Carstic waters as strategic ressource. Management and planning tools – an international comparison

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1 ABSTRACT

Water availability and water quality are considered to be of highest importance in the new century. The problem view of national and international agencies in this matter of course may differ markedly, but there is agreement, that the future focus will have to be on water management rather than water development. Obstacles to that objective are insufficient (or not enforced) regulations and legislative frameworks and the problem of data gaps and missing tools to provide information to decision makers. This paper focusses on the latter topic, and exemplifies possible step-by-step solutions which result from the international water management and research project KATER (KArst waTER research programe).

PROBLEMS OF WATER AVAILABILITY AND WATER QUALITY

In 1980 the UN declared the decade of „drinking water and hygiene“. Its another decade now that this decade has gone, but the problems of water availability and water quality are still there. In many respects this problem is likely to worsen in the next decades. A few figures may describe the situation:

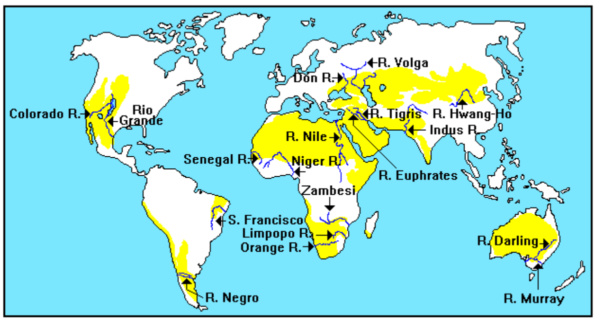
- More than 25 % of worlds population suffer from a lack of good quality drinking water
- Its estimated that 10 – 25 Mio people die each year from diseases transmitted through drinking water
- The problem of water availability and water quality is highly heterogenous in its distribution on a global as well as a regional scale

Levels of water use per person are steadily increasing: in 1930 the average european used 80 ls / day, in 1995 this had increased more than threefold (300 l) !!

Water availability shows marked differences between the worlds major regions, which even increase if the per person water availability is taken into account. The water availability in world regions is shown in the table below:

Region	1960	1970	1980	1990
Europe	5.4	4.9	4.6	4.1
North America	30.2	25.2	21.3	17.5
Africa	16.5	12.7	9.4	5.1
Asia	7.9	6.1	5.1	3.3
South America	80.2	61.7	48.8	28.3
Oceana	91.3	74.6	64.0	50.0

Table 1: Water availability in world regions, Source: IRC(Water Resources & Third World Development; http://www.arts.mcgill.ca/152-497b/h20/water/gwater/supply.htm; 12/2000)



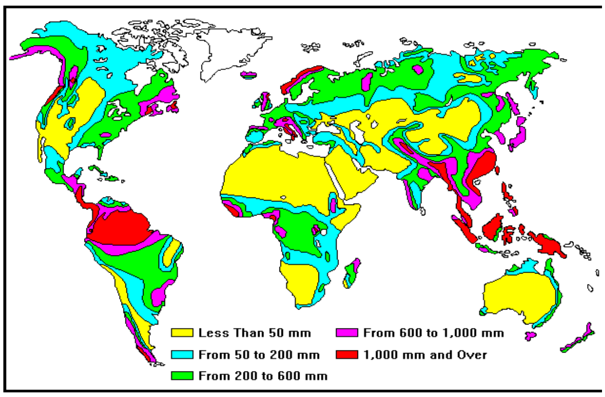


Figure 1 and Figure 2: Arid areas (left) and rainfall distribution (right) (Annotated Digital Atlas of Global Water Quality: www.cciw.ca/gems/atlas-gwq/gems10.htm; 12/2000)

The access to safe drinking water is even more heterogenous in its global distribution. A marked contrast can also be shown between urban and rural areas in developing countries:

Country	Urban	Rural
Algeria	85	55
Cameroon	43	24
Ghana	93	39
Kenya	85	15
Tanzania	90	42
Zaire	52	21
Costa Rica	100	83
Dominican Republic	85	33
Mexico	99	47
Afghanistan	38	17
Cyprus	100	100
Iraq	100	54
Pakistan	83	27
India	76	50
UK	100	100
Portugal	100	22
New Guinea	95	15

Table 2: Access to safe drinking water by country
Source: IRC(Water Resources & Third World Development; http://www.arts.mcgill.ca/152-497b/h20/water/gwater/supply.htm; 12/2000)

The question of water quality will be shown by just one example. The map below shows the risk areas of acidification in a global comparison. The old industrialised areas in Europe and North America turn out to be the most important problem areas. A relativly recent problem area is China, due to the high speed of (industrial) development in the last decades. This situation is likely to change in the near future, with protection measures taken by the old industrialised countries and the newly industrialising countries having a comparativly low awareness of environment problems.

But the issue of water quality is usually locally concentrated and can also be tackled only on a local scale, even if the problem originates on a far larger scale.

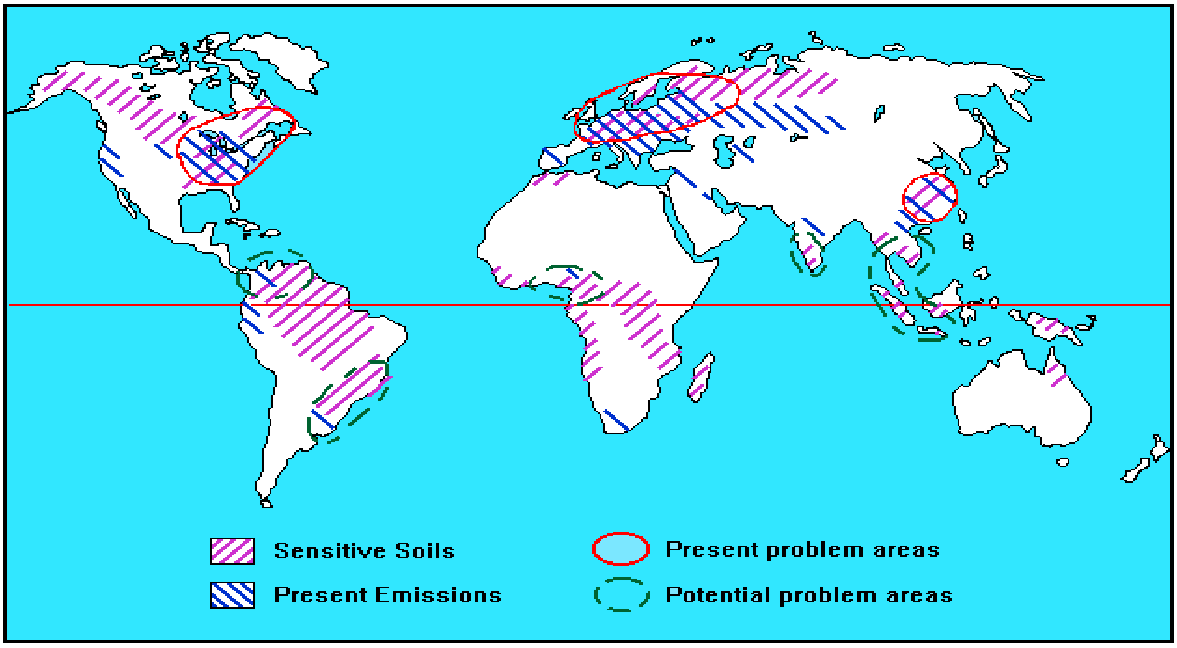


Figure 3: Global risk of surface water acidification (Annotated Digital Atlas of Global Water Quality; www.cciw.ca/gems/atlas-gwq/gems10.htm; 12/2000)

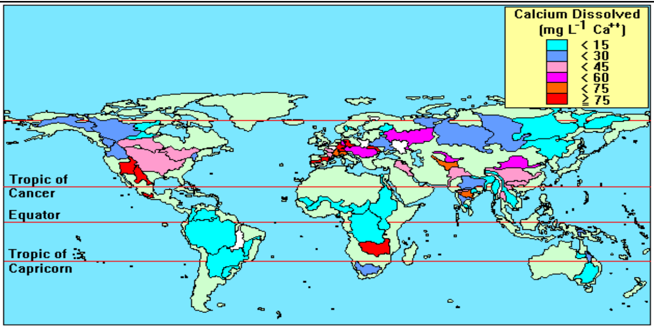
As surface water is increasingly polluted, drinking water has to rely on the groundwater ressources. In Europe this changed from the middle ages on (when water was drawn usually directly from the rivers or from wells) and in Germany nowadays 77 % of the water used in households stems from groundwater (8 % from springs, 6 % from reservoirs and only 4 % from lakes and 1 % from rivers).

In direct contrast 50 % of Austria´s water supply stems from groundwater and the other 50 % from springs – the share of surface water is neglectable. But this water is provided by about 3000 different providers, (communes and some even smaller private providers), making the exchange of information and an efficient common water management difficult to achieve.

CARSTIC WATERS AND THEIR SPECIAL MANAGEMENT NEEDS

On a global scale carstic waters mainly occur (in higher concentration) in Europe, as can be shown in the following map (showing the calcium concentration of the major rivers). This concentration is due to geological influences (and is not caused by anthropogenic impacts).

Thus in many european regions water is taken from carstic springs. Carstic waters are usually attributed high water quality, especially in the case of the City of Vienna, which relies heavily on carstic waters for its water supply. In the well-known case of Vienna the water is transported from regions 80 to 150 km afar from the city. But in principle carstic waters are highly sensitive to environmental changes and human influences. This is due to the special environmental (esp. geological) conditions, in which carstic waters occur. High porosity and often low levels of soil and vegetation coverage lead to a low filtering capacity on the surface, so that water from carstic springs often directly reflects rain water quality. In addition the reaction time of carstic springs, which may vary strongly, can be very short (few days) so that pollution in catastrophic events may directly degrade the water quality.



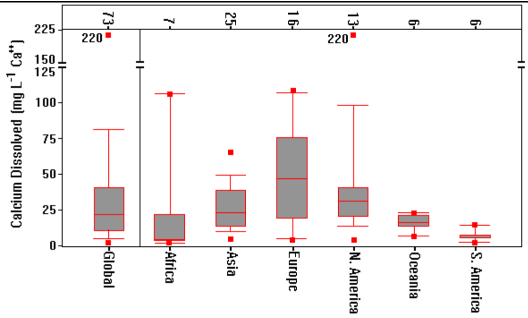


Figure 4 and Figure 5: Global variation of calcium concentration (Annotated Digital Atlas of Global Water Quality; www.cciw.ca/gems/atlas-gwq/gems10.htm; 12/2000)

The importance of carstic waters for the water supply of Austrians biggest city as well as the specific needs of water management in the carstic water case, have led to the formulation of an Interreg IIC project, in order to provide a sound management basis taking into account the complexity of environmental interactions in case of the carstic waters. The partners of this project involve institutions from Italy, Slovenia and Croatia, all of them countries with a partially high reliance on carstic waters for the water supply. The experiences and solutions of this project will be shown in the next paragraphs, as examples how to deal with the problem situation described below. More information about this project KATER (KArs waTER research programe) can be found at www.kater.at.

WATER MANAGEMENT – ISSUES / TASKS / COMPARISON

Water management is a central issue in the 21st century, because water is rapidly becoming a scarce ressource. The focus in dealing with water ressources on a global scal thus has to shift from a water development perspective to one of water development (WORLD BANK 1998). The issues involved seem to differ quite strongly between developing countries and industrialised countries. In the developing countries the studies of the last years usually agree on the main issues (LEE and BASTEMEIJER 1991):

- Need to address water source protection more systematically

Although water related environmental problems have received much attention in the last years, because of their central importance for sustainable development in many sectors, there is still the need to a more systematical identification and analysis of source problems.

- Lack of reliable information

Due to the complex interactions between natural environment and human action, which determine both the quantity as well as the quality of water ressources, the knowledge about water ressources and their (possible) contaminations is often very low.

- Legislation not enforced

Environmental legislation and water laws often concern only large watersheds and so do not provide adequate protection for smaller water ressources. The enforcement of laws and regulations is often hampered by a lack of awareness of drinking water problems and the interactions between environment and human action.

- Lack of awareness

A general lack of awareness of the environmental issues can be attributed to both planners and decision-makers and sometimes even to water users. Short term needs are often given higher priority than longterm protection of water ressources. More attention should also be given to training local stuff and users, in order increase awareness and to allow them to play a more active role in water ressource protection.

They name measures how to cope with these issues:

Strategy development is necessary to come to terms with the wide range of causes and effects of drinking water source problems. But the lack of information does not allow to formulate clear guidelines for land-use management and catchment area protection. Thus even those cases, where a policy framework exists there are no operational strategies in place.

Environmental profiles and monitoring indicators are needed as a basis for decision making. This would include the differentation of water sources in different environments and the definition of their vulnerability. Parameters for the monitoring of water sources and checklists for preventive actions would form a starting point for water source protection.

Simple tools and methods have to be developed in order to provide even small water providers with the necessary tools for decision making.

Community and local government involvement is necessary to increase awareness and problem responsiveness. But those institutions often lack the physical infrastructure as well as the manpower skills to deal with the problems adequately.

The *role of women* has to be strengthened because they are most heavily affected by a lack of adequate water sources.

Cost – benefits analysis need to be carried out in order to get a thorough understanding of incentives or discentives of protecting waters.

Low-cost techniques for waste management have to be developed and applied where appropriate.

Collecting information about pesticides and chemicals may be necessary to fill the data gap in regard to negative effects on health.

The World Bank (1998) and the National Indian water board authorities have formulated an action plan, which includes the following recommendations:

- Improving the policy framework
- Strengthen the legislative and regulatory framework
- Establish institutions (private - public)
- Introduce economic incentives
- Using technological improvements
- Improve data availability and modeling, environmental monitoring and public information

Of course the problem of World Bank and other developing aid agencies differ in many respects, but the problem of insufficient (or not enforced) regulations and the problem of data gaps and missing tools to provide information to decision makers is agreed upon. This paper focusses on the latter topic and discusses the problem view and possible solutions mainly for the data collection and management issued and the related issue of efficient decision support. The main points to be learned from the discussion above are therefore:

- collection of additional information (about water quantity and water quality)
- develop profiles of vulnerability and define parameters for monitoring
- develop simple tools for decision support
- provide public information

Surprisingly many of these issues can be found in industrialised countries and developing countries as well. But an international comparison does show a clear distinction on a more detailed level. On this level the problem situation differs markedly and the measures to take as well as the tools available / necessary show very differing priorities.

Issue	Industrialised countries	Developing countries
Policy framework	In place	In place or in development
Legislative and regulatory framework	In place and well developed Information about regulatory framework	often weak, due to a lack of information and awareness low enforcement rate
Conflicts	Industry as main user and polluter Settlement and infrastructure projects increasingly tourism	Agriculture (irrigation) as main water user and (increasingly) polluter Political conflicts (inter-state as well as water allocation between social groups and within states)
Regulations	In place, but with strong differences between countries Property related water rights provide (potential) problems	Often weakly defined only by common law Few regulations for allocation and protection priorities
Objectives of water management	Assuring high quality Managing ressources to cope with future demands Allowing for flexibility in water use / allocation / regulation	Making ressources usable Coping with information deficit Generation of regulations and management structures

Table 3: Comparison matrix of water management related issues

SOLUTIONS – PROJECT KATER AS AN EXAMPLE

The main objectives of KATER have already been described above. In the development of the project it turned out that many of the problems shown above are also due for the participating countries, although on a different level and with different priorities. But even in a comparison between the participating countries (neighbouring countries which have have shared a common history for many decades) marked differences turned out. These differences were on the levels of

- data availability and data access
- legislative and regulatory framework for water protection
- water management systems

- and the nature of conflicting land-use activities.

In order to exchange experiences and benefit of each others work the major steps identified were:

- to define a *common terminology*[1] and *problem view* (this resulted – among others in a comparison matrix of data, regulations and terms used; the problem view is shown below);
- definition and categorization of *land-use activities* and their relationship to water management;
- *metadata* definition and development of a metadata database;
- development of simple *GIS* tools for data management and data visualisation, based on an overview of user needs and the identification of user groups;

These points show the strong resemblance between tasks to be done in the industrialised and the developing countries.

1.1 Common terminology and problem view

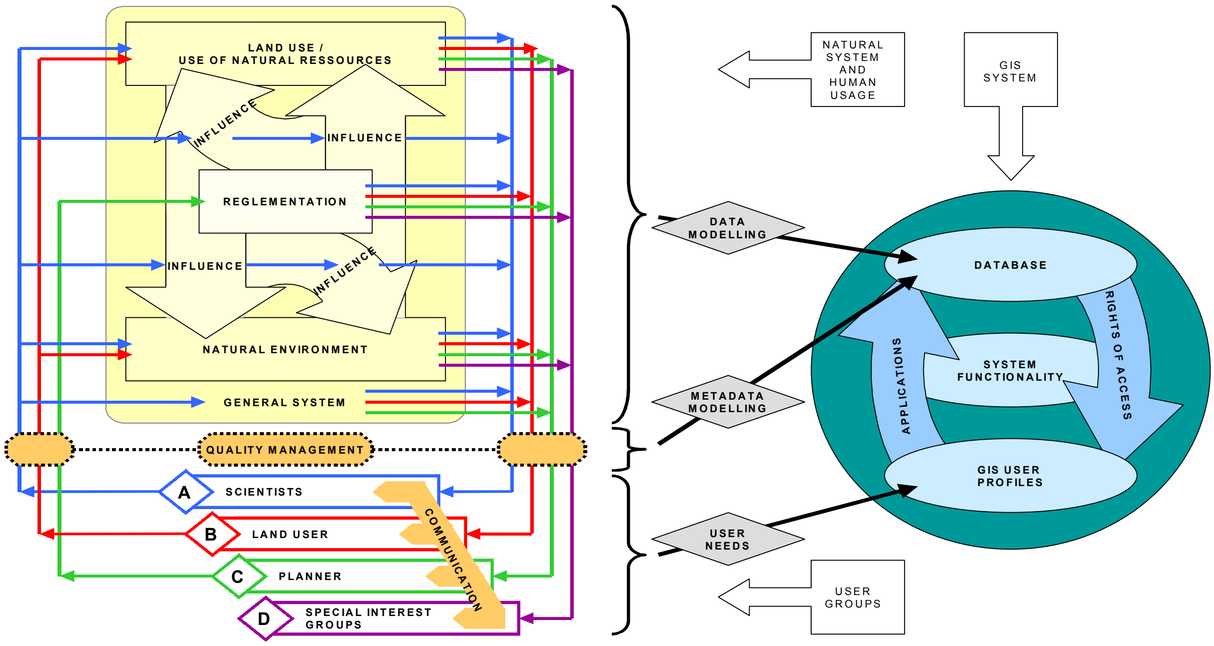


Figure 6: Problem view of water management (KATER)

The basic problem view developed and agreed upon in project KATER differentiates between the water system („general system), the users and the data model plus software developed to support the users in fulfilling their tasks (GIS system).

The scheme show clearly that a multidisciplinary approach has to be taken and this means in further consequence that the interfaces (between and within the general system, the users and the software) have to be clearly defined in order to allow for *communication* between all institutions.

1.2 Metadata definition and metadata management

Metadata are regarded as the main key for successful and lasting multidisciplinary work (eg. STREIT and BLUHM, 1998). They provide users with information about data availability and – even more important – about the possible use and usage restrictions of this data. This includes basic information about data (projections, attributes, paths and so on) but also information about data quality, which determines the possible level of detail of analysis and the depth of results of analysis. Thus the development of metadata have become an important step in most integrative research projects in the last years.

From the point of data quality, a main task in realising quality management is building up a consequent *metadata organisation*. These metadatasets which describe the content of the 'normal' datasets are the basis for further data processing and analysation.

As the basis of the metadata definition the internationally well known FGDC[2] standard was choosen and a database application built with MS ACCESS. This tool serves as the metadata management tool for all partners involved in the project. In order to minimize the effort of integrating data in the metadatabase (which improves update frequency and consistency of the metadatabase) and to maximize the potential use of the metadatabase the following additional decisions were taken:

- Metadata generation is automatised with the help of a GIS-based application, which feeds the metadata database directly from a GIS dataset with information such as the extent of the dataset, its outline, attribute data and attribute information, spatial organization (vector and raster data details) etc. For attribute data also the management of relationships with external tables is enabled.
- The metadata system is used not only for storing and querying metadata, but also as the main navigation mechanism of the software developed. Thus users do not have to interact directly with information about paths or data formats, but data

[1] A common terminology for central terms (vulnerability, hazard, risk) is being defined in COST620 action (www.lgih.ulg.ac.be/cost/index.htm)

[2] Federal Geographic Data Committee: defined a widely accepted and adopted standard for spatial metadata

access is provided via the metadata entries, which can be individually configured and categorised by application specific needs.

1.3 Integrate the effects of Land Use Activities

Starting from the results of efforts to enhance the scientific basis of water management and planning in the catchment areas of the Vienna waterworks (which includes data collection campaigns on vegetation (GRABHERR et al. 1999) and on hydrology (STADLER and STROBL 1997)) additional detailed data about land-use turned out to be of importance.

The basic steps for the integration of land-use effects were an

- evaluation of effects with regard to their influence on the water system and its vulnerability;
- an identification of possibilities / necessities for an implementation of land use information in vulnerability models;

Vulnerability as a basic concept may be defined dependent / independent of the kind of contaminant / human activity (general vulnerability vs. specific vulnerability).

The objectives of including land-use data were to

- identify potential influences (dangers) and to
- gain additional control possibilities.

Basic influence	*Physical*	*Bacterio-logical*	*Chemical*	*Radiological*
Intermediate	Vulnerability			
Target categories of effects	water quality + water quantity			

Table 4: Basic categories for evaluating land-use effects

When using this basic catgorization as a starting point it was further differentiated between *direct influences* (eg. contamination in bacteriological terms due to pasture) and *indirect influences* (increase of vulnerability due to soil changes as effect of overstocking by cattle). For the different land-use categories (or its subcategories, its up to the user to refine this categorization) thus the effects on the different levels can be identified and weighed (high / low weight; local / regional effect; short / medium / longterm effect):

LAND-USE	*Physical*	*Bacterio-logical*	*Chemical*	*Radiological*
Pasture	■	⊗		
Motorway (construction)	⊗	■	■	
Motorway (use)			⊗	
Tourism (skiing)	⊗	⊗	⊗	
+++				

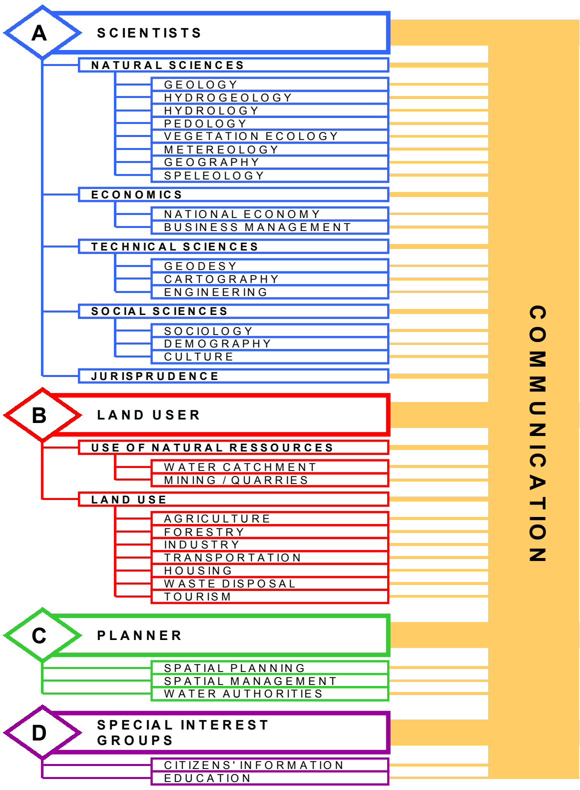
Table 5: Example of a detailed categorisation of land-use effects

1.4 User needs and system definition

The main objective of the development of the software application for KATER is to provide a basis for decisions to be taken on the ground of the existing data. The main characteristics of a Decision Support System (DSS) for sustainable water resources management include (FLÜGEL and STAUDENRAUSCH 1999)

- the flexibility for tackling various 'what-if?' scenarios,
- the facilitation of problem identification and solving by analytical tools enabling the end-user to manage, analyse and present information,
- interaction and ease of use to involve the stakeholders into the management process themselves.

1.4.1 User orientation



Concerning the most important user of such a GIS-based decision support system the situation in all participating countries (Austria, Italy, Croatia and Slovenia) is nearly the same: the water supplier – fulfilling the main tasks of water supply on the one hand and ground water protection on the other hand – is the main user.

The graphic on the left shows the GIS user groups identified. The listing in this graphic is comprehensive and does not imply a weighing of the users. Of course the most intensive users of the system to be developed are the water authorities with their different tasks in water management and those scientists providing background information and analysis to the water authorities.

Figure 7: User groups for GIS

In order to get an idea of the different needs of these heterogenous GIS user groups, it is necessary to define the main tasks of each user group. These tasks can be divided into

- administration,
- crisis management and
- planning activities.

A more detailed task List for the user 'Water Supplier' and ‚Water Protection' can be defined as follows:

Task category	Water supplier	Water protection
Administration	• monitoring of Discharge and Outlet (water quantity and water quality) • regulation of used amount of water	• Property Management • Monitoring of Land Use Activities • Monitoring of Natural Environment
Crisis management	• technical accidents • water contamination	• Elementary Natural Accident • Global Contamination • Local Contamination
Planning	• maintenance work • forecast of quantity and quality • analyses supply versus demand	Analyses concerning possible changes in interdependences: • Land Use with Water Balance • Natural environment with Water Balance

Table 6: Task lists for ‚water supplier' and ‚water protection'

This detailed analysis and categorisation of tasks can be done for each important user group and allows thus the tailoring of the software application (including the structuring of data access, the way of data presentation and the system functionality) to user needs.

Regarding the objectives of KATER project, the main goal is the development of a decision support system to handle the main tasks of water management: administration, crisis management and planning. But before starting the actual application development process, it was necessary to collect details about the actual workflow. A detailed analysis of the workflow gives on the one hand the possibility for optimisation of the workflow (avoiding duplicate work, etc.), on the other hand it is the basis for the conception of any support by tools like GIS.

The *workflow analysis* is based on lots of interviews, which have been made with different people working in the catchment area. These interviews were analysed and structured to many different work steps. Each of these steps contains information about the content of work, the function of the person being responsible for the work, the intervall of repetition, the location where the work is being carried out, the kind of information (analogous or digital data) being created within the work step and also the tools (electronic data processing, etc.) which are necessary to support this kind of work. This structurisation of work steps, which corresponds completely to the idea of ISO9000's total quality management, has been further analysed and evaluated.

With this information it was possible to work out some guidelines for an optimisation of the common workflow in the whole catchment area. This optimisation has to be seen as an objective, which has to be regarded at each time, when any new measure is taken which could have an influence on the existing workflow.

In addition this analysis is the basis for the creation of GIS concept, especially for the definition of user requirements to the system, that has to support their daily work and helps them to work more efficiently.

1.4.2 Ease of use

The ease of use of a software application is strongly dependent on the user interface. The user interface was built upon common windows standards and includes an

- explorer-like treeview (which allows navigation through data, detailed viewing of data and an overview of all documents available),
- content windows (maps with GIS functionality, tables with basic spreadsheet functionality, graphics and specialised forms)
- command menu and button bar for user interaction
- status bar for additional information about the documents used.

The example below shows a part of the hydrogeological map of the carstic areas in norther Styria, which was defined by using the explorer on the left hand side.

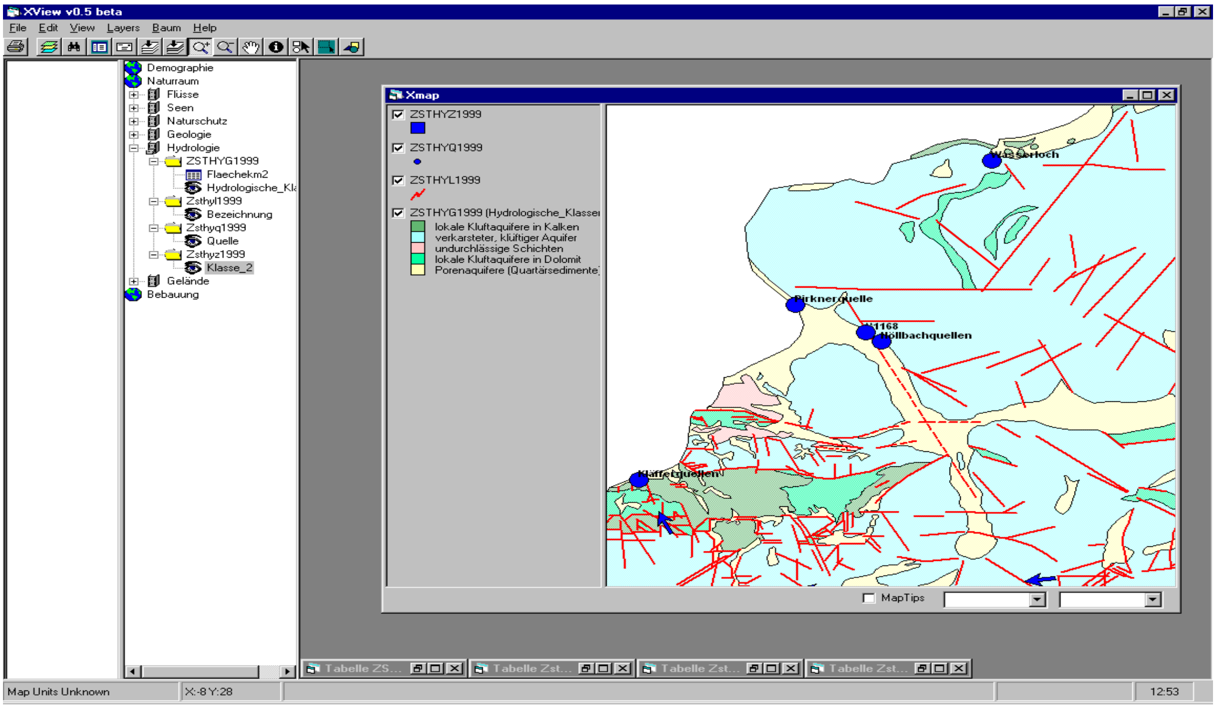


Figure 8: Example of KATER software application

The application allows the user to navigate the data by the treeview (which he is used to from his Operating System) as well as by spatially navigating the data or by using forms. All of the different types of document are specific views on the same data and are built on the same selection of data, so that different perspectives of the information available can easily be found.

1.4.3 Specialised information: the example of legislative / regulatory information

Concerning land use activities and the reglementaion of some of these activities by laws, contracts, etc. it is necessary for the water works at least to have an overview on these documents and above all their spatial connex. This is the reason, why the software application will include all relevant legislative information, collected in and implemented in a GIS database.

Therefore many hundreds of documents that are stored in the archive of the water works will have to be catalogued with regard to various aspects: content, persons or institutions involved, various time related aspects, the spatial reference, etc. When operationally implemented this GIS-based application will support different departments of the water works giving an overview as well as detailed information to many different legislative aspects.

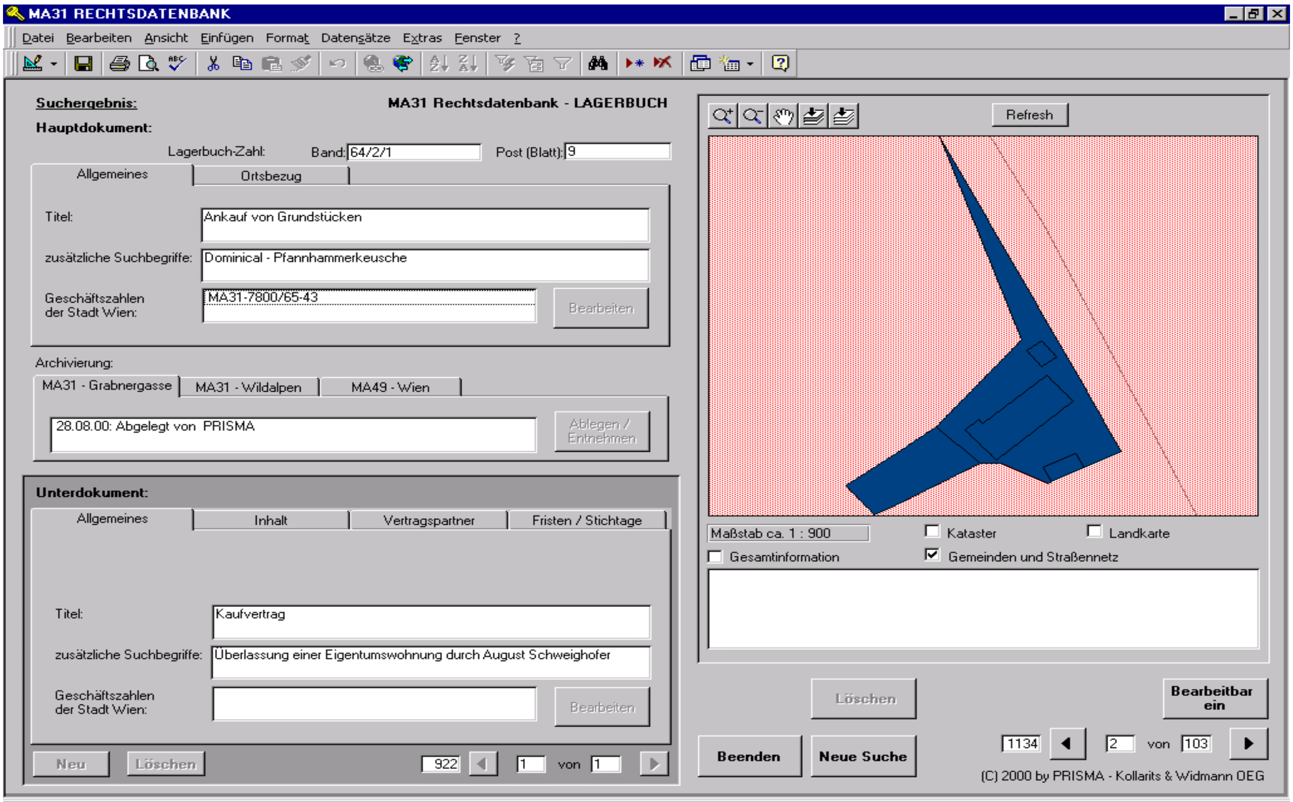


Figure 9: Example of the GIS-based regulation management system

1.5 Summary and outlook

The discussion above and the experiences of many transnational and international projects allow to define a list of basic steps how to proceed in the development of a water management system. This list is by no means complete and it has to be considered that it still includes desiderata, which have not yet been delivered by the scientific community.

- A common language, to integrate the views on water issues of the diverse actors in the water management process, including scientific disciplines (eg. hydrology), water authorities, planners and economists as well as people from technological discisplines (information processing...)
- Metadata have been proven to be of highest priority to make the results of any project and data collection process usable. The metadata issue is in many respects directly related to point a).
- A multi-disciplinary approach has to be taken, to integrate the heterogenous problem views of scientists, water authorities, technicians and users.
- Decision support systems have to be simple in use but allow to integrate a wide range of data (of very heterogenous data quality) and presentation facilities.

The steps shown above do fulfill some of the tasks which are necessary in water supply and water protection. But for more detailed analyses and an in-depth understanding of the underlying processes further steps will be taken:

- spring monitoring concept;
- further measurement campaigns in order to collect additional information about certain contaminants, like bacteriological contaminants;
- measurement database with online-integration in the software application;
- vulnerability model of carstic aquifers; for this purpose a flow-chart model will be developed, which allows for easy parametrization of the model and easy extension of the model with new / enhanced data sets and model functions. The models available and used differ by country in Europe and include EPIK (Switzerland; GOGU et a. 1996; STADLER 2000) and SINTAX (Italy; CIVITA and De MAIO 1997.). These models will serve as examples and will be directly used by some of the project partners and adopted by others.

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