This is only possible to evaluate for relatively few major hazardous installations which have been subjected to detailed site investigation, but these are normally closely-controlled anyway and, thus, paradoxically not the major concern for the WFD.

In practice the assessment of **groundwater pollution risk** (in this case perhaps more accurately termed **aquifer pollution hazard** will be addressed by two possible approaches :

- the **direct method** involving appropriate chemical quality monitoring of the groundwater body to given an indication of incipient degradation
- the **indirect method** involving surveys of 'subsurface contaminant load' and estimates of 'pollution vulnerability' of the underlying aquifer.

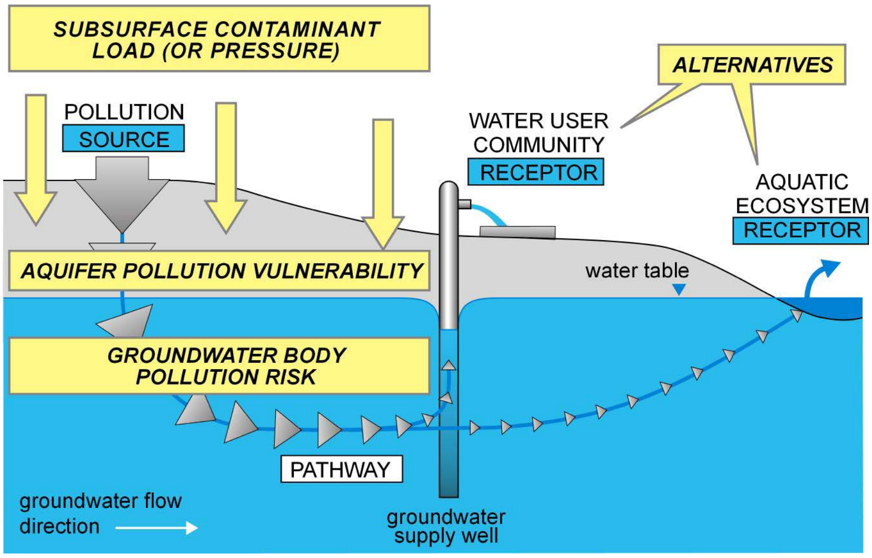


Figure 2: Conceptual Schemes of Groundwater Pollution Risk Assessment

In the initial implementation of the WFD a high-level of dependency upon indirect methods for groundwater pollution risk assessment is likely because of the:

- **inadequacy of groundwater quality monitoring networks** in terms of spatial design and analytical determinands;
- **complexity of some hydrogeological conditions** (and groundwater recharge and flow regimes), which called into question how effectively their groundwater quality could be represented by monitoring alone.

Aquifer pollution hazard is best conceived as the interaction between:

- the **man-made subsurface contaminant pressure** (or load) that is (or will be) generated cumulatively by land-surface activities;
- the intrinsic pollution vulnerability of the underlying aquifer.

It is thus through a combination of these **risk-screening tools** that groundwater pollution risk assessment will normally have to be carried out.

It must be recognised that there is a **close relationship** between groundwater pollution risk assessment and the:

- 'threshold values' for good groundwater chemical quality status
- specification of groundwater supply protection perimeters
- approaches to groundwater quality monitoring network design,

and a degree of harmonisation of all of these 'management tools' is needed.

2.3 Relevant considerations

The pressures on a groundwater body may have an impact, or measurable effect, upon it. The nature of the impact will depend on factors such as the type and severity of the pressure and the degree to which the groundwater body is susceptible to the pressure. Additionally, the geographical scale (e.g. distribution and density of pressures) and timescale effects (e.g. time lag for pollutants released at the land surface to reach the water table or migrate within an aquifer) are important considerations in assessing the risks to the groundwater body as a whole, and over time.

2.3.1 Scaling issues

Different kinds of pressures do not impact the different water bodies at the same space and time scales. Hence the analysis of pressures must be carried out to ensure that a) the final reporting that is produced with the collected information is consistent with the WFD objectives and b) that data collection is feasible on the long term.

Most impacts cannot be monitored or even assessed directly. In many cases, their identification is derived from observation of changes in the state and the likelihood of these changes to be caused by known pressures. The correct time and space scales of data collection of both pressures and states are the most important points that make it possible to establish sound (therefore recognised as true) relationships, and consequently appropriate programmes of measures. The assessment of the relevant space and time scales is made easier when considering that a pressure results from a load exerted during a certain time over a certain target that has a particular size. For example, the abstraction of a certain volume of water may have no impact if pumped throughout the year but be a significant pressure if taken out of a groundwater body only during the summer months.

Regarding the **temporal scale**, it is important to adopt appropriate temporal scales in the pressures and impacts analysis since some pressures may result in impacts many years in the future, and some future impacts will relate to past pressures that no longer exist. For example, pesticide application may lead to increased concentrations of the pesticide in the groundwater many years after it was released. Monitoring information should be used, where available, to validate estimates of impacts obtained from pressure analyses.

Regarding **spatial scales**, the important features of data are the location, especially if the water body comprises very different components (e.g. recharge area of a confined groundwater etc) that respond differently to the pressure. Pressure location can be analysed as precise information or as density information. In the first case, the relevant component of the water body is identified. In the latter, the area on which the pressure is exerted must be identified and small enough to make it possible to link the pressure to its target. For example, considering confined groundwater, the important data is the emissions on the recharge area only, not over the total extent of the water body.

2.3.2 Grouping of water bodies

Grouping water bodies, provided this is done on a sound scientific basis, will also be important in ensuring the most cost effective approach to the pressures and impacts analyses. The ability to group bodies will depend on the characteristics of the river basin district and the type and extent of pressures on it.

2.3.3 Taking account of uncertainty

The first pressures and impacts analyses must be complete by the end of 2004. However, the environmental conditions required to meet most of the Directive's objectives will not have been firmly defined by this date as elements of the groundwater objectives await clarification in the Article 17 Daughter Directive. The confidence and precision in the estimated environmental effects of different pressure types will also be very variable, depending to a great extent on the quality of national and local information and assessment expertise. This is because consideration of many of the pressures and impacts relevant under the Water Framework Directive has not previously been required by other Community water legislation.

Member States will need to complete the first analyses using appropriate estimates for pressures and impacts but they should be aware, and take account of, the uncertainties in the environmental conditions required to meet the Directives' objectives and the uncertainties in the estimated impacts.

The consequence of these uncertainties is that Member States' judgements on which bodies are at risk, and which are not, are likely to contain more errors in the first report than will be the case in subsequent planning cycles. It will be important for Member States to be aware of the uncertainties so that their monitoring programmes can be designed and targeted to provide the information needed to improve the confidence in the assessments. Where the assessment contains significant uncertainty, those water bodies should be categorised as at risk of failing to meet their objectives. Obvious failing of pressures is not an uncertainty.

2.4 Summary of key tasks for groundwater - First assessment

Ideally, a pressures and impacts assessment will be a four-step process;

1. describing the "driving forces", especially land use, urban development, industry, agriculture and other activities which lead to pressures, without regard to their actual impacts;
2. identifying pressures with possible impacts on the water body and on water uses, by considering the magnitude of the pressures and the susceptibility of the water body;
3. assessing the impacts resulting from the pressure; and,
4. evaluating the likelihood of failing to meet the objective.

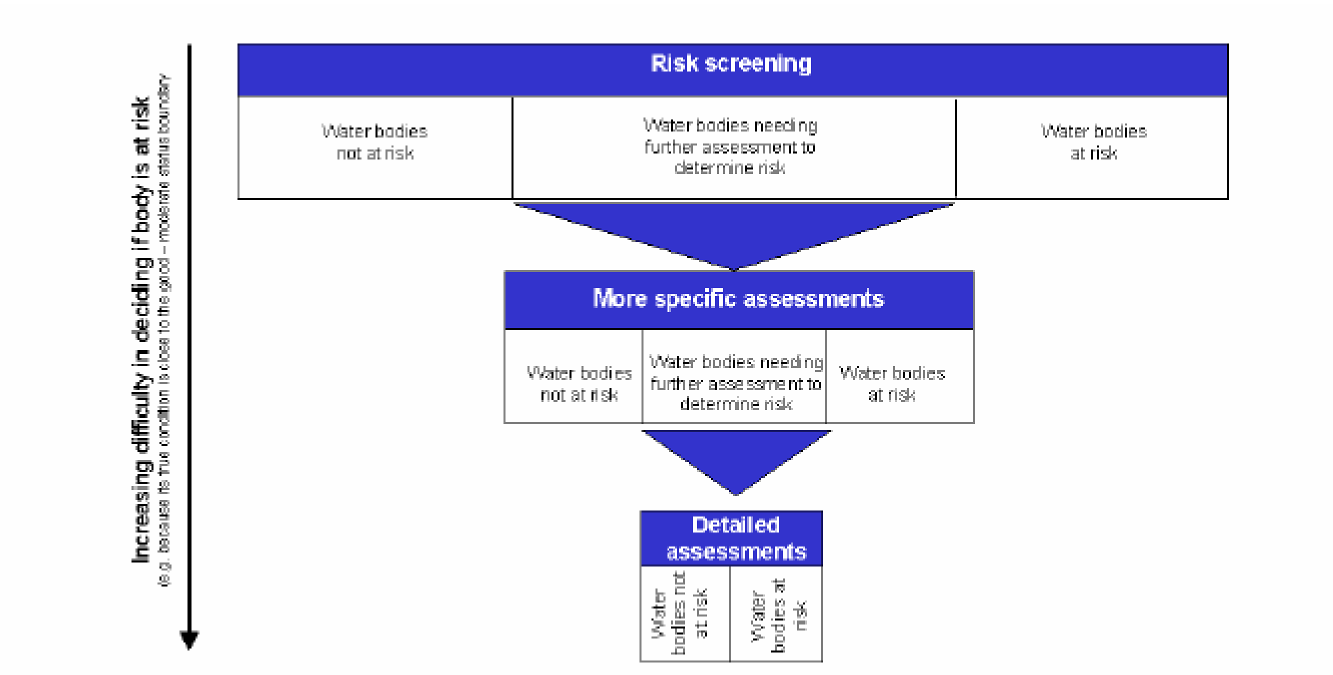
The most important goal of the first review, required in 2004, is to understand the significant water management issues within each river basin and how they affect each individual water body. The timetable for completing the first pressures and impacts analyses and reporting their results is very short. The first analyses will therefore **rely heavily on existing information** on pressures and impacts and existing assessment methods.

A screening approach is likely to simplify the tasks prior to additional description and analysis at a later stage, as it means focusing on the search for pressures on those areas and pressure types that are likely to prevent meeting the objectives. This screening should identify issues to be addressed in the drawing up of the river basin management plan (RBMP), and it may also reveal a number of gaps in data or knowledge that should be filled during the process of drawing up the RBMP and the monitoring programme. A list of pressures and the assessment of impacts on a water body shall ensure the identification of all of the potentially important problems. Assessing the likely impacts arising from each of the pressures will produce a list that can be used to identify points where monitoring is necessary to better understand if the water body is at risk of failing to achieve good status. This list then becomes a basis for developing a programme of measures which might be undertaken in order to achieve good status.

Member States should aim to achieve the best estimate of significant pressures in the time available. The pressures and impacts analyses should be focused in such a way that the effort involved in assessing whether any body, or group of bodies, is at risk of failing to achieve its environmental objectives is proportionate to the difficulties involved in making that judgement. To improve confidence, the estimates of the type and magnitude of pressures should be crosschecked, where possible, with monitoring data and with information on the key drivers for the pressures.

The identification of significant pressures could involve a combined approach of assessing monitoring data, model usage and expert judgement. These pressures and furthermore those water bodies at risk of failing the environmental objectives shall be identified and reported. This reporting process must be practicable for Member States, but also demonstrate transparency of Member States' decision-making processes (e.g. in exercising its experts' judgement).

In the longer term, the achievement of the goals will be assessed through the monitoring of a water bodies' chemical and quantitative state.



2.4.1 Initial characterisation

Using existing data:

- Collate data on pressures on the groundwater body, taking particular regard to those pressures listed under Annex II, 2.1;
- Collate information on impacts on the groundwater, taking particular regard to those pressures listed under Annex II, 2.1, and having special regard to the natural condition;
- Review existing groundwater monitoring data (chemical and water level), and data on dependent surface waters and ecosystems, having regard to the known pressures and impacts on the groundwater body, and the environmental objectives that are relevant to the body (Art. 4);
- The development of a conceptual model of the groundwater flow, which also incorporates flow to/from associated surface waters, and a model for the chemical system are recommended as the basis for understanding and documenting the groundwater body, and to aid decision making;
- Assess vulnerability of groundwater to pollution from the recorded pollution pressures, to assess whether the groundwater body is likely to be at risk of failing to achieve good chemical status;
- Assess the water balance of the groundwater body, having regard to the recorded quantitative pressures, to assess whether the groundwater body is likely to be at risk of failing to achieve good quantitative status;
- Consider possible relationships between the groundwater body and connected wetlands;
- Consider both chemical and quantitative status to decide whether the groundwater body is likely to be at risk of failing to achieve good status, including an assessment of time-lag of pollutants in aquifers;
- A review of the delineation of the groundwater body may be undertaken if the data on pressures and impacts indicates that it may be helpful to subdivide bodies for the purpose of developing a practical programme of measures. However, any subdivision should conform to the 'rules' on groundwater body definition contained within Commission guidance.

Where there are no monitoring data for a groundwater body, the likely presence or absence of pressures and impacts should be considered when making a decision of the likely status of the groundwater body. Where it is clear from monitoring data that the groundwater body is 'at risk', or where there is inadequate data to make a decision with reasonable confidence that a groundwater body is 'at risk', the process should continue to further characterisation.

2.4.2 Further characterisation

The key stages replicate initial characterisation but rely on additional data and more sophisticated analysis techniques.

3 Specific Guidance

This chapter explains the general approaches that can be taken according to water body type and data availability. In doing so it aims to show where the process and data requirements are common to the various water bodies within a river basin.

The key stages of the general approach as laid down in the WFD are:

- Identifying driving forces and pressures;
- Identifying the significant pressures;
- Assessing the impacts; and,
- Evaluating the likelihood of failing to meet the objectives.

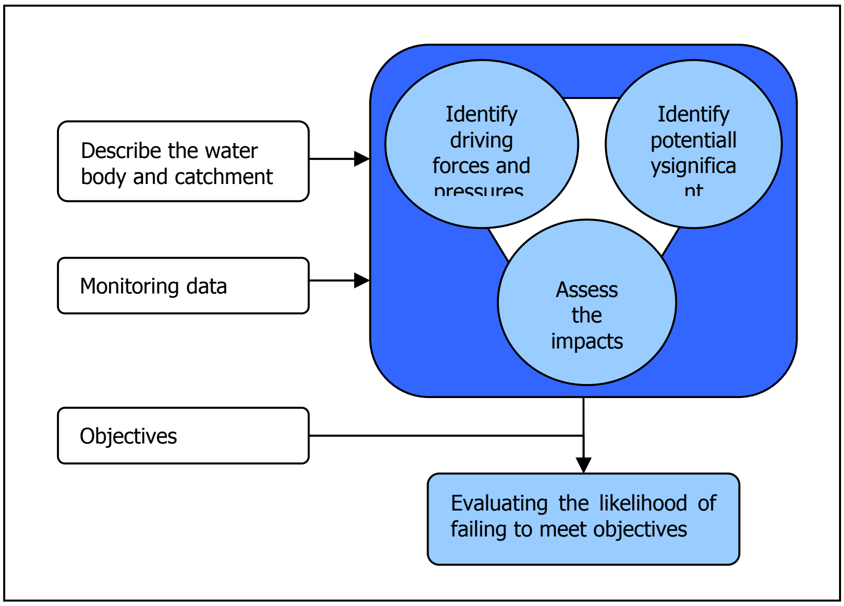


Figure 3: Key components in the analysis of pressures and impacts.

To undertake the four key stages, three supporting elements must be considered (shown on the left of Figure 3). The description of a water body and its catchment area will underpin the pressures and impacts analysis, and there are many types of information that may be useful, e.g. climate, geology, soil and land use. During the process, monitoring data relevant to the water body may also be introduced (see section 3.3). A comparison of monitoring data with driving forces may help to screen where pressures are likely to cause a failure in meeting objectives. It is also necessary to understand the objectives against which the actual state will be compared (see section 2.1.1). In many cases these key stages need not be undertaken as a linear sequence but in general, all key stages are to be addressed.

Assessing "who needs to get involved" requires addressing some of the following questions:

- Who can or will provide basic or additional input into the pressures and impacts analysis?;
- Who will use the results of the pressures and impacts analysis?; and,

- Who will be influenced by the follow-up of the results of the pressures and impacts analysis?

Developing a stakeholder analysis with possible involvement of key stakeholders can be an appropriate step for finding answers to these questions[11] (see chapter 2.1.3). It also helps in identifying key steps in the analytical process when involvement or input from specific stakeholders is required (different "Who" for different steps).

3.1 Identifying driving forces and pressures

Driving forces are sectors of activities that may produce a series of pressures. A pressure results from an activity that may directly cause deterioration in the status of a water body. In most cases, a pollution pressure relates to the addition, or release, of substances into the environment. This can be the discharge of a waste product, but may also be the side-effect or by-product of some other activity, such as the leaching of nutrients from agricultural land. A pollution pressure may also be caused by an action such as a change in land use. The most usual categorisation of pollution pressures is to distinguish between diffuse and point sources. However, the distinction between point and diffuse sources is not always clear, and may again relate to spatial scale. For example, areas of contaminated land might be considered as either diffuse or point sources of pollution. A quantitative pressure relates to the change of groundwater levels or the modification of flow directions but also to the intrusion of salinity, the reduced dilution of chemical fluxes or the modification of dependent aquatic or terrestrial ecosystems. This can be changes in land use like land sealing, water abstraction or artificial recharge.

For screening purposes, driving forces are quantified by aggregated data, simple to obtain, e.g.: hectares of arable land, population density, etc., per area. Comparing this driving force data with appropriate aggregated monitoring information quickly allows assessing the likelihood that the considered driving force is related to environmental pressures. In that case, only the expected pressures should be investigated in greater details.

The screening procedure is not only a way to speed up data collection by focusing on those pressures that are reasonably expected. It provides an independent assessment of pressures and impact relationships, which is valuable especially if emission and abstraction registers are poorly populated. Information describing driving forces and pressures will be required for both surface water and groundwater bodies, as, for example agricultural activity may exert a pressure on both surface water and groundwater bodies. Clearly the use of GIS will facilitate this process which is addressed in the GIS Guidance[12].

3.2 Identifying significant pressures

The inventory of pressures is likely to contain many that have no or little impact on the water body. The initial characterisation requires a general analysis of pressures corresponding to that described above, but set in the context of evaluating the risk of failing to meet objectives. This requires an understanding of the nature of the impact that may result from a pressure, and appropriate methods to monitor or assess the relationship between impact and pressure.

The assessment of whether a pressure on a water body is significant must be based on knowledge of the pressures within the catchment area, together with some form of conceptual understanding, of water flow, chemical transfers, and biological functioning of the water body within the catchment system. In other words there must be some knowledge that a pressure may cause an impact

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[11] Guidance Document No 8. Public Participation in relation to the Water Framework Directive. ISBN 92-894-5128-9

[12] Guidance Document No 9. Implementing the Geographical Information System Elements (GIS) of the Water Framework Directive. ISBN 92-894-5129-7

because of the way the catchment system functions. This understanding coupled to the list of all pressures and the particular characteristics of the catchment makes it possible to identify the significant pressures. However this approach often requires two stages.

In the first one, correlation assessment can be carried out. It has the advantage of using monitored data and doesn't require complex hypotheses. When necessary and appropriate, strict causality assessment may then be required using, for instance, numerical modelling, that will simulate the impact of numerous pressures. However these tools are seldom reliable, since they are based on hypotheses on the functioning of the ecosystem. Some likelihood assessment and models are considered in section 3.3.

In the second approach the conceptual understanding is embodied in a set of simple rules that indicate directly if a pressure is significant. One approach of this type is to compare the magnitude of the pressure with a criterion, or threshold, relevant to the water body type. Such an approach cannot be valid using one set of thresholds across Europe since this fails to recognise the particular characteristics of the water body and its vulnerability to the pressure. This approach effectively combines the pressure identification with the impact analysis since, if any threshold is exceeded, the water body is assessed as likely to fail its objectives. While simple, these methods can be an effective method of encapsulating expert judgement, and be based on sound science.

These methods can be more effective if coupled to state monitoring. A successful pressures and impacts study will not be one that follows prescriptive guidance. It will be a study in which there is a proper understanding of the objectives, a good description of the water body and its catchment area (including monitoring data), and a knowledge of how the catchment-system functions (Figure 4).

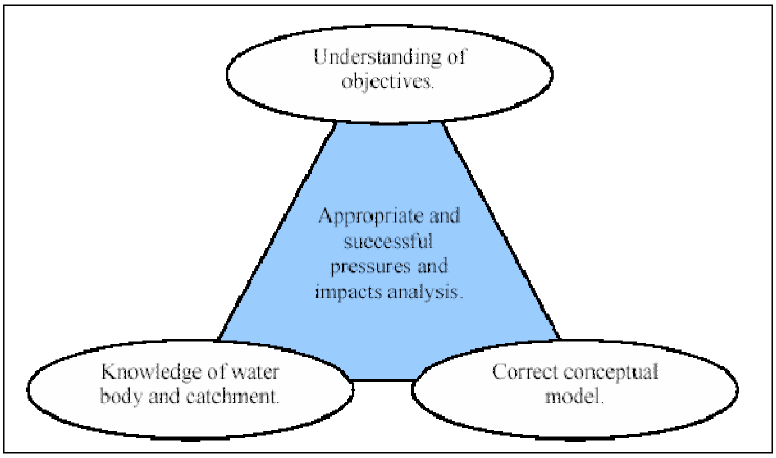

Figure 4: The three prerequisites for an appropriate and successful pressures and impact analysis.

3.2.1 Screening approach

The objective of the screening approach is to point out with simple assessments those water bodies that are clearly "at risk" or "not at risk" of failing to meet the objectives in 2015. This may happen both if the current state is good enough or too bad, and if there is no expected change in pressures. Compared to the general approach, the screening approach may be carried out in any order (assess state, assess lack or certainty of impact), using driving force assessment as substitute of pressures. Consequently, the screening approach preferably stands on existing data, not on modelling; otherwise the required transparency of the approach would not be met. Three examples of screening techniques should be mentioned for the following cases:

1. If only pressure data are available, their screening can be used as hint of a risk of failing objective;
2. If driving forces are correctly assessed and computed on small areas, and can be used to stratify observation data;

3. If only observation data (state) is available. In this case, a pressure analysis supposed to be applied where unwanted state is observed.

3.2.2 Variations in pressures and impacts

By definition the pressure of point sources cannot be spatially uniform, but it is probably also true that the pressures from diffuse sources, and quantitative pressures, are spatially variable within the catchment area of a water body. Furthermore, a specific pressure will not always cause a particular impact. Scale, both temporal and spatial, is one of the issues that will determine the impact of a pressure. Different characteristics of the catchment areas of the water bodies influence the nature of the pressure. For example, the impact of acid rain will be greater on the catchment located on granite geology with thin soils that have little acid neutralisation capacity, than on a catchment with calcareous (limestone or chalk) geology and soils with high acid neutralisation capacity.

Recognising this variability leads to two conclusions:

1. It is easier to provide guidance on identifying all pressures (i.e. potential pressures) than on identifying significant pressures (i.e. those that may cause an impact likely to cause a failure of an objective). The latter will generally require a case-by-case assessment that considers the characteristics of the particular water body and its catchment area.
2. In case when the variability in pressures and impacts could result in different status in different parts of a water body, it might be appropriate to redefine the boundaries of the water bodies in order to develop a practical programme of measures for each.

The Water Framework Directive does not differentiate between groundwater in different strata – all groundwater requires the same degree of protection from pollution. However, the impact that a pollution pressure is likely to have on groundwater varies from site to site, depending on the hydrogeological properties of the underlying soil, drift and solid geological strata. Consequently, for a given pollution pressure, the impact on the status of a groundwater body, and the potential programme of measures will vary in different aquifers.

3.3 Assessing the impacts of pressures

Once the likely activities handling pollutants, abstracting from, or discharging to groundwater have been identified, the problem remains of translating this information into a measure of "pressure". There are two main issues to be addressed:

- For a given activity potentially producing a pollutant, how can the intensity and distribution of the activity be translated into a pressure?; and;
- How can the pressures assessed from different activities be combined to produce a measure of total pressure on the groundwater body?

3.3.1 Initial characterisation of groundwater bodies

It is suggested that the concept of "potential impact" is introduced to describe the effects that a pressure is likely to have on a groundwater body, and that potential impact is used in the evaluation of whether the body is "at risk" of failing the Article 4 objectives. This concept recognises that, with the constraints on the characterisation process, it will not always be possible to accurately measure the impact by monitoring groundwater levels and quality. For pollution pressures the potential impact is judged by considering the pollution pressure (where this occurs at the ground surface) in combination with a measure of the vulnerability of the groundwater body to pollution (Figure 5). Thus, for example, a high pollution pressure caused by anthropogenic activities at the ground surface above an aquifer ***may*** have little impact on a groundwater body within the aquifer ***if*** that body is protected by a significant thickness of low permeable layers. For quantitative pressures, such as abstraction, the potential impact of the pressure on the body is likely to evolve lowering of the water level and reduced outflows. These may be estimated using the conceptual model of the flow system, and undertaking a water balance for the groundwater body.

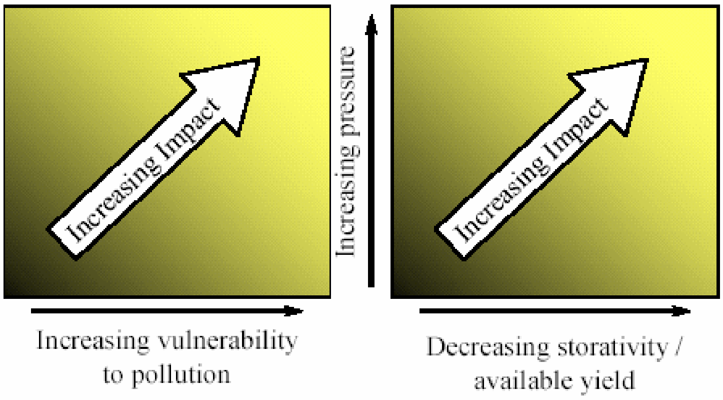

Figure 5: Impact is a consequence of both the magnitude of the pollution or abstraction pressure and the susceptibility of the groundwater to that pressure.

3.3.2 Further characterisation of groundwater bodies

A "review of the impact of human activity" for 'at risk' groundwater bodies and those crossing Member State boundaries is explicitly required by WFD Annex II, Section 2.3. The approach recommended follows that outlined for the initial characterisation, but requires the collection of more detailed information and data, such as that detailed in Annex II, 2.3. The wording of Annex II suggests that the information specified shall be included "where relevant". In this context "relevant" is taken to mean relevant to the assessment of risk of failure to meet Article 4 objectives. It does not give licence to avoid collecting information. The concept of "relevance" also involves questions of the level of detail that should be sought and, for human activities, the timescale over which the effects of the activity may be deemed relevant. In deciding these matters it is important to refer back to the purpose of further characterisation - to improve the assessment of risk and identify any measures to be required under Article 11. Thus, if the collection of more detailed information of a particular type is likely to improve the conceptual model sufficiently to enable the risk assessment to be enhanced, and if the extra detail can be obtained then the data should be collected.

3.4 Tools to assist assessing the impacts

Assessing the impacts on a water body requires some quantitative information to describe the state of the water body itself and/or the pressures acting on it. The type of analysis will be dependent on what data are available. Regardless of the particular process to be adopted, and as with the identification of significant pressures described above, the assessment requires a conceptual understanding of what causes impacts. In many cases a simple approach might be absolutely suitable for assessing the impact of a pressure. However, there will be a vast range of catchment types, water body types, interacting pressures, process conceptualisations, data requirements and possible impacts, and adopting such a simple model for all cases might be naïve. Annex 1 gives a brief overview of tools which might assist in assessing the impacts. It comprises the use of observed data to assess and to refine the assessment, a conceptual model, the use of analogue water bodies and the use of numeric models.

3.5 National and regional approaches for groundwater risk assessment

Session 2 and 3 of the groundwater risk assessment workshop gave the floor to the presentation of national and regional approaches and experiences of groundwater risk assessment. A brief summary of the presentations can be found in Annex 3.

Most of the countries and regions apply combined screening approaches considering pressures data, vulnerability information and monitoring data. In the Netherlands a modelling approach is applied.

England and Wales combine pressure exposure and vulnerability information together with measured data. A large number of "at risk" groundwater bodies is expected where further characterisation should resolve this uncertainty. In the Shannon PRB in Ireland the assessment relies on pressures and vulnerability assessment as well. Monitoring data are used for validating the assessment. In the Piemonte region in Italy the assessment relies on vulnerability and pressure analysis only.

Sweden as well as Lower Saxony (Germany) combine data on pressures with monitoring data and Hungary applies a screening approach focusing on pressures only regarding point sources where the area of the impact zone (>20 % of the groundwater body) and the amount of the polluted recharge to the total recharge (>10 %) are screening limits for assigning groundwater bodies at risk. Regarding the diffuse sources of pollution observed data (<25 mg/l in >20 % of groundwater body) as well as data on the pressures are used for the screening in order to assign a groundwater body as at risk. In assessing groundwater quantitative status the strategy is similar.

The Netherlands assess the risk by modelling the flux of water and chemicals from soil to draining surface waters. The uppermost horizon (1 m below surface) is therefore used as an early warning level subject of risk and trend assessment.

3.6 Evaluating the risk of failing the objectives

In theory, evaluating the risk of failing objectives should be a straightforward comparison of the state of the water body with quality standards or threshold values that define the objective.

For groundwater bodies, the use of monitoring data for evaluating the risk of failing to achieve good chemical status needs careful consideration, having regard to the specific environmental objective(s) that could lead to a failure to achieve good status. It is clear that the process of evaluating the risk of failure is to some degree an iterative collaboration between those undertaking the pressures and impact analysis, and those defining thresholds for the as yet undefined elements of status (Figure 6).

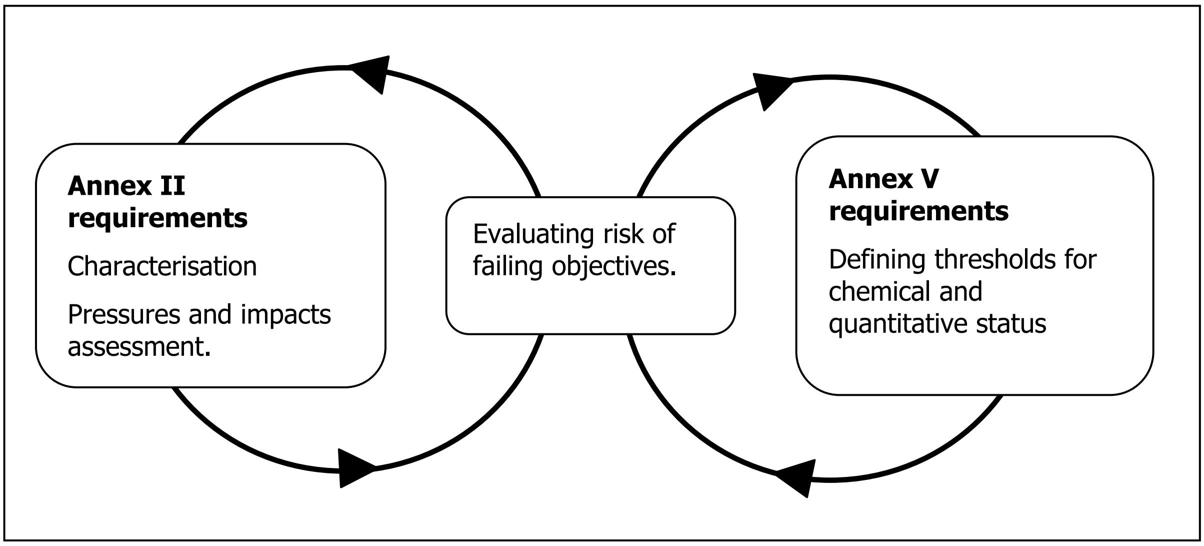

Figure 6: The iterative evaluation of the risk of failing objectives

3.7 Recommendations on reporting on the pressure and impact analysis

Article 15 (2) requires Member States to submit a summary report of the pressures and impact analyses to the Commission within three months of their completion (i.e. the first report must be submitted by March 2005). This section provides initial recommendations on the content and presentation of the summary report, in order to support consistency and comparability of results across the Community. All recommendations will be discussed within the EAF Reporting, which will provide the final Guidance on all reporting commitments. The summary report has several aims:

- It fulfils Directive's reporting obligations with regard to the pressures and impacts analyses by Member States;
- If a common format is used this will provide a comparable basis for harmonization of water management on a river basin scale between countries within international RBDs;
- Provides a transparent overview of the analysis & results to communicate with government, stakeholders and the public.

The summary report sent to the Commission should be concise and give an overview of water bodies, their current state and the specific conditions of the RBD. The summary report will be complemented by reporting obligations within the respective RBDs. Suggested elements of the reporting required for 2005 are:

- Short summary of relevant characteristics of the RBD (map of river basin district, protected areas, main water bodies, land use map);
- Summary of methods used (tools, thresholds, classifications) and assumptions made within the analyses;
- Cross reference to the other reporting obligations (article 5).

Pressures and Impacts report - It is recommended that the following is produced as a report:

- Overall map of water bodies which are assessed to be at risk of failing their environmental objectives;
- Summary map for each general pressure type identified in Annex II identifying where (in which water bodies) that pressure type is identified as one of the main causes of the risk of failing to achieve the environmental objectives (i.e. for which the pressure is a significant pressure);
- The summary map should also include an indication of the variation in the level of uncertainty achieved in the pressure analysis;
- These maps may be presented in GIS format.

Alternatively the following could be produced:

- Overall map of water bodies being at risk of failing to meet the environmental objectives;
- Supplementary table showing the main sources of pressures (e.g. substances);
- Summary table on number or area /percentage of water bodies which are at risk of failing their environmental objectives;
- Summary of major issues/pressures in the river basin district.

Regardless of the reporting format, the summary report should also include information on:

- applied methods, tools, thresholds, environmental quality objectives, classification schemes etc. used within the analyses;
- the amount of (un)certainty of analysis and results. The detailed RBD report may contain further information on the relative contribution of monitoring data, models and expert judgement within each analysis.

More detailed information should be available on demand for public and stakeholder consultation.

Annex 1: Tools to assist assessing the impacts

Assessing the impacts on a water body requires some quantitative information to describe the state of the water body itself and/or the pressures acting on it. The type of analysis will be dependent on what data are available. Regardless of the particular process to be adopted, and as with the identification of significant pressures described above, the assessment requires a conceptual understanding of what causes impacts. In many cases a simple approach might be absolutely suitable for assessing the impact of a pressure. However, there will be a vast range of catchment types, water body types, interacting pressures, process conceptualisations, data requirements and possible impacts, and adopting such a simple model for all cases might be naïve.

It is also the case that what initially appears a simple assessment can have hidden complexities. For example, the impact on the quantitative status of a groundwater body from the pressure of an abstraction might be investigated by a simple water balance model in which the change in storage is the difference between the recharge rate and the sum of the outflow plus abstraction. One criterion for good quantitative status is that both the outflow and the abstraction are sustained in the long term. The level at which the outflow must be maintained is such that good ecological status is achieved in any associated surface waters. Thus, what appears to be a simple water balance of a groundwater body actually requires knowledge and understanding of the ecological status and ecological flow requirements of an associated surface water body.

For the pressures and impacts analysis the conclusion cannot be that such analysis can only be achieved by elaborating a detailed, process-based, numerical computer model of the entire linked surface and groundwater system. This type of approach might be feasible in some cases and examples are described below. In practice, the information required to adopt the modelling approach will rarely be available at present, and probably not generally in the foreseeable future. By implication, the initial analysis will usually be based on less demanding methods for which the required data are available, e.g. pressure screening tools (see next chapter and section 3.2.1). Such analyses will be subject to refinement as further analysis is needed to determine risk, relevant data become available, and useable tools are developed.

Pressure checklist

The pressure checklist contains an uncompleted list of pressures that should be considered as part of the WFD pressures and impacts assessment. The list can be considered as a reminder of the driving forces and the pressures that should be considered and therefore represents a precursor to the actual pressures and impacts analysis. The driving forces and pressures within this table are listed mixed and independent from whether paths or sources of substance entries etc. are mentioned. The pressure checklist is presented in two stages. In Table 3 the pressures, where groundwater is concerned, are grouped into main classes of driving forces that may impact the different water body categories and prevent them from meeting the objectives. This table is an entry to the following uncompleted list of pressures in Table 4, as the numbers in the first column of Table 3 refer to the corresponding lines in Table 4.

Table 3: Pressures to be considered. See next table for details.

n°	DRIVING FORCES	Water Body Category					OBJECTIVES				
		Rivers	Lakes	Coastal/ Transitional	Groundwater		WFD (biota)	Tap water, NO3	Bathing, recreation	Habitats, Birds	Shell/fish farming
10	**Pollution**										
11	Household	x	x	x	x		x	x	x		
12	Industry (operating, historical)	x	x	x	x		x	x			
13	Agriculture	x	x	x	x		x	x	x	x	
15	Forestry	x	x	x	x						
17	Mines, quarries	x			x		x				
18	Dump, storage sites	x		x	x		x			x	
20	**Alteration of hydrologic regime**										
21	Abstraction (agri, indus, househ)	x	x		x		x	x			x
26	Flow enhancement (transfers)	x			x		x			x	

Table 4: Uncompleted list of pressures regarding groundwater

n°	Source	Source within the source type
10	**DIFFUSE SOURCE**	
12	urban drainage (including runoff)	industrial/commercial estates
11		urban areas (including sewer networks)
13	agriculture diffuse	arable, improved grassland, mixed farming
13		crops with intensive nutrient or pesticide usage or long bare soil periods (e.g. corn, potato, sugar beets, vine, hops, fruits, vegetables)
13		over grazing – leading to erosion
13		horticulture, including greenhouses
13		application of agricultural waste to land
15	forestry	peat mining
15		planting/ground preparation
15		Felling
15		pesticide applications
15		fertilizer applications
11	other diffuse	sewage sludge recycling to land
		atmospheric deposition
	POINT SOURCE	
11	waste water	municipal waste water primarily domestic
11		municipal waste water with a major industrial component
11		storm water and emergency overflows
11		private waste water primarily domestic
11		private waste water with a major industrial component
12	industry	gas/petrol
12		chemicals (organic and inorganic)
12		pulp, paper & boards
12		woollens/textiles
12		iron and steel
12		food processing
12		brewing/distilling
12		electronics and other chlorinated solvent users
12		wood yards/timber treatment
12		Construction
12		leather tanning
12		other manufacturing processes
17	mining	active deep mine
17		active open cast coal site/quarry
17		gas and oil exploration and production
15		peat extraction
17		abandoned coal (and other) mines
17		abandoned coal (and other) mine spoil heaps (bings)
17		tailings dams
18	contaminated land	old landfill sites
18		urban industrial site (organic and inorganic)

18		rural sites
18		military sites
13	agriculture point	Slurry
13		silage and other feeds
13		sheep dip use and disposal
13		manure depots
12		farm chemicals
18	waste management	operating landfill site
18		operating waste transfer stations, scrap yards etc.
18		application of non agricultural waste to land
12	manufacture, use and emissions from all industrial/agricultural sectors	priority substances
12		priority hazardous substances
12		other relevant substances
	ABSTRACTION	
21	reduction in flow	abstractions for agriculture
21		abstractions for potable supply
21		abstractions by industry
21		abstractions by quarries/open cast coal sites
20	**ARTIFICIAL RECHARGE**	
26		groundwater recharge
	OTHER ANTHROPOGENIC	
12		litter/fly tipping
11		sludge disposal to sea (historic)
		mine adits/tunnels affecting groundwater flows
10		Recreation
10		climate change
		land drainage

Using observed data to assess impacts

If data are available for the water body itself, it might be possible to perform a direct assessment of the impact. The types of data that might be used are as diverse as the impacts themselves.

Data itself is not enough to assess a possible impact: a correct indicator of the expected impact must be constructed. Moreover, it must be kept in mind that most pressures do not create a clear-cut impact, but substantially change the probability of adverse conditions representing a threat to the ecosystem.

Water quality statistics present specific difficulties as well. Comparison in state (i.e. is there an impact?) requires comparison between series of data. To carry out a meaningful comparison, the internal structure of the data must be considered. Normal distribution of data is in many cases preferred. Removing the seasonal and the hydrologic component of annual data dramatically reduces the calculated variance and allows comparison to be made between data sets monitored at short time intervals. These sophisticated statistical techniques might not be familiar to European water experts.

Using observed data to refine the assessment of impacts and pressures

Monitoring data may indicate that there are no current impacts. This information itself reveals that none of the pressures identified in the initial screening process is significant, or that the time lag required for a pressure to give rise to an impact has not yet passed. The latter is likely to be of particular importance when assessing groundwater bodies in which pollutants travel very slowly. Such data could also be used within a model as a check that the inputs to and processes within the model correctly reproduce the observed data.

Conceptual model approach

(Note: Model is used in this Chapter as a synonym for "understanding" and does not usually mean "numerical model"!). A conceptual understanding of the flow system, chemical variations and the interaction between groundwater and surface ecosystems is essential for characterisation. A significant strength of the approach is that it allows a wide variety of data types (including, for example physical, biological and chemical data) to be integrated into a coherent understanding of the system. As new data are obtained they help to refine, or change, the model; conversely the model may indicate errors and inadequacies in the data.

A conceptual model is dynamic, evolving with time as new data are obtained and as the model is tested. Its development and refinement should adopt an iterative approach. The approach therefore fits in well with the various levels of knowledge required at different stages of the WFD. For example a basic model will be appropriate for initial characterisation; this (if appropriate) will be refined and improved during further characterisation, and again during the review cycle of the RBMP. The construction of basic conceptual models of groundwater flow and chemical systems, and then of groundwater bodies must be undertaken early in the process of initial groundwater characterisation. This will include the delineation of the groundwater body boundaries and an initial understanding of the nature of the flow and geochemical system and interaction with surface water bodies and terrestrial ecosystems. It will also involve water quality information and an early assessment of pressures. In essence the model should describe the nature of the aquifer system, both in terms of quantity and quality, and the likely consequences of pressures. It is vital, even at the stage of groundwater body delineation that a coherent understanding of the body is reached. All data concerning the nature of the groundwater body collected during the characterisation process should be tested against the conceptual model, both to refine the model and to check for data errors.

Use of analogue water bodies

In situations with no observed data, one possible means to evaluate status is to use a similar *analogous* site for which data are available, and to assume that the assessment made from the observed data can be applied validly to both sites. To be most useful in the concept of the WFD pressures and impacts analysis the site for which data are available must have good status, since a failure may require more detailed study. The possibility of grouping water bodies for the purpose of pressure and impact analysis and monitoring is addressed in the Horizontal Guidance on "Water Bodies"[13]. Bodies subject to similar pressures and with similar characteristics could be grouped. The assessment of similarity is probably best made on the basis of transparent and accountable expert judgement of the general characteristics. However, it is possible to formalise this process by having a numerical evaluation of each characteristic and combining these to give some form of objective measure of similarity. Such a scheme would require some local weighting of the characteristics included and would therefore need to be developed regionally within Europe. Anthropogenic modifications that take effect at a particular location (e.g. abstraction or discharge) may not be useful in this assessment.

Numerical models

Modelling approaches allow impacts to be estimated, and should therefore be considered subordinate, or complementary, to monitored data from the water body. Mathematical models may be used to simulate the movement of water, and the fate and transport of pollutants within water bodies. In general the more complex the model, the greater the data requirements and the greater the time and costs needed to improve it. As a consequence, the accuracy of a robust numerical model may be greater than that which can be achieved using a simpler model. However, in the context of water body characterisation under the WFD there are many questions that may be answered adequately with a simple model.

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[13] Guidance Document No 2. Identification of Water Bodies. ISBN 92-894-5122-X

An iterative approach is recommended, where assessors begin with simple conceptual understandings or analytical models and shift to mathematical models only where water bodies appear to be at risk, or where a detailed programme of measures is being developed. In many cases simple analytical models will be adequate to allow an assessment of contaminant behaviour.

Numeric models might be useful to make predictions about combined point and diffuse source pollution effects on the wider groundwater body and on dependent surface waters and ecosystems, and to predict the effects of abstractions and artificial recharges on water resources.

Groundwater flow modelling is useful for three principal purposes.

- It may be helpful for predicting the likely impacts of abstractions and artificial recharges on the groundwater body and associated water bodies, and subsequently assessing whether the groundwater body is likely to achieve good quantitative status.
- The development of a robust groundwater flow model is a necessary prerequisite to any contaminant transport modelling undertaken as part of the analysis of the pollution pressures on that body.
- The model is valuable later in the WFD process for developing an effective programme of measures and for management of the water body.

Groundwater flow models simulate the interaction of groundwater with other parts of the hydrological cycle. Interactions between the groundwater and surface waters and wetlands may be simulated, which is vital for predicting the interactions between surface water bodies and their assigned groundwater bodies. Groundwater resource models take many forms, from simple, normally analytical water balance models of the water inputs and outputs to a groundwater body, to complex numerical models of the groundwater flow system within a body.

Simple models include standard analytical solutions for the effects of abstractions. Commonly available tools such as **Aquifer Win32** (http://www.aquiferanalysis.com) and **P-Test** are already available that allow analysis of borehole pumping data to predict the impacts on water levels.

For regional studies or where more complex analysis is needed **MODFLOW** (http://water.usgs.gov/software) is widely used (freeware). Alternative codes, such as **MIKE-SHE** (http://www.dhisoftware.com/mikeshe) are also used in a number of Member States to simulate groundwater flow on a catchment scale.

When the groundwater flow regime is understood it is possible to then consider the effects of pollution pressures. A range of tools might be helpful, including **ConSim** (http://www.environment-agency.gov.uk) an analytical model produced by the Environment Agency (England & Wales) that uses probabilistic techniques to predict the impact on groundwater quality from soil contamination and surface discharges. Where more complex codes are appropriate **MODFLOW** can be combined with contaminant transport codes, **MT3D** or **MT3DMS** (http://hydro.geo.ua.edu/mt3d) (freeware) to predict the impacts from point source pollution. Proprietary pre-processors are also available for **MODFLOW**.

For diffuse pollution, existing numerical models are less helpful, however, groundwater vulnerability assessments are a valuable tool for assessing risks to groundwater quality in these circumstances.

A study (see Annex 3, chapter 0) tested and compared human health risk models used in Europe and concluded that differences in model results can be orders of magnitude and that using model defaults has to be carried out very carefully as this can lead to large differences.

For assessing the ecological risk regarding the interaction of surface water and groundwater and possible effects on ecology, only a limited number of specific models are available. The use of groundwater models is only recommended for large project areas with sufficient and well known information on the hydrogeology of the site and surrounding areas

It was concluded that model results have to be defensible and that many models are too conservative. There is a clear need to critically assess model assumptions and the way software is applied. Poor understanding of differences may undermine credibility of risk assessment

Vulnerability maps or indices

Groundwater vulnerability maps or indices are useful tools for assessing the likely impact of pollution pressures during the characterisation process. By taking account of a range of factors, the susceptibility, or vulnerability, of groundwater to pollution from pollution pressure on the land surface can be ranked. Groundwater vulnerability maps, based on a regional assessment using an index based system can be used as a screening tool to rapidly assess the relative scale of impacts arising from pressures. They may be useful for assessing whether groundwater bodies are 'at risk' from pollution sources at initial characterisation. Groundwater vulnerability assessments may be combined with models of diffuse pollution source behaviour, to consider the overall risks to water quality on a groundwater body scale.

The **pollution vulnerability of an aquifer** (or groundwater body) is most simply and robustly interpreted (Figure 2) as a function of the contaminant attenuation and vertical flow capacity of the overlying strata (unsaturated zone or confining beds or perched aquifers), which, given adequate basic data, can be estimated in a qualitative sense (or using indexation) by hydrogeologists from their geological (lithological and structural) characteristics and thickness.

All **schemes of aquifer pollution vulnerability mapping** incorporate these factors, but some also include factors relating to saturated zone flow and contaminant attenuation capacity in the aquifer under consideration. This might be seen as mistaken, since these latter factors are more readily and transparently included specifically through the concept of **protection perimeters** around public water-supply sources and wetland ecosystems, which is a separate provision of the WFD. The **karstic limestone aquifers**, whose groundwater is characteristically under the 'rapid influence of surface watercourses', are the extreme case which lend themselves to complete integration of the vulnerability concept (based on unsaturated zone vertical flow) and the protection perimeter concept (based on saturated zone horizontal flow).

Aquifer pollution vulnerability mapping, which attempts to represent complex processes in simple fashion, inevitably have some limitations that need to be recognised – the principal of which is whether the use of a single '**integrated absolute vulnerability**' is defensible. It might be an acceptable simplification providing that:

- sufficient emphasis in aquifer vulnerability evaluation is put on the presence of fissure-flow and other preferential-flow pathways leading to the potential occurrence of rapid downward contaminant transport with limited opportunity for elimination
- the associated definitions are clear – for example that the **extreme vulnerability category** implies 'vulnerable to most water pollutants with relatively rapid impact in many pollution scenarios' and the **low vulnerability category** indicates 'only vulnerable to conservative pollutants in long-term when continuously and widely discharged or leached'.

Using such definitions, the **assessment of aquifer pollution hazard** (which involves evaluating the probable effect of an estimated loading of a specific class of contaminant on an aquifer with a given integrated vulnerability index) will be specific for the contaminant class under consideration.

Annex 2: Information needs and data sources

The description of the general approach required for the analysis of impacts and pressures has noted the many types of information and data that will be required. These can be divided into those that are generally descriptive of the drainage basin and its water bodies (i.e. they are not specifically related to either pressures or impacts), data that describe pressures, and data that describe impacts. Thus far the data requirements have been specified generally for surface waters, with rather greater detail for groundwaters.

With all information and data it is likely that the best and most readily accessible sources are national or regional datasets within the Member State. The IMPRESS guidance indicates ***what*** types of data may be useful in the analysis of impacts and pressures, ***why*** the data may be useful, and gives a ***European-scale source*** for the information, if one exists. Therefore the column "Source" in the following tables is not filled in completely. Competent authorities undertaking pressures and impacts analysis may need to be innovative in order to collect sufficient data, for example by asking stakeholders groups who may hold useful records.

The following tables focus on sources of information relevant to Annex II. It is recommended that, where possible, data is collected in digital form and used within a GIS.

The type of data, which has to be collected, shall at first focus on the water body (e.g. type, geology, geographical and meteorological terms, physico-chemical conditions etc.), as this is the starting point for an analysis of pressures and impacts. Additionally, data about current uses (e.g. pressures from urban, industrial and agricultural point and diffuse sources, about water abstractions, water flow regulation, land use etc.) and about the state of water bodies are needed. Due to the short time span for completing the first pressures and impacts analysis, it should mainly rely on existing data.

General information

Input from key stakeholders

Stakeholder participation is important as it can fulfil many functions, including that stakeholders can be a useful source of information and have expertise of direct use for the pressures and impact analysis. Key stakeholders that could be involved in the IMPRESS analysis are listed in the following table.

Key Stakeholders	Where they can help with information and expertise

Experts from Ministries (agriculture, transport, planning, economy, …	- Provide data for characterisation
	    - hydrological knowledge on behaviour of (ground) water bodies
	    - driving forces
	    - pressures
	    - changes in the state of the water body
	    - the impact of the pressures on the water status
	- Identification of key stakeholders
	- Assessing implementation and effect of existing Community legislation, in general but also in relation to protected areas
	- Characterising water uses and their importance with regard to pressures
	- Defining coherent methodologies for assessing key variables at Member State level

Water Service Suppliers,	- Provide data for characterisation (see above)

Water using sectors & stakeholders (farmers, industrialists, etc.)	- Provide input for assessment of pressures
Environmental NGOs	- Identifying key environmental issues - Assessing environmental impacts
Stakeholders/civil society/public	- Providing specific input for the assessment of pressures
Researchers/Experts (usually as consultants of the mentioned stakeholders)	- Assessing the impacts of pressures on water status (e.g. via modelling)

Descriptive information relevant to groundwater bodies

Data type	**Use**	**Source**
Water bodies		
Type of water body	Starting point for pressure and impact analysis.	
Spatial extent		
Meteorological		
Rainfall	Water balances.	National Meteorological Services, EEA?, other European?
Geographical		
Topography	Identify drainage areas for water bodies.	Mapping services, EEA?, other European?
Solid geology	Aquifer characteristics. Water chemistry	National Geological Surveys and Institutes
Drift geology	Vulnerability of underlying aquifer. Run-off and drainage characteristics of catchment	National Geological Surveys and Institutes
Soils	Vulnerability of underlying aquifer. Run-off and drainage characteristics of catchment	National Soil Surveys and Institutes
Land use		
Urban areas	Preliminary screening for point pollution sources.	National and regional statistical services, CORINE-Landcover (EEA)
Agriculture	Preliminary screening for point and diffuse pollution sources.	Agricultural administration, National and agricultural services, CORINE-Landcover, (EEA)
Industrial land	Preliminary screening for point pollution sources.	CORINE-Landcover, (EEA)

Mining/quarrying	Preliminary screening for point pollution sources	
Commercial forestry	Preliminary screening for point and diffuse pollution sources.	CORINE-Landcover, (EEA)
Fallow land	Preliminary screening for diffuse pollution sources.	CORINE-Landcover (EEA)
Recreation, e.g. golf courses	Preliminary screening for point and diffuse sources	
(Pattern of utilisation)	Preliminary screening for point and diffuse pollution sources.	

Information on pressures

Information on diffuse and point sources of pollution

Data type	**Use**	**Source**
Nitrate Directive (91/676/EEC) designated areas	Identify areas of aquifer with high, or rising, nitrate concentrations. Assessment of releases of agricultural nitrates	National Data Storages and Reports
Pesticides Licensing Directive (91/414/EC)	Information on pesticide usage	Pesticide Licensing Administrations
Directive 98/8/EC on Biocidal Products	Information on usage of Biocidal Products.	National Data Storages and Reports
Agricultural fertiliser application / sales data. Use data where readily available.		Agricultural administration
Integrated Pollution Prevention Directive (96/61/EC) Data and Reports	Collate sites authorised under the IPPC Directive and their discharges. At further characterisation consider detailed nature of activity.	National Data Storages and Reports, EPER
Activities authorised for purpose of the Groundwater Directive (80/68/EEC)	Collate locations of activities authorised under the Groundwater Directive. At further Characterisation consider detailed nature of disposal activity	National Data Storages and Reports, EPER
Activities authorised for purpose of Directive 1999/31/EC	Directive on the landfilling of waste. The Directive provides information on the amount of waste ending up at landfill sites. Collate locations of activities regulated for the Directive on landfilling. At Further Characterisation consider detailed nature of activity.	National Data Storages and Reports, EPER
OSPAR Guidelines for Harmonised Quantification and Reporting Procedures for	Assessment of nitrate discharges	National Data Storages and Reports

Nutrients (HARP-NUT)		
OSPAR Guidelines for Harmonised Quantification and Reporting Procedures for Hazardous Substances (HARP-HAZ)	Assessment of discharges of hazardous substances	National Data Storages and Reports
Known point sources from contaminated land, old landfills, mines etc.	Identify key sites that are likely point sources, but are not regulated under above directives	
Railway lines (herbicides) and road verges	Identify railway lines and herbicides applied	
Oil distribution pipelines	Identify location of sub-surface oil pipelines	
Soakaways from major roads	Identify where major highways (motorways etc.) drain to ground. At further characterisation identify pollution prevention measures.	
Potentially polluting activities (e.g. industry, opencast mining, petrol stations)	Identify areas where there are numerous potential point sources	
Rates of discharges to ground	Further detail on discharges identified above (further characterisation)	
Chemical composition of discharges	Effluent composition (further characterisation)	

Information on groundwater abstraction and recharge

Information regarding the location and the amounts of water abstracted respectively recharged might be obtained from:

- Water management administrations,
- Drinking water supply companies
- National Data Storages and Reports

It has to be considered that water abstractions might be illegal. In that case the abstracted amount should be estimated.

Information on impacts

Information on susceptibility / vulnerability of water bodies

Data type	Use	Source
Statistical climate data	Information on susceptibility of water bodies, e.g. regarding substance- or heat-discharger	Climatic data
Groundwater vulnerability data	Data on soil and drift presence and type. Depth to water table. Groundwater flow mechanism (e.g. fracture or matrix flow dominated system)	National Geological or Soil Survey / Institute)
Natural habitats of wild fauna and flora Directive (92/43/EEC)	Possible information on vulnerability of the area.	National Data Storages and Reports
Measurements of concentrations of possible pollutants in a water body	Information on susceptibility of the water body regarding pollutant discharges.	Environmental data

Environmental data

Data type	Use	Source
Groundwater quality monitoring data substances with article 17 standards conductivity substances relevant for article 4 objectives of dependent systems	Review existing data from groundwater abstraction and monitoring boreholes for evidence of impacts.	National water quality monitoring programmes; requisite surveillance of activities under Directive 80/86
Information on the chemical status of the water body from e.g. National Classification Schemes, "State of the environment" type reports, etc.	Assessment of chemical status.	National Data Storages and Reports

Annex 3: Summaries of the Workshop on Groundwater Risk Assessment

Introduction

The workshop was held in Brussels on 28th January 2004 and was structured into four parts:

Session 1 gave an overview of aquifer pollution vulnerability and contamination risk. It covers a general discussion of the key terms and goes into more detail regarding diffuse pollution sources and point sources of pollution, especially contaminated sites and plume assessment. Finally a study was presented which compared risk assessment models which are in use in Europe.

Session 2 and 3 of the groundwater risk assessment workshop gave the floor to the presentation of national and regional approaches and experiences of groundwater risk assessment. England and Wales, Sweden, the Netherlands and Hungary took the opportunity to present their national strategies and Lower Saxony, the Piemonte region, the Shannon PRB and the Tevere PRB presented their regional approaches.

Most of the countries and regions apply combined screening approaches considering pressures data, vulnerability information and monitoring data. In the Netherlands a modelling approach is applied.

England and Wales combine pressure exposure and vulnerability information together with measured data. A large number of "at risk" groundwater bodies is expected where further characterisation should resolve this uncertainty. In the Shannon PRB in Ireland the assessment relies on pressures and vulnerability assessment as well. Monitoring data are used for validating the assessment. In the Piemonte region in Italy the assessment relies on vulnerability and pressure analysis only.

Sweden as well as Lower Saxony (Germany) combine data on pressures with monitoring data and Hungary applies a screening approach focusing on pressures only regarding point sources where the area of the impact zone (>20 % of the groundwater body) and the amount of the polluted recharge to the total recharge (>10 %) are screening limits for assigning groundwater bodies at risk. Regarding the diffuse sources of pollution observed data (<25 mg/l in >20 % of groundwater body) as well as data on the pressures are used for the screening in order to assign a groundwater body as at risk. In assessing groundwater quantitative status the strategy is similar.

The Netherlands assess the risk by modelling the flux of water and chemicals from soil to draining surface waters. The uppermost horizon (1 m below surface) is therefore used as an early warning level subject of risk and trend assessment.

Session 4 was dedicated to on-going research in groundwater risk assessment presenting the projects W-SAHaRA, Aliance, WATCH, INCORE and AgriBMPWater.

Session 1: Overview of aquifer pollution vulnerability and contamination risks

Overview of Groundwater Pollution risk – by Stephen Foster

In the case-specific sense of Environmental Impact Assessments (EIAs), the term 'groundwater pollution risk' means the actual/potential consequence on the health of a specific **receptor** (water-user community of groundwater supply or an aquatic groundwater-dependent ecosystem) of pollution arising from a specific point **source** via a defined subsurface **pathway** (indicated by background of Figure 7). This is only possible to evaluate for relatively few major hazardous installations which have been subjected to detailed site investigation, but these are normally closely-controlled anyway and, thus, paradoxically not the major concern for the WFD.

In practice the assessment of **groundwater pollution risk** (in this case perhaps more accurately termed **aquifer pollution hazard** will be addressed by two possible approaches:

- the **direct method** involving appropriate chemical quality monitoring of the groundwater body to given an indication of incipient degradation
- the **indirect method** involving surveys of 'subsurface contaminant load' and estimates of 'pollution vulnerability' of the underlying aquifer.

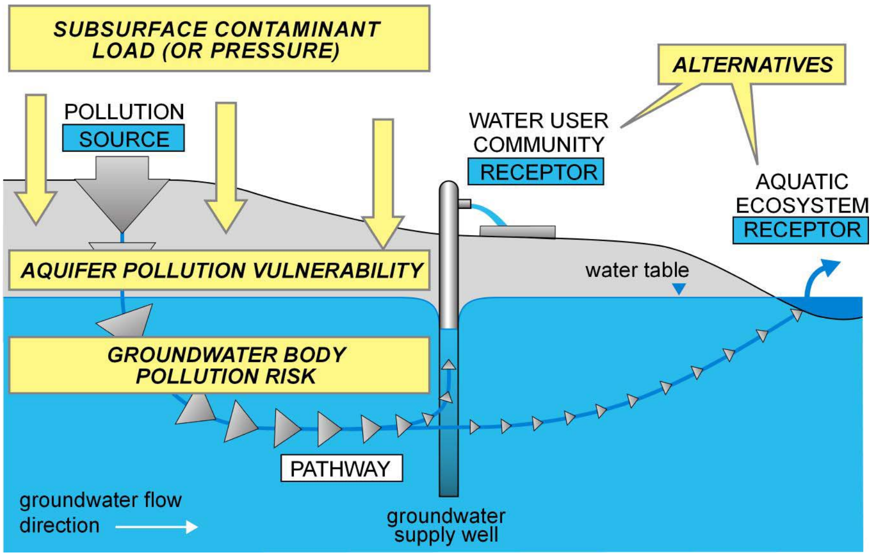

Figure 7: Conceptual Schemes of Groundwater Pollution Risk Assessment

In the initial implementation of the WFD a high-level of dependency upon indirect methods for groundwater pollution risk assessment is likely because of the:

- **inadequacy of groundwater quality monitoring networks** in terms of spatial design and analytical determinands;
- **complexity of some hydrogeological conditions** (and groundwater recharge and flow regimes), which called into question how effectively their groundwater quality could be represented by monitoring alone.

Aquifer pollution hazard is best conceived as the interaction between:

- the **man-made subsurface contaminant pressure** (or load) that is (or will be) generated cumulatively by land-surface activities;
- the intrinsic pollution vulnerability of the underlying aquifer.

It is thus through a combination of these **risk-screening tools** that groundwater pollution risk assessment will normally have to be carried out.

Much practical effort needs to go into surveying subsurface contaminant pressures – this is especially the case for **diffuse pollution sources** in both the rural and urban environments, but perhaps less so for point sources which have received more attention in the past with 'generic modelling packages' being available for solid-waste landfills, industrially-contaminated land, etc.

The **pollution vulnerability of an aquifer** (or groundwater body) is most simply and robustly interpreted (Figure 7) as a function of the contaminant attenuation and vertical flow capacity of the overlying strata (unsaturated zone or confining beds or perched aquifers), which, given adequate basic data, can be estimated in a qualitative sense (or using indexation) by hydrogeologists from their geological (lithological and structural) characteristics and thickness.

All **schemes of aquifer pollution vulnerability mapping** incorporate these factors, but some also include factors relating to saturated zone flow and contaminant attenuation capacity in the aquifer under consideration. This is mistaken (in the view of the writer), since these latter factors are more readily and transparently included specifically through the concept of **protection perimeters** around public water-supply sources and wetland ecosystems, which is a separate provision of the WFD. The **karstic limestone aquifers**, whose groundwater is characteristically under the 'rapid influence of surface watercourses', are the extreme case which lend themselves to complete integration of the vulnerability concept (based on unsaturated zone vertical flow) and the protection perimeter concept (based on saturated zone horizontal flow).

Aquifer pollution vulnerability mapping, which attempts to represent complex processes in simple fashion, inevitably have some limitations that need to be recognised – the principal of which is whether the use of a single '**integrated absolute vulnerability**' is defensible. It is the view of the writer that this is an acceptable simplification providing that:

- sufficient emphasis in aquifer vulnerability evaluation is put on the presence of fissure-flow and other preferential-flow pathways leading to the potential occurrence of rapid downward contaminant transport with limited opportunity for elimination
- the associated definitions are clear – for example that the **extreme vulnerability category** implies 'vulnerable to most water pollutants with relatively rapid impact in many pollution scenarios' and the **low vulnerability category** indicates 'only vulnerable to conservative pollutants in long-term when continuously and widely discharged or leached'.

Using such definitions, the **assessment of aquifer pollution hazard** (which involves evaluating the probable effect of an estimated loading of a specific class of contaminant on an aquifer with a given integrated vulnerability index) will be specific for the contaminant class under consideration.

Finally, it must be recognised that there is a **close relationship** between groundwater pollution risk assessment and the:

- 'threshold values' for good groundwater chemical quality status
- specification of groundwater supply protection perimeters
- approaches to groundwater quality monitoring network design;

and a degree of harmonisation of all of these 'management tools' is needed.

Diffuse Pollution Sources – by Dietrich Halm and Peter Grathwohl

In contrast to point sources diffuse pollution sources are almost invisible. Diffuse pollution of groundwater is usually directly connected to soil contamination or damage of soil functioning (filter, buffer, transformation). The unsaturated zone is the key zone regarding groundwater pollution.

Another unknown risk are emerging pollutants, previously unknown or unrecognised and therefore generally not included in the legislation (non-priority pollutants). Detective work ('environmental forensics') is needed in this case. Some cause long-established, widely recognised risks, as POPs or PBT (persistent bioaccumulative toxicants), some cause unexpectedly growing/developing risks (due to increasing consumption, such as MTBE. Some bear hidden, latent risks (previously unrecognised risk existing for some time, now recognised, such as personal care products – PCP) and some carry future, currently not-existing risks (new generation of chemicals/drugs subjected to approval).

Future research should focus on an inventory of pollutants, on on-going processes as the natural attenuation, on scale issues, on monitoring and on management of diffuse pollution.

- Inventory of pollutants: Risks from "emerging", i.e. until now not studied potential pollutants (i.e. such as pharmaceuticals, steroids and hormons, personal care products, antiseptics, surfactants, flame retardants, industrial additives and agents, gasoline additives).
- Natural attenuation becomes accepted as "remediation" tool, but only in groundwater. In the unsaturated zone, natural attenuation is "terra incognita" especially with respect to the relevant biogeochemical processes and the population dynamics of micro-organisms.
- Response of the soil system to climate change and long-term anthropogenic perturbations
- Heterogeneity and scale issues: An important issue in the future are "urban soils", which already today have levels of e.g. lead and PAHs above the precautionary limit.
  In some floodplains, Hg is above the trigger limit or even the action threshold. How to deal with such large scale pollution and how to prevent future ones?
- Cost-effective innovative screening and monitoring of soil pollution such as proxy mapping and identification of indicators for soil functioning
- Links between soil policy and other policies must be addressed, e.g. regulation of emission into the atmosphere can result in deposition fluxes of pollutants into soils at a large scale which are not sustainable. Environmental economics and socio-economic issues have to be included.

The following Table 5 gives some brief information on selected emerging pollutants and Table 6 gives an imagination of the distribution of PAHs in the environment in the case of the UK environment[14].

Table 5: Emerging pollutants - selected information

Compound	**Origin**	**Persistence, bioaccumulation**	**Observed in environment**	**Concentration level**
Nonylphenol (since 2002 detectable in food!)	Degradation product of non ionic surfactants	Medium persistent, bioaccumulative	Soil, Sediment, Sludge, **Water**	Low mg/kg* Low-high mg/kg Low µg/L
Phthalates	Plastics (Atmospheric deposition)	Low to medium persistent	**Water**, Sludge, Sediment	Low-medium µg/L Low µg/kg
PBDE	Flame retardant (Atmospheric deposition)	Persistent, Highly accumulative	Sediment, Sludge, Soil	Low-medium µg/kg Low-high ng/kg*
Sulphonamides	Human and veterinary drug	Slightly–very persistent	**Surface water**	
Tetracyclines	Human and veterinary drug	Moderately–very persistent	**Groundwater**, Soil, Sludge	
Steroid sex	Contraceptives	Moderately	**Water**, Sediment,	Low ng/L

[14] Estimations of PAH in the UK Environment. Data source: Wild, S. R. & Jones, K. C. (1995), Environmental Pollution, 88: 91-108

hormones		persistent	Sludge	Low µg/kg Low-medium µg/kg
MTBE	Gasoline additive –(ubiquitous in the atmosphere)	Persistent–Not bioaccumulative	**Groundwater**	

* sludge amended soil

Table 6: Sources and concentrations of PAHs in the UK

«Sinks»						**Sources**		
Soils and waste material		Conc. [mg/kg]	Burden [tonnes]		[%]	**Emissions**	[tonnes/a	[%]
Diffuse	Rural soil	0.187	6664	46930	85.3	Domestic heat	600	85.2
	Forest soil	**4.809**	21400			Vehicles	80	11.4
	Urban soil	**4.239**	18866					
Point	Gaswork	**4.441**	8100	8118	14.7	Power stations	5.84	0.8
	Sewage sludge	**16.1**	18			Incinerators	0.056	-
						Industrial	18.3	2.6
Total				55048			704.2	

Precautionary value = 3–10 mg/kg

There are several environmental policies relating to diffuse pollution covering a broad field of environmental media targeting on an integrated protection of soil and water:

- EU Chemical Legislation: REACH (Registration, Evaluation and Authorisation of CHemicals),
- Thematic Strategy Clean Air for Europe (CAFE)
- Common Agriculture Policy
- Nitrate Directive, Water Framework Directive, Groundwater Directive
- Thematic Strategy for Soil Protection,
- Landfill Directive, Sewage Sludge Directive, Compost Directive

It can be summarised that:

- Many persistent (emerging) anthropogenic compounds are emitted to the atmosphere and transported at different scales such as: PCB, Dioxins, DDT, Lindane, Phthalates, heavy metals, PAHs, MTBE,... (and probably many unknown compounds...);
- These compounds are deposited/precipitated on environmental compartments (soil, water, biota). Diffuse pollution of groundwater is usually directly connected to a damage of soil functions (filter, buffer, transformation);
- Due to continuous emission there is a risk of accumulation in soils and the release to groundwater. The water extractable part of PAHs indicates the potential risk of vertical migration with seepage water;
- Intact soils act as pollution filter in the water cycle. If the buffer capacity is exceeded, then contaminated soils can become a secondary source (sudden contaminant release, "chemical time bomb");

- The catchment approach (mass balance) works not only for inorganic, but also for organic compounds such as POPs;
- Future research needs are identified concerning the inventory, scales, processes, monitoring and management of diffuse pollution

Contaminated Sites, Point Sources & Plume Assessment – by Dietmar Müller

The relation between point sources and plume behaviour should be assessed via a stepwise working approach. This approach covers a preliminary assessment clarifying the relevant factors for the distribution of contaminants, a site investigation including mapping and characterisation to prediction and modelling.

A conceptual model would be very helpful and should be a living tool. It has to describe all necessary parameters for a risk assessment like physical properties, geological and hydrogeological features, relevant pathways, the point of compliance and receptors. With regard to the monitoring design a specific monitoring is needed for point sources. The influence of different properties on the expansion of contaminants is illustrated in the following Figure 8.

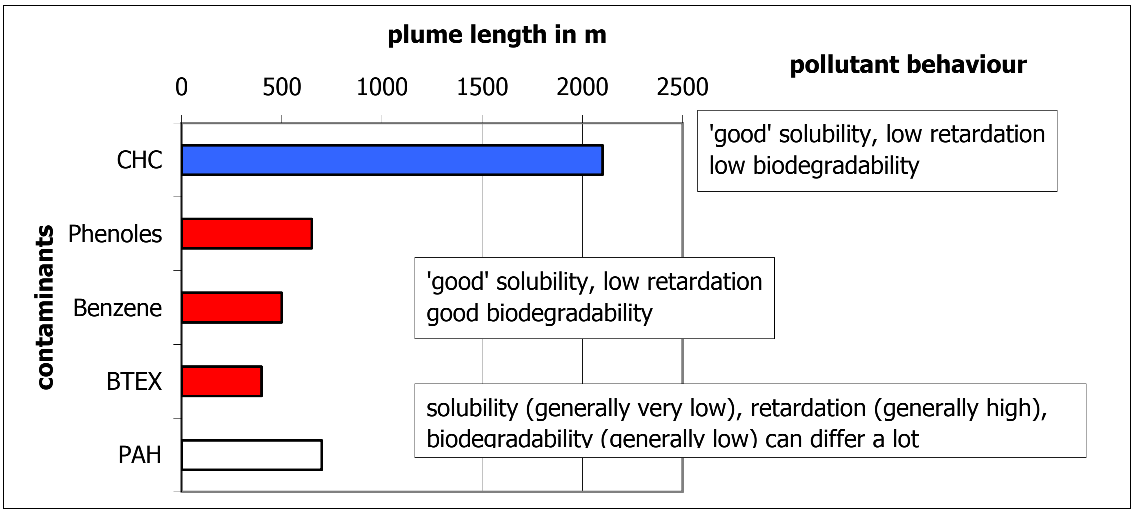

Figure 8: Characteristic plume-lengths (observed maximum length of plumes: 75 % percentile)

The monitoring design needs to take regard of several questions like: Does the monitoring network allow plumes to be defined, as well as background conditions? Is the appropriate horizon(s) being monitored? Are sufficient monitoring data available to define seasonal and long-term trends e.g. at least two years of monitoring? Are right parameters being measured and to an adequate degree of accuracy e.g. electron acceptors, parent and daughter compounds?

The no deterioration clause stated in the WFD calls for a risk management for point sources. The major concerns of the Common Forum for Contaminated Land are:

- Point sources cause long & small plumes - do not affect a groundwater body (three-dimensional)
- By considering 'groundwater bodies' the WFD is focused on diffuse sources and may neglect point sources or may cause unreasonable efforts and measures on reporting and monitoring (e.g. reporting of millions of point sources)
- Diversity of point sources and as a consequence of pollutants may imply contradictions to the assessment of the groundwater chemical status.
- In particular pollution of groundwater by 'historical' point sources will cause major problems not to achieve a 'good status' of groundwater bodies by 2015 - restoration will often be neither technically nor economically feasible

Key elements for a risk management for point sources are inventories of point sources (old/new), concepts for prevention of contamination, assessment strategy for point sources and plumes behaviour and concepts for the remediation of contamination. Transferring the idea of the no deterioration clause and trend assessment to point sources means that expanding plumes are not acceptable. There should be a distinction between new contamination triggering immediate and strict clean-up measures and historical contamination tackled by risk based & site specific approaches under the principle of BATNEEC, which means 'the best available technology not entailing excessive costs'.

Comparison of Risk Assessment Models used in Europe – by Wouter Gevaerts

The risk assessment process can be described by a conceptual model which is mainly based on chemicals and concentrations as source, their transport along different pathways and finally the toxicity of the contaminant and the resulting exposure of the receptor.

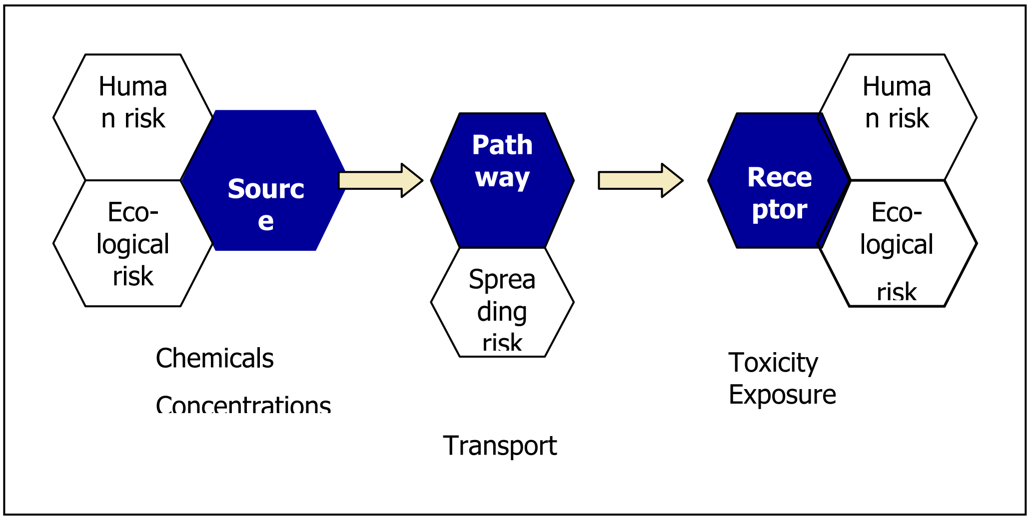

Figure 9: Conceptual model of the risk assessment process

The presented study compares human health risk models used in Europe to explain output differences and determine whether fate and transport codes in models are conservative screening tools. Differences in model results can be orders of magnitude and poor understanding of differences may undermine credibility of risk assessment. Several models were selected and test cases were used to identify the differences between generic and test case results. A main conclusion was that using model defaults has to be carried out very carefully as this can lead to large differences.

For assessing the ecological risk regarding the interaction of surface water and groundwater and possible effects on ecology, only a limited number of specific models are available. The main focus is put on assessing spreading risks as contamination in groundwater can result in human or ecological risks as well as the soil-groundwater interaction is a topic to tackle. The use of groundwater models is only recommended for large project areas with sufficient and well known information on the hydrogeology of the site and surrounding areas.

It was concluded that model results have to be defensible and that many models are too conservative. There is a clear need to critically assess model assumptions and the way software is applied.

Session 2: Groundwater risk assessment approaches in the light of the Water Framework Directive - National approaches

Groundwater characterisation in England & Wales - by Stuart Kirk

The progress on the characterisation of groundwater bodies ranges from the initial delineation across England and Wales to the full integration of risk assessment results wherefrom an overall risk category for groundwater bodies can be derived. About 400 preliminary groundwater bodies for the risk assessment screening were defined.

Categories for assessing and reporting pressures and risk are represented by four exposure pressure categories and the impact assessment which is modified according to monitoring evidence or reported dependent ecosystem impacts. As a result four risk categories are established which are then merged into the two categories of being at risk and not being at risk (see Table 7)

Table 7: Categories for assessing and reporting pressures and risk

Exposure Pressure Categories	Impact Assessment	Risk Categories		
		EA Risk Category	**UK-TAG Risk Category**	**EU Risk Category**
High Pressure	Modify according to monitoring evidence or reported dependent ecosystem impacts	High Risk	At Significant Risk	At Risk
Mod Pressure		Moderate Risk	Probably at Significant Risk but for which further info is needed to support this view	
Low Pressure		Low Risk	Not at Significant Risk on the basis of available info (confidence in the available info is low)	Not at Risk
No Pressure		No Risk	Not at Significant Risk on the basis of available info (confidence in the available info is high)	

Notes: EA…Environment Agency, UK-TAG…United Kingdom Technical Advisory Group

Chemical methods, combination of maps and combination of pollution pressures lead to risk maps for individual pressures where the risk classification is based on the highest risk of pressures assessed. Chemical assessments were undertaken for nitrogen, phosphorus, pesticides, urban, point sources and mining and the applied methods vary depending on the availability of pressure and impact (monitoring data) information (i.e. point or diffuse) and the receptor (groundwater, surface water, terrestrial ecosystem).

Chemical status – Example: Nitrogen

From about 3 700 boreholes the trend of nitrate monitoring data were extrapolated until 2015 and a Kriging map was generated (see Figure 10). In parallel a map showing high pressure and vulnerability was produced (see Figure 10: Areas with high nitrate concentration).

Step 1 comprises the combination of both maps leading to a common over-lapping map (map A) showing areas with high nitrate concentrations and high pressure & vulnerability (Figure 11) and a map (map B) showing the combined area of high nitrate concentrations and/or high pressure & vulnerability (Figure 14).

In step 2 the risk characterisation is performed based on the percentage area based on Table 8. Groundwater bodies may need to be sub-divided where % cover is low but the area is large.

Step 3 combines the risk maps for individual pressures (nitrogen, phosphorus, urban, pesticides, points sources and mines) and the risk classification is based on the highest risk of pressures assessed (one out all out principle applied).

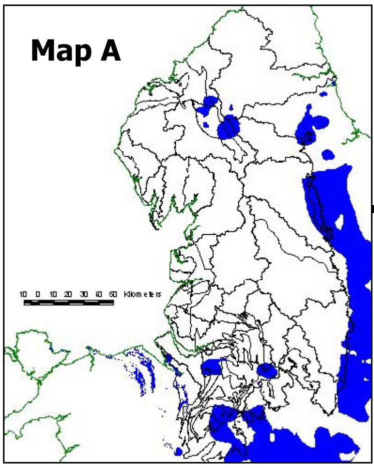

Figure 10: Areas with high nitrate concentration

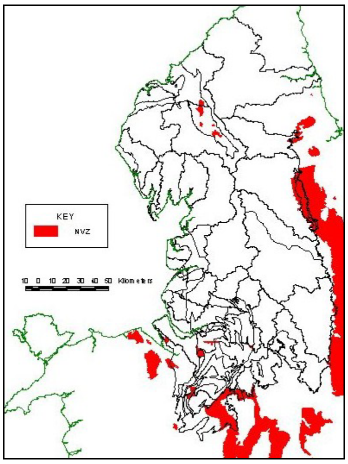

Figure 11: Areas with high nitrate concentrations and high pressure & vulnerability (common over-lapping area)

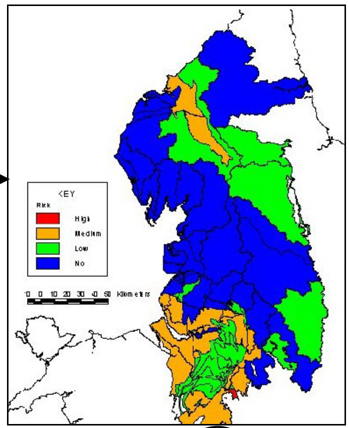

Figure 12: Groundwater body risk map for nitrate

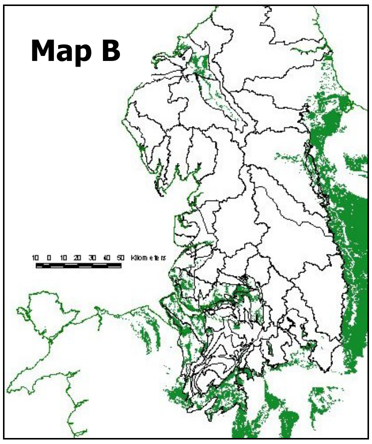

Figure 13: Areas with high pressure and vulnerability

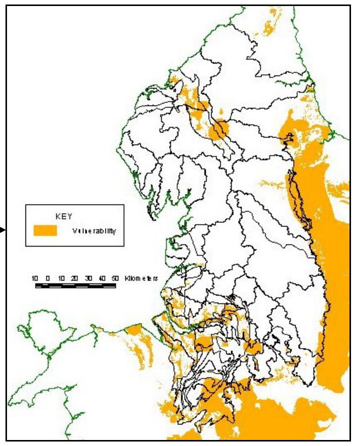

Figure 14: Areas with high nitrate concentrations and/or high pressure & vulnerability (combined area)

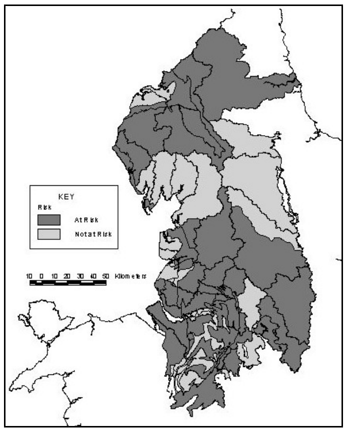

Figure 15: Groundwater body risk map (WFD, interim)

Table 8: Risk characterisation based on percentage area cover

Risk classification	Percentage cover (Map A)	Percentage cover (Map B)
High	> 50 %	
Moderate	→	> 25 %
Low	→	5–25 %
No	→	< 5 %

Quantitative status

The assessment of the risk of failing the good quantitative status is based on the preliminary groundwater bodies assigned to aquifer types, based on resource potential. It leads in a stepwise approach from the groundwater abstractions and the groundwater recharge (in %) to the abstraction exposure pressure and via the impact assessment to the risk assessment which finally leads to the risk categories according to Table 7. The results of the quantitative risk assessment and the chemical risk assessment are then combined to assign the final risk.

Results of the analysis

Point sources are mostly subject to strict permits to comply with the existing Groundwater Directive. Their effects are usually localised. Diffuse sources are generally not subject to the Groundwater Directive permits and have widespread, long term effects that will be difficult and often slow to reverse. There is evidence of some over-abstraction of groundwater but these are largely being addressed under various schemes. Furthermore, there could be difficulties with respect to lag effects due to stored contamination in deep unsaturated zones.

Conclusions

Overall there is likely to be large number of "at risk" groundwater bodies in England & Wales initially, reflecting intensive land use and uncertainty over some groundwater characteristics. Further characterisation should resolve the uncertainty. Diffuse pollution (especially nitrate) is a major issue for the WFD in England and Wales and a better understanding of some catchment processes is required for further characterisation.

Planned Risk Assessment in Sweden – by Magnus Asman

Present activities concentrate on the collection of information on abstraction points as not all groundwater abstractions are registered. As the eskers (esker = a sinuous ridge of sedimentary material [typically gravel or sand] deposited by streams that cut channels under or through the glacier ice) are most important for the water supply the general survey concentrates on them. The delineation of the groundwater bodies and recharge areas is done with already available data based on soil maps and topographic maps. All collected water wells must belong to a delineated groundwater body with re-charge area.

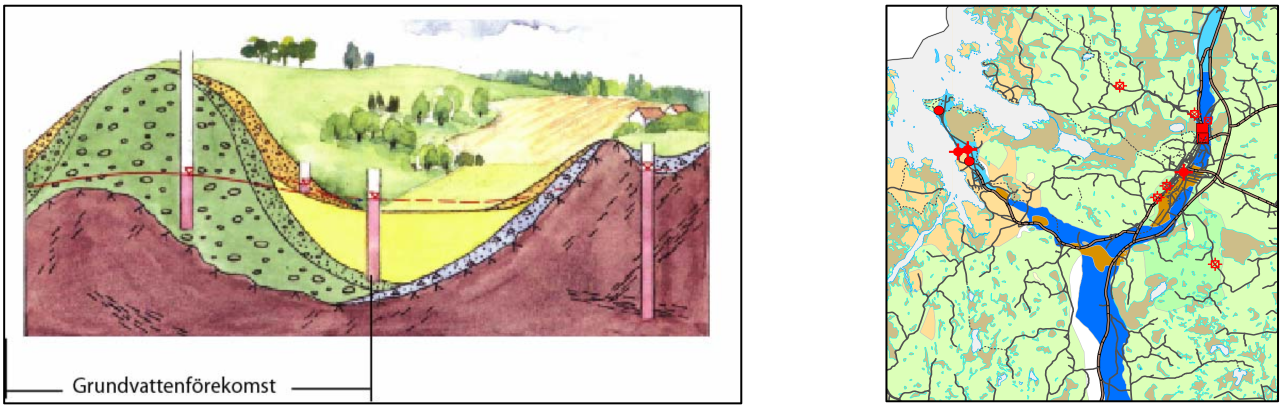

Figure 16: Groundwater in Sweden

Water authorities are responsible for the inventory of pollutant sources whereas the Geological Survey of Sweden and Swedish EPA are responsible for the national guidance. The impact assessment is based on data availability, on significant impact and on the impacts as reason for failing to achieve the quality objectives. Available data for risk assessment include data on emissions, on contaminated soil (29 400 locations identified), on the monitoring at large waste deposits, on abstraction and on groundwater quality monitoring which comprises 130 sites with an average length of time series of 17 years. Main problem areas reported by Water Managers are roads, agriculture, urban areas and forestry.

The national guidance includes checklists and provides a scheme for the identification and categorisation of impacts into: insignificant influence on the groundwater body, uncertain influence and probable significant influence (see Figure 17).

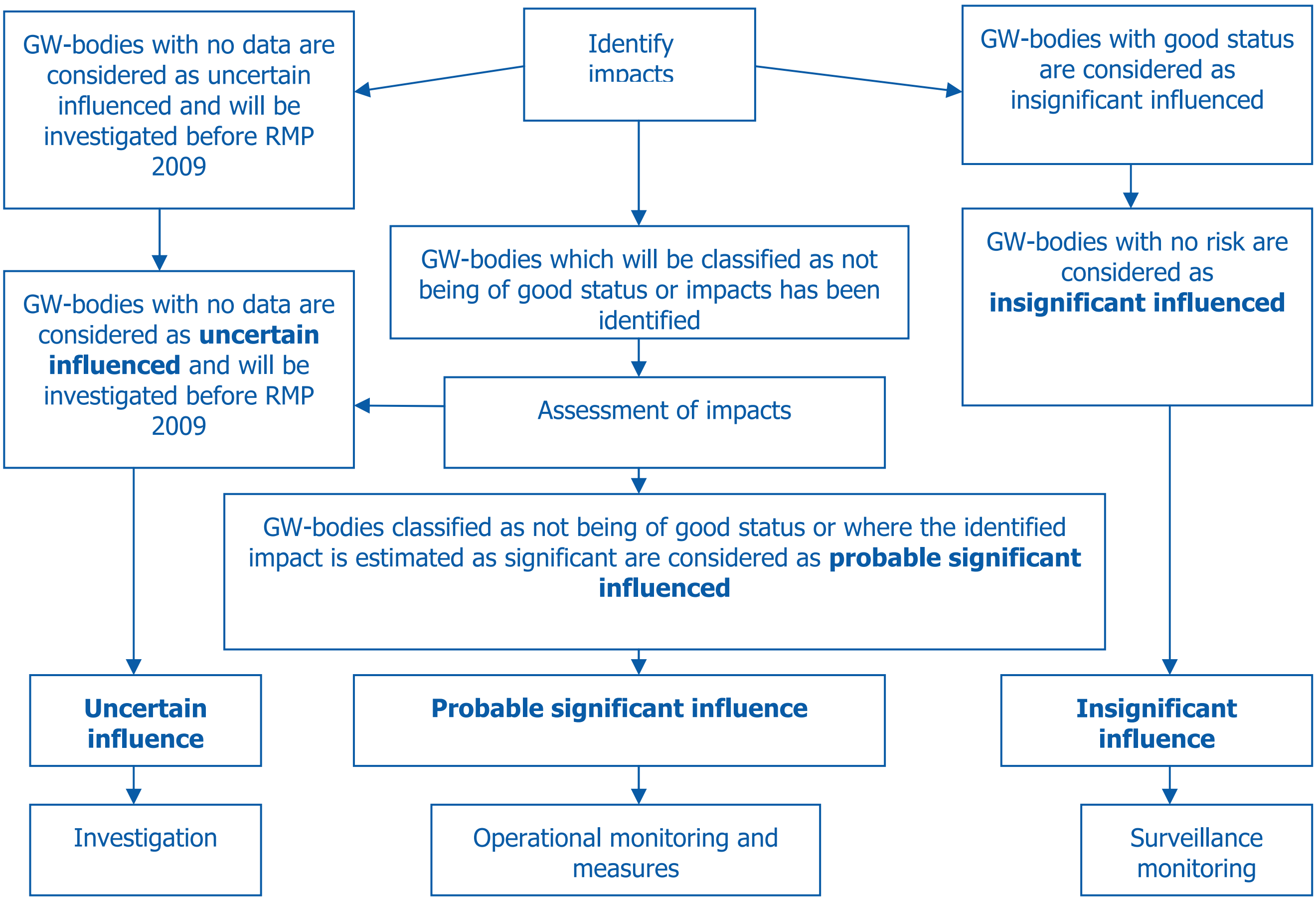

Figure 17: Scheme for the identification and categorisation of impacts

Groundwater bodies, chemical characterisation and monitoring for the Water Framework Directive in the Netherlands – by C. R. Meinardi

The hydrogeological conditions in the Netherlands do not allow for a delineation of groundwater bodies therefore another proposal for the division into different groundwater bodies is used. 20 groundwater bodies with exchange of groundwater are defined. There are separate groundwater bodies in the clay and peat layers which are not an aquifer in the classical sense but influence the ecosystem. The groundwater quality monitoring network refers to the four different groundwater level layers, upper, shallow, intermediate and deep groundwater. The density is about one well per 50 to 100 km².

Due to a strong increase in pressures from the 1950s on and due to the travel time of groundwater a quality stratification of groundwater can be recognised. Upper layers show high concentrations and denitrification is predominant in upper layers as well. The flux of water and chemicals from soil to draining surface water in sandy areas is computed by the NPKRUN model.

Three compliance checking levels (land surface minus 10 m, land surface minus 25 m, abstraction levels for public supply) are proposed and the early warning level at land surface minus 1 m should be used for risk assessment and trend analysis.

Hungarian approach to determine groundwater bodies at risk. (focus on quantitative status) – by Zoltán Simonffy

The identification of groundwater bodies is done by a hierarchical approach taking into account geological structures, hydraulic boundaries, temperature and flow regime and it is mainly suitable for quantitative analysis. 102 groundwater bodies are delineated and half of them are transboundary. For all water bodies detailed characterisation is available.

According to the special characteristics of Hungary the methodologies for pressures and impacts and the risk assessment of failing good status have to be adapted. For assessing the risk of failing good chemical status point sources of pollution and diffuse sources of pollution are taken into account. Different specifications define whether a groundwater body is at risk or not. For assessing the risk of failing good quantitative status analysis of time series and bottom up and top-down approaches for controlling the use of groundwater are applied. In Hungary 95 % of the drinking water abstractions and 75 % of the total water use derive from groundwater.

Chemical status

Regarding **point sources** of pollution the risk assessment of the chemical status is based on an estimation of danger including the type of source, vulnerability and uncertainty. The assigned impact zones are proportional to the estimated danger.

A groundwater body is at risk if:

- the area of impact zones is > 20 % of the projection of the groundwater body
- the polluted recharge > 10 % of the total recharge of the groundwater body

Regarding **diffuse sources** of pollution a groundwater body is at risk if:

- Immission approach: average concentration of nitrate in the upper part of the aquifer is > 25 mg/l in > 20 % of the area of the groundwater body
- Emission approach: the N-load and the recharge is considered together

Quantitative status

The risk assessment of the quantitative status of a groundwater body relies on the analysis of time series and the use of groundwater. A groundwater body is at risk if:

- area with significant decreasing trend > 20 % of that of the groundwater body

Regarding groundwater dependent ecosystem a groundwater body is considered at risk if:

- a significant part of a groundwater dependent ecosystem at risk is inside this water body A groundwater dependent ecosystem is at risk if 20 % of its area is in the area of depression of a groundwater abstraction.

The available groundwater recharge is estimated considering recharge from precipitation and surface waters, evapotranspiration, baseflow of surface waters and the lateral flow to neighbouring water bodies (Table 9). A groundwater body is at risk if

- actual abstraction > 80 % of the available groundwater resources

Table 9: Criteria for good quantitative status and components to be considered when estimating the available groundwater resource.

Type of water body	**Base flow of surface waters**	**Evapotranspiration**	**Lateral flow to neighbour GW-body**
Karstic	Springs (by body)	Wetland (by body)	towards thermal water body (by body)
Mountains (mixed GW-body)	springs (by body) + 0.3 Avg(Q)	No	towards karstic and porous water body (by body)
Porous in hilly regions	0.3 Avg(Q)	150 mm/a in wide valleys	towards discharge area: $1.1R.A_M/(A_U+A_M)$ 0, if no discharge area down to thermal water body (by body)
Porous in plateau and at bottom of mountains	0.25 Avg(Q)	200 mm/a in local discharge area	towards discharge areas $1{,}2R.A_M/(A_U+A_M)$ down to thermal water body (by body)
Porous in discharge area	0.2 Avg(Q), (only for small local water body)	50 mm/a in large forest or agricultural areas	down to thermal water body (by body)
Porous thermal	No	No	towards neighbour thermal water body (by body)

Session 3: Groundwater risk assessment approaches in the light of the Water Framework Directive – Regional and PRB case studies

Groundwater risk analysis in Lower Saxony (Germany) – by Martin Böhme

Lower Saxony holds 4 river sub-basins and about 150 groundwater bodies whereas Germany has about 1 000 groundwater bodies. A national guidance paper on the grouping of groundwater bodies is available. The identification of groundwater bodies is based on hydraulic and hydrogeological criteria and the size ranges from 100 km² to 1 500 km².

Risk is defined as the status before a groundwater body is moving from good to bad status. The approach of being at risk concentrates on impacts and pressures. Information on pressure is combined with the interpretation of measurement values to define the criteria for being at risk. The approach where groundwater bodies were sliced into sub-bodies due to land-use aspects and the integration of additional measurement data has led to the most satisfactory results. This identification of risk areas is then combined with pressures and impacts and forms the risk assessment. Risk in this case has to be defined as the preliminary assessment if a body is at risk of failing good status.

Groundwater risk assessment in the Piemonte region (Italy) – by Stefano Lo Russo

The Piemonte region is dominated by the Po plain where 15 million people are living. Intense groundwater abstractions and the deterioration of groundwater quality are the main effects of the densely populated and intense used area. More than 2 000 monitoring sites (~ 1 monitoring site per 15 km²) provide data on both quality and quantity monitoring.

According to G.O.D. (**G**roundwater hydraulic confinement in the aquifer under consideration; **O**verlying strata [vadose zone or confining beds]; **D**epth to groundwater table) the aquifer vulnerability is computed for each hydrogeological unit and then divided into five classes - from extreme to negligible. Basis for the assessment of the nitrogen load deriving from agricultural activity are agronomic units. The supply and removal of nitrogen from fertilisers is balanced and can be transformed to hydrogeological units. For further development test sites in the Piemonte region are used to evaluate some methods for risk assessment. The same approach is also applied to other contaminants than nitrogen.

Groundwater Risk Assessment in the Shannon PRB (Ireland) – by Garret Kilroy

The Shannon River Basin holds about 100 groundwater bodies. The risk assessment methodology mainly focuses on the chemical status of groundwater. As the methodology is based on the source-pathway-receptor model information on pressures, pathway and receptor characteristics are needed (see Figure 18). In addition the developing of a conceptual understanding of each groundwater body is emphasised. By using monitoring data for the assessment their representativeness and sufficiency have to be proved (see Figure 19).

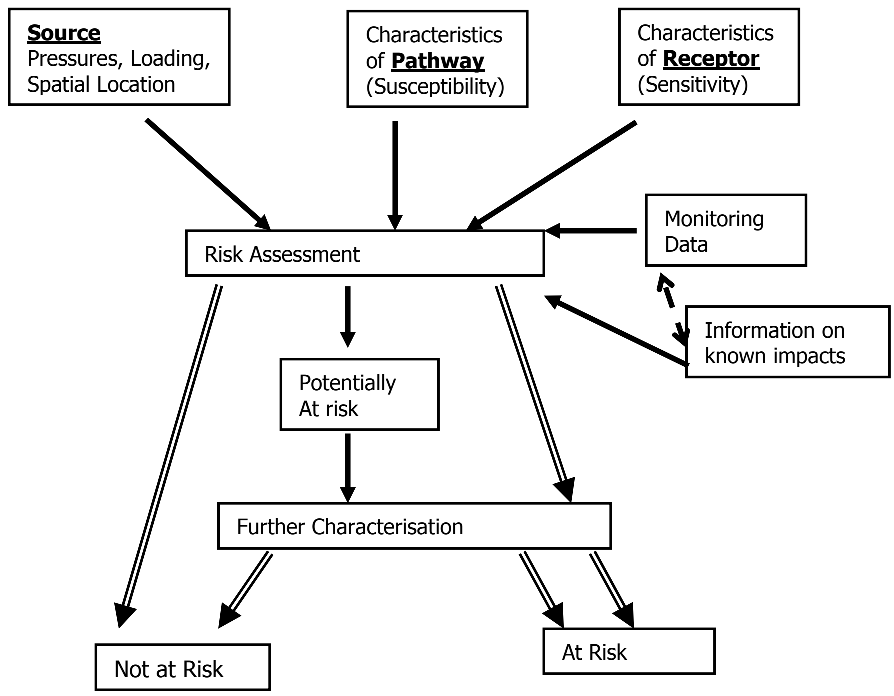

Figure 18: Risk assessment methodology

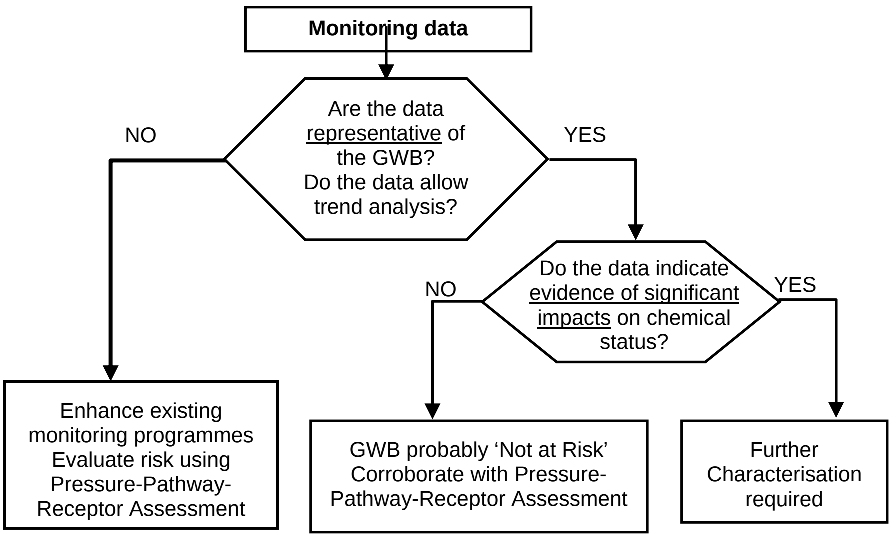

Figure 19: Use of monitoring data

Chemical status

For **risk posed by diffuse pollution** groundwater vulnerability and groundwater flow regime are used to identify the pathway susceptibility (see Table 10).These classes together with the pressure magnitude thresholds (e.g. life-stock densities) finally provide information on the impact potential (see Table 11). The designation of groundwater bodies at risk is carried out according to the number of groundwater bodies with high impact potential (see Table 12). Monitoring data are required to validate the assessment.

Table 10: Identifying pathway susceptibility to nitrate (& similar pollutant types)

Pathway Susceptibility		**FLOW REGIME**			
		Karst	Fissured	Intergranular	Low Flow
GROUNDWATER VULNERABILITY	Extreme (outcrops)	E	E	E	E
	Extreme	E	E	E	H
	High	H	H	H	M
	Moderate	M	M	M	L
	Low	L	L	L	L

Table 11: Combining Pathway Susceptibility to Pressure Magnitude

Impact Potential		**PATHWAY SUSCEPTIBILITY**			
		E	H	M	L
PRESSURE MAGNITUDE	High	high	high	moderate	low
	Medium	moderate	moderate	low	low
	Low	low	low	low	low
	Minimal	minimal	minimal	minimal	minimal

Table 12: Designation of groundwater bodies 'at risk'

% of GWB with high impact potential	Risk Category
>30%	'at risk'
15–30%	'potentially at risk'
<15%	'not at risk'

Quantitative status

To assess the **risk posed by abstraction** the effective rainfall and the groundwater vulnerability are combined to estimate the groundwater recharges. The effective rainfall is calculated by an interpolation of 30 year average annual rainfall (1960–1990) using a triangular irregular network, the interpolation of evapotranspiration data and the assumption that ER = Rainfall – Evapotranspiration. The groundwater recharge coefficient is the proportion of ER which reaches the groundwater body and is estimated by groundwater vulnerability maps using e.g. for extreme vulnerability the coefficient 0.8, for karst/rock 0.85, for high vulnerability 0.65, medium 0.3 and for low vulnerability 0.1. The recharges are estimated by calculating for each polygon: Recharge = ER x recharge coefficient x area

Finally, the abstraction pressure is included to define the significance of the pressure which depends on the sensitivity of the receptor. For less sensitive receptor the criteria in Table 13 are applied.

Table 13: Significance of abstraction

GW abstraction impact (as % LTA recharge)	Risk Category
>30%	'at risk'
15–30%	'potentially at risk'
<15%	'not at risk'

Risk assessment for groundwater. Some examples in the Tevere PRB – by Manuela Ruisi

The Tevere Pilot River Basin has an area of 17 000 km² and about 4 million inhabitants. Carbonate structures, alluvial aquifers, volcanic structures and terrigenous Flysch facies deposits are the main components of the hydrogeological structure. 2 test areas, one in an alluvial aquifer and one in a volcanic aquifer were selected for risk assessment purposes.

According to the chemical analysis the Conca ternana alluvial aquifer was divided into four areas. For assessing the risk the pressures, the vertical vulnerability according to DRASTIC, the interaction between surface and groundwater and the monitoring data are taken into account. This leads to the result that three out of the four groundwater bodies are at risk.

In the volcanic aquifer Colli Albano the methodology is based on information on the physical features, the hydrogeological balance areas, the climatic features and the information on water consumption and withdrawal. For the risk assessment the pressures, the abstraction-recharge ratio, the interaction between surface and groundwater and the monitoring data are taken into account. As result all four groundwater bodies are at risk.

Session 4: On-going research on groundwater risk assessment

W-SAHaRA - Stochastic Analysis of Well Head Protection and Risk Assessment – by Thomas Ptak

W-SAHaRA has developed tools to assist decision making on the basis of explicit recognition and quantification of uncertainty associated to predictions of groundwater flow and contaminant movement within drinking water well fields operating in naturally heterogeneous aquifers. Such tools maximise the use of the available information and are therefore strongly field-based (both in terms of improvement of site characterisation and knowledge of the real state and inputs to the system).

There is always uncertainty about naturally heterogeneous formations as well as aquifer boundary conditions, and data are often scarce. A (traditional) deterministic analysis of flow and transport represents not actual but smooth predicting values with associated prediction errors and uncertainties. Therefore, the problem of wellhead protection zones and well flow prediction was tackled in a probabilistic framework, to quantify in a rigorous way prediction errors that can be fed directly into probabilistic risk assessment and risk management analyses. Similar information is required for the planning, design and management of aquifer restoration and monitoring at contaminated sites. Many of the techniques being developed by W-SAHaRA are applicable to a wide range of problems involving the impact of groundwater pollutants on environmental systems. The techniques may be used to deal with problems not only at scales of well capture zones, but also at larger scales of whole catchments and basins.

Two non-exclusive approaches can be adopted to address uncertainty: acknowledge it and reduce it. In this sense, concepts developed within W-SAHaRA can be transferred into practical tools for decision-making in the following key respects:

- **Quantification of risk and vulnerability**, with protocols for risk zone identification, formally introducing uncertainty associated to predictions;
- **Best site characterization** and data collection practice.

In these tasks two ingredients interact: on one hand the data from **subsurface characterisation**, which contrary to data for mere deterministic modelling should contain the variability aspects and connectivity of the measured quantities, and on the other hand the models. The demonstration of techniques for optimising the interaction of these components is one of the key outcomes from the W-SAHaRA project.

Development of tools/methods and conclusions

The work performed by W-SAHaRA leads to the following tools/methods and major conclusions:

Quantification of uncertainty:

- importance of considering aquifer heterogeneity and uncertainty of boundary conditions when designing wellhead protection measures and aquifer remediation actions.
- Stochastic analytical, semi-analytical and numerical methods/tools have been developed/extended that yield improved estimates of a well catchment, together with a quantification of uncertainty. These methods can handle more sources of uncertainty, more complex situations and different kinds of conditioning.
- Expressions and algorithms for computing statistical key figures (expected value and variance as a measure of prediction uncertainty) of hydraulic head, fluxes, residence time and trajectories of contaminants to pumping wells in heterogeneous aquifers have been provided.
- Analytical expressions are offered for two- and three-dimensional scenarios, when aquifer transmissivity is modelled as a statistically homogeneous, correlated random field. Numerical solutions are given for general flow conditions.
- Impact of different sources of uncertainties has been analyzed. Such sources include: hydraulic conductivity, recharge, boundary conditions, geological facies distribution.

Reduction of uncertainty:

- A methodology to incorporate available information from probabilistic methods into solutions has been developed. Predictions are conditioned/constrained by using hydraulic conductivity, hydraulic head and sedimentological data (i.e., information rendering the spatial distribution of facies within an aquifer). Combined use of such information, so called conditioning, allows reducing uncertainty associated to predictions.
- A method has been proposed to **optimise sampling networks** of hydraulic head and transmissivity in order to characterise the groundwater flow in a region as good as possible. This approach is also valid for multiple wells.
- **Incorporation of additional data** is recommended. Measurements of contaminant travel time and/or concentration can further reduce uncertainty.

Best site characterization and data collection:

- **Specific type of measurements and data collection practices** need to be established targeted to the application within a probabilistic approach.
- A **multilevel-multitracer subsurface investigation methodology** has been developed, tested and implemented.
- An alternative novel methodology was proposed allowing to **infer statistical parameters of local hydraulic conductivity from larger scale pumping and cross-hole interference tests**, avoiding computationally intensive and complex inverse procedure.

The most relevant **hydrogeological data** are:

- Hydraulic conductivity of aquifer materials (e.g. from pumping and piezometer tests in boreholes or wells).
- Saturated aquifer thickness
- Elevation of lower and upper aquifer boundaries
- Piezometric head
- Water table elevation
- Areal recharge/replenishment rate
- Kinematic porosity (derived from tracer investigations).
- Location and fluxes of aquifer boundaries
- Tracer data sampled in boreholes and wells from tracer investigations (dye tracer, environmental tracers etc.).

Implementation of W-SAHaRA methodology

Even though the primary objective of W-SAHaRA has been to investigate and develop stochastic methods and tools for representing the effects of uncertainty on well capture zones and catchment areas, it is also recognised that there exist many wells where (1) **deterministic capture / protection zones and catchments** have only been determined in a traditional way, based on standard previous investigations, or even wells where (2) **no capture / protection zones** have been defined yet.

Given resource constraints, it is necessary for managers and water regulators to appreciate how the methods developed through W-SAHaRA can be applied in such cases. Therefore, a **decision system** (SWECADS) for the formulation of well capture/catchment zones has been set up. The procedure provides the resource manager with a method for determining what stochastic tools are required and how these may be used to reduce uncertainty (i.e. increase confidence) in the result.

'Aliance' Project – New downhole sensors and long-term monitoring approaches to document salt-water intrusion in coastal aquifers – by Philippe Pezard

Aliance means Advanced Logging Investigations of Aquifers iN Coastal Environments. Controlled experiments are basis of the work during this project which is constituted of seven partners and five countries.

The aim of the fluid flow imaging at the borehole is to optimise the description of the subsurface which can be achieved e.g. by the help of acoustic methods. SHyFT functions and applications provide information on the permeability of media and can help to inform on groundwater quality, industrial and domestic waste sites and to identify subsurface seals.

Two new experimental sites were developed, one in Mallorca and one in Brittany (France). The test site in Mallorca provides information on saltwater intrusion 15 km away from the coast by optical and acoustic borehole wall images. In Brittany the main interest is put on the transmissivity of the fragments.

The perspectives for the project are the deployment of a new design for a geophysical measuring device, the testing of new long-term monitoring methods and studies on the natural variations of groundwater quality.

WATCH - Water catchment areas. Tools for management and control of hazardous compounds – by Thomas Track

Based on the legal framework the requirements for WATCH are to define good groundwater chemical status, to identify or reverse upward trends and to prevent and limit pollution. These requirements are divided into the following four work packages:

Work package 1 is dealing with surveillance and monitoring techniques and concentrates on the detection of certain compounds like e.g. BTEX and MTBE. In work package 2 the aim is to assess the environmental fate of MTBE and BTEX whereas the results of work package 3 should cover issues of monitoring and decision support. The application scale ranges from contaminated sites to river basin dimension. A conceptual hydrogeological model, a knowledge increasing model and the decision support system are the main tool within this work package. Whereas the MIKE-SHE model can be well used for long lasting pollution the decision support system provides answers for risk assessment, recommendations for monitoring, impacts on water supply and on protective measures. The evaluation at model sites is the topic of work package 4. In this case it was executed on a test site in Salzburg (Austria) and the decision support system provided advice for the prevention of groundwater pollution, for the protection of the abstraction well and for the treatment of raw water.

INCORE – Integrated Concept for Groundwater Remediation – by Dietmar Müller

The INCORE project involved partners from five European countries and was terminated in summer 2003. In urban areas contaminated sites often show overlapping patterns and therefore the identification of the most polluted areas and the main sources, the proof of responsibilities for the application of the polluter pays principle and the definition of cost effective remediation approaches taking into account the pattern of contamination of the whole area were the main challenges.

INCORE was based on a cyclic approach which started with plume screening followed by source screening and finally should end with either a plume or a source remediation or combined measures in cycle three. To backtrack groundwater pollution systematically integrated pumping tests have been proven to be a strong tool. By an algorithm developed by the University of Tübingen it is possible to delineate the plume and calculate a total contaminant mass flux within the plume.

As the project area Linz-Heilham in Upper Austria still showed high concentrations of pollutants after first remediation projects at contaminated sites INCORE was implemented. After having executed the whole cyclic approach at the project area the final interpretation lead from 22 possible pollutant sources to 2 contaminated sites, which cause the major impacts for groundwater. Under the aspect of health risk an assessment was done by RiskWater, a software developed by the Polish partner.

AgriBMPWater – Systems approach to environmentally acceptable farming – by Ramon LaPlana

The multidisciplinary project was intended to provide information on which Best Management Practices (BMPs) are the most cost effective and how to improve farmers' commitment. A BMP is defined as any cropping method, any fertiliser and pesticide application technique or any landscape structural fixture, which potentially reduces water pollution from agriculture and which is proposed on a contractual basis to farmers.

During the first step 30 BMPs in agriculture were evaluated and the effectiveness referring to hydrology has been tested on several watersheds under different aspects. As practical result it was stated that due to the heterogenic nature it is difficult to find a single BMP. Therefore different good practices exist. Further the delineation of critical areas and the environmental effectiveness were assessed by different models.

The second step with regard to economics covered estimations for direct and indirect costs. Three mains types of costs have been defined: the amount bored by the regulator (subsidy), the amount bored by the agricultural producers (farmers' profit variation) and the amount bored by the rest of the economy (consumer surplus). Four methods have therefore been developed: A computable general equilibrium model: indirect costs, a Principal-Agent model: direct costs, a linear-programming model: direct costs, and a cost budget balance: direct costs.

Referring to sociology, farmers were interviewed to assess the acceptability of BMPs within the third step. The willingness to contract and so to improve the acceptability is a multidimensional phenomenon from economic considerations to social and cultural conditions.

Aim of the last step was to build a selection grid as a decision support tool. This is immediately usable for local land managers. The framework can be used on the local scale as the models are calibrated and validated.