Introduction

The collection of hydrologic data both, quantitative as well as qualitative data sets, for surface water and for groundwater systems involves several procedures such as data recording, acquisition, storage, and data transmission. In general networks of water data concern all open freshwater bodies which are in direct contact with the atmosphere: rivers, lakes and reservoirs.

Monitoring water systems is most important where the amount of water is not excessive. And, as a direct consequence, this also affects the water quality. But also where water is available at an adequate amount, which is the fact for most parts of Central Europe, it is essential to look on monitoring techniques and methods and to work out plans for a future improvement of such techniques. Through monitoring land managers can determine how well an activity is meeting resource management objectives, for example the protection of drinking water or other beneficial uses.

The main reason for the assessment of the quality of the aquatic environment has been, traditionally, the need to verify whether the observed water quality is suitable for intended uses. The use of monitoring has also evolved to determine trends in the quality of the aquatic environment and how it is affected by the release of contaminants, anthropogenic activities, and waste treatment operations. More recently monitoring has been undertaken to estimate nutrient or pollutant fluxes discharged by rivers or groundwaters to lakes and oceans.

General definitions for various types of environmental observations have been proposed (after: Chapman, 1992):

Water Quality	**Definition**
Monitoring	Long-term, standardised measurement, observation, evaluation and reporting of the aquatic environment in order to define status and trends.
Survey	A finite duration, intensive programme to measure, evaluate and report the quality of the aquatic environment for a specific purpose.
Surveillance	Continuous, specific measurement, observation and reporting for the purpose of water quality management and operational activities.

Monitoring, survey and surveillance are all based on data collection, evaluation, and reporting where data are principally collected at a given site of the water body. Monitoring data must also be characterised and recorded with regard to time at which the sample has been taken. It also requires the knowledge of water discharge in streams and flow situations in groundwater bodies. Therefore, monitoring data must provide an

definite determination of these parameters in order to be used for data interpretation and further water quality assessment.

The following types of monitoring can be defined (after: MacDonald et al., 1991):

- Trend Monitoring:

Measurements are made at regular, well-spaced time intervals in order to determine the long-term trend in a particular parameter.

- Baseline Monitoring:

Use to characterise existing water quality conditions, and to establish a database for planning or future comparisons.

- Implementation Monitoring:

Assesses whether activities were carried out as planned.

- Effectiveness Monitoring:

Is used to evaluate whether the specified activities had the desired effect.

- Project Monitoring:

Assesses the impact of a particular activity or project.

- Validation Monitoring:

Is dealing with the quantitative evaluation of a proposed water quality model to predict a particular water quality parameter.

- Compliance Monitoring:

Used to determine whether specified water-quality criteria are being met.

In Table 1 a broad classification of monitoring types according to the parameters being measured, the frequency of monitoring, the duration of monitoring, and the intensity of data analysis is given.

Table 1 Table 1: General characteristics of monitoring types (after: MacDonald et al., 1991).

Type of monitoring	Number and type of water quality parameters	Frequency of measurements	Duration of monitoring	Intensity of data analysis
Trend	Usually water column	Low	Long	Low to moderate
Baseline	Variable	Low	Short to medium	Low to moderate
Implementation	None	Variable	Duration of project	Low
Effectiveness	Near activity	Medium to high	Usually short to medium	Medium
Project	Variable	Medium to high	>Project duration	Medium
Validation	Few	High	Usually medium to long	High
Compliance	Few	Variable	Dependent on project	Moderate to high

Water level monitoring as such is of great interest considering navigational aspects flood warning of river systems. Because surface water profiles show more variation along the river than the discharge, the network for water levels should be more dense than the discharge network. Because in most cases the discharges are derived from rating curves, the discharge network can easily be integrated in the water level network.

In general water level network data should be gathered at specific sites, for instance at:

- inflows of important tributaries,
- branching points of rivers,
- at inflows of a river (into a lake, reservoir or the sea),
- upstream and downstream of weirs and sluices.

Political and organisational aspects may also play a role in choosing the site for a measuring station, for instance at international boarder crossings or at important cities.

The transfer of data from gauged to non-gauged stations can be realised by interpolation or hydraulical computations considering pure mathematical interpolation, interpolation based upon statistical considerations or by the use of physical models.

Networks of river discharges can have a lower density than those for water levels. Values at non-gauged intermediate sites can be reconstructed with adequate accuracy like the values for the water level.

Finally, social as well economic aspects do have considerable influences on the design of hydrological networks. In fact most of these aspects can be reduced to the question in

how far a society and its policy makers are willing to do investments and efforts in order to realise a network. This, at its turn, is related to the value that is attached to the information about the hydrological phenomena.

Although water is essential for life, public as well as policy makers do not always realise the need of any numerical information on water resources. Very often expenses for health care or food production are favoured even detailed information about water and water resources are the basis for any other production or existence.

The discharge of a river is the single most important measurement that can be made because it provides a direct measure of water quantity and hence the availability of water. It allows for the calculation of loads of specific water quality variables, it characterises the origins of many water quality variables by the relationship between concentrations and discharge and it provides the basis for understanding river basin processes and is essential for interpreting and understanding water quality. Therefore there is a direct link between water quantity and quality monitoring.

River systems itself represent the dynamic flow of drainage water, which is the final product of surface runoff, infiltration to groundwater and groundwater discharge. From Figure 1 the general relationships between these and the importance of river transects when monitoring river stage and -discharge can be seen.

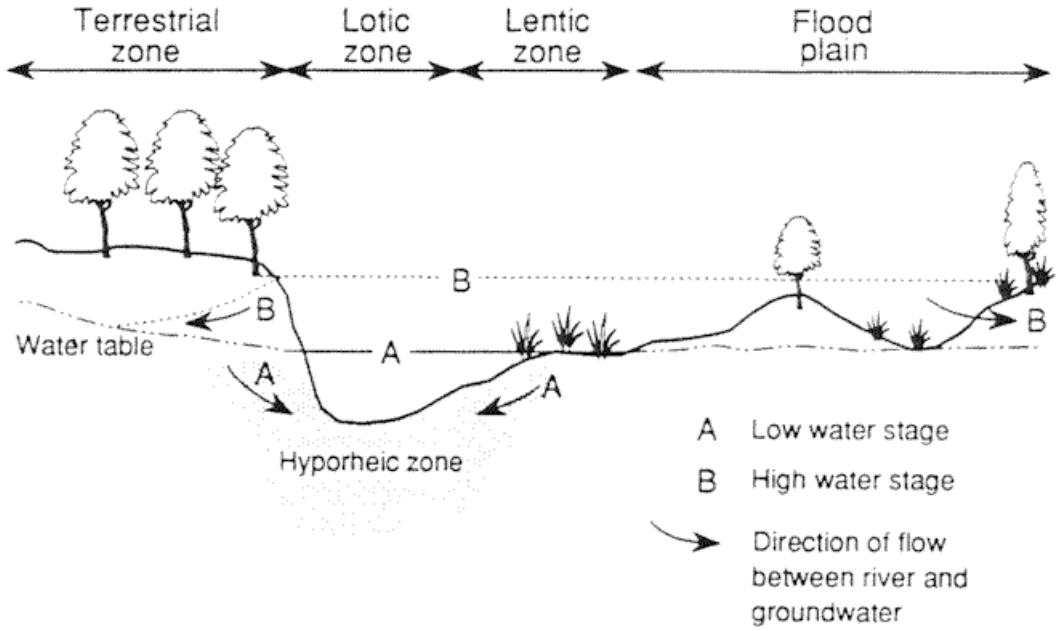

Figure 1: Generalised cross section of a river showing the relationship between physical features and the low and high water stages (after: Chapman, 1992).

Technical Review Overview

The symposium was opened by the presentation of fourteen different country papers of all *EurAqua*-members attending the Second Technical Review, October 18-20, 1995, Paris, titled "Optimizing Freshwater Data Monitoring Networks including Links with Modeling".

The workshop itself was separated into two different sessions where both were divided into two subtopics individually chaired by the Chairmen and Rapporteurs:

Part 1: Groundwater quantity and -quality monitoring

Sub-topic 1:	Aspects of regionalisation and upscaling from measuring stations to regional scales
Chairman:	H. Henriksen, Denmark
Rapporteur:	Frans C. van Geer, The Netherlands
Sub-topic 2:	Identification and development of monitoring techniques
Chairman:	A. Van der Beken, Belgium
Rapporteur:	J. Fejes, Sweden

Part 2: Surface **water quantity and -quality monitoring**

Sub-topic 1:	Optimization Techniques for monitoring networks
Chairman:	M. Lees ,United Kingdom
Rapporteur:	P. Givone, France
Sub-topic 2:	Legislative framework for monitoring networks
Chairman:	Marcello Benedini, Italy
Rapporteur:	Nils Roar Sælthun, Norway.

The country paper presentations together with the results of the workshops lead to the summary and *EurAqua* position on the topic monitoring networks for surface and groundwater systems which are outlined at the end of this chapter.

WORKSHOP 1: Groundwater quantity and -quality monitoring

Sub-topic 1: Aspects of regionalization and upscaling from measuring stations to regional scales.

Chairmen: H. Henriksen, Danish Geological Survey, Denmark

Rapporteur: Frans C. van Geer, TNO, The Netherlands

The underlying question during the workshop was "how can we assess the representativeness of individual measurements in respect to the objectives, both in space and time. For network design this representativeness has to be quantified in order to define criteria on which networks can be designed.

Representativeness is closely related to two types of scales: 1 the process scale, giving the dominant scales of the groundwater process, and 2 the management scale, giving the scales on which water management is performed. The network should provide information on the management scale. It should be possible to filter out all relevant process scales. The scale on which measurements are collected could be called the measurement scale. This scale, dependent on measurement support, network density and observation frequency, is within certain boundaries, the only scale that can be chosen.

In this framework of scales, we can identify four major points of research, that could benefit from a joint European approach.

1. Monitoring related to objectives and strategic levels of interest.
2. Regional (large scale) monitoring of groundwater systems
3. Local scale monitoring of flow systems
4. Pilot areas, in particular for the unsaturated zone.

1. Monitoring related to objectives and strategic levels of interest.

Problem description

On a strategic level management objectives are defined in rather global terms. Such objectives can be for example: "to follow the salt water intrusion", "to detect a global trend", or " to evaluate the effect of protection measures". Data from monitoring networks should provide information to support management decisions. The problem is that from the management objective it is not obvious what the minimum information is that is needed, In other words the management objectives should be translated into quantifiable monitoring objectives.

Research goal

The corresponding research goal is to make a European inventory of types of management objectives on a strategic level and to provide guidelines to translate those management objectives into quantifiable monitoring objectives.

2. Regional (large scale) monitoring of groundwater systems

Problem description

On a regional scale often the network serves to provide general information about the behaviour of the groundwater system. For instance, one would like to evaluate reference values for groundwater quality parameters, including insight into the changes in time. In order to do this in an efficient way, information about the complete system is needed. In practice, however, all different variables (levels, quality parameters, groundwater recharge, vulnerability, land use, etc) are measured separately.

Research goal

To provide guidelines and methods for efficient monitoring of large scale groundwater systems, integrating all relevant sources of information.

3. Local scale monitoring of flow systems

Problem description

In many cases throughout Europe protection zones are defined on a local scale. These zones can be meant to protect a pumping well for water supply from getting polluted. The opposite case is a zone around a polluted spot to provide the environment from getting polluted. In both cases monitoring systems are installed, but there is no full prove method to assess the risk of a pollutant crossing the boundary.

Research goal

To provide guidelines and methods to optimally design monitoring networks around protection zones, such that it can be assured that pollutants are not crossing the boundary up to a given level of confidence.

4. Pilot areas, in particular for the unsaturated zone.

Problem description

For certain types of variables it is very hard or even impossible to obtain information on a regional or national level. Yet it can be very relevant to have that information for the management objectives. A clear example of this is the recharge of groundwater via the unsaturated zone. Scattered around Europe there might be a number of Pilot areas, where this type of variables is monitored and studied in detail. However, the use of the information from these pilot areas is very limited and no guarantee can be given that the monitoring programs are permanent.

Research goal

The research goals can be divided into the following steps:

1. Inventory of relevant pilot areas in Europe, including a classification of the type of area,
2. Inventory of the representativeness of existing pilot areas for Europe, and defining area types that are not covered by the existing pilot areas
3. Feasibility study for a structure of data exchange and (if yes) developing a set-up for such a structure.

WORKSHOP 1:Groundwater quantity and -quality monitoring

Sub-topic 2: Identification and development of monitoring techniques

Chairman: A. Van der Beken, VUB-IUPWARE, Belgium

Rapporteur: J. Fejes, IVL, Sweden

Topics discussed, conclusions and recommendations

The following two sections were used to set the definitions and goals of the topic that should be discussed.

Definitions of monitoring techniques

1. Instruments/equipments

For sampling, including drilling and geological/soil characterisation.

In-situ measurement/research site

2. Software and management

Network design, monitoring methodologies, operational procedures including (i) data quality control, (ii) storage/handling and (iii) analysis, and applications.

Why (in a European perspective) should we identify and develop new technology?

for harmonisation, exchange of data

for common policies (=DG XI: prevention etc.)

for pooling of expertise, dissemination and demonstration

for marketing for better cost/benefit

for promoting innovations and new technologies - transfer of knowledge from other disciplines or towards other disciplines

Identification of problems and development of new technology needed to fulfil the objectives mentioned in the previous section.

Instruments/equipment

Drilling

Commercial drilling is not enough encouraged to make properly records during drilling. Examples of this were that the bottom of the aquifer very rarely is defined and that effects of salinity intrusion is not always correctly handled.

Recommendation

Enhance code of good practice and specification for drilling and installation activities and network design and selection.

Sampling techniques

The need for more effective and less time consuming sampling techniques was stressed. The development of new in-situ sensors are proposed in DGXII projects which probably will be funded.

Recommendation

Follow-up the outcome of the DGXII projects. These new techniques should be compared with conventional techniques in pilot sites and in laboratories. These pilot sites and laboratories could be proposed as large installations under TMR.

There is also a need for assessing connectivity and storage capacity in fractured aquifers.

Recommendation

Enhance the research on the use of multi-dicipline (srtuctured geology, hydrology, landuse etc.) techniques in resource assessments for fractured aquifers.

Analytical methods

The available methods for determine the age between 50 and 500 years has to large discrepancy.

Recommendation

Develop more accurate methods for determination of age between 50-500 years.

Dispersion models

It was concluded that it is still to complicated to use dispersion models for monitoring purpose. The first step to understand this process could be reached by harmonising the protocols for studies of anisotropy and dispersion within Europe.

Recommendation

Enhance research on development of protocols for studying anisotropy and dispersion

Indicators

The use of indicators for assessing the water quality could offer new opportunities for monitoring.

Recommendation

Enhance development of isotopes and biological indicators for different types of pollution.

Software and management

Geostatistics contra traditional methods

The gap between geostatistics and traditional methods in network design was stressed. We all believe that this gap should be over bridged to increase the quality and cost benefit of monitoring networks.

Recommendation 1

Enhance the use of simulation/optimisation and decision support models to optimising networks.

Recommendation 2

Support development of methods for "intelligent" selection of monitoring stations considering surface/sub-surface processes, especially in ground water discharge areas.

Data management

Integration of monitoring network for surface and ground water will increase the ability to assess the processes that affects the water quality and quantity. Integration should not be limited to network design and sampling methods, but also involve data management.

Recommendation 1

Support research that would enhance the integration of data management for surface and ground water with appropriate monitoring frequencies.

Recommendation 2

Enhance the harmonisation of data protocols for analysis and capture with respect to different local conditions. The harmonisation include processes that supports storage of data together with geographic information.

Recommendation 3

Enhance procedures that increase the compatibility of data files and hardware/software.

Recommendation 4

Support development of specific application programmes in "groupware" for data handling of surface and ground water monitoring and management.

Models

Since all agree that it is very difficult to use models for assessing chemical fates in aquifers, we concluded that models could be used in small pilot areas were the model could be verified.

Recommendation

Support research on chemical fate models for small well defined pilot areas.

WORKSHOP 2: Surface water quantity and -quality monitoring

Sub-topic 1:Optimization Techniques for monitoring networks

(Summary by *EurAqua*-Secretariat)

Chairman: M. Lees, IH, UK

Rapporteur: P. Givone, Cemagref, France

The principal and fundamental key-questions for this session, which were outlined by M. Lees, can be summarized as follows:

* What do we need to measure?

* Where should measurements be made? (Network density, distribution criteria)

* Which sampling frequency should be perceived?

* Who are the users? (Potential users vs. policy issues).

An input to this was made by P. Reiniger questioning also any future users: The EU-Commission could give at present standards on quantity, not on quality issues.

In the following discussion was aimed to three different topics:

* Harmonisation of data sampling methods.

* Harmonisation of data storage methods.

* Harmonisation of data access methods.

Another item being discussed in this context was the point how easily are data avaialbale to end-users? Additional the cost/benefit factor cannot be neglected and the question "Who pays and who has benefit"? is getting an important issue. However, there are multiple users of existing networks.

In the follwoing the discussing was aiming at surface water quantity data and the following points were mentioned:

* Transboundaries

* Mass loads

* Floodings risk and

* Resource Assessment.

The research priorities which were named to be of importance should be aiming at surface water quantity issues. Regarding the topic floods new measuring techniques must be investigated and new

models to be developed. Monitoring should inform environmental objectives and tracing chemical and biological species.

The term "bio-diversity" (biological diversity) was discussed in more detail and thought to be of high importance in this field, too.

WORKSHOP 2: Surface water quantity and -quality monitoring

Sub-topic 2:Legislative framework for monitoring networks

Chairman: Marcello Benedini, IRSA, Italy

Rapporteur: Nils Roar Sælthun, NIVA, Norway

1. The workshop was structured according to the following agenda:

- To what extent does legislation influence actual monitoring?
- What level and degree of specification are desirable?
- Institutional aspects;
- Conclusions and recommendations.

2. Points from the discussion

The participants pointed to the importance of international agreements for as setting frameworks for monitoring activities, and also as to influence national legislation. Legislation should not enter into much detail as concerns the practical aspects of monitoring, but should act primarily as a framework for the monitoring activities. To much detail can easily hamper technical innovation. It is important that legislation considers and specifies the responsibilities on different administrative levels. In many cases a multi-tier system, with regional bodies responsible for monitoring and data collection, and a central institution responsible for standards, data exchange, etc., can be an efficient structure.

The institutional structure should be such that high standards of monitoring and data analysis are ensured, including data dissemination and use of data for scientific purposes. Training is an important issue to maintain high levels of qualifications in the monitoring institutions and the laboratories. The present trend to subcontract monitoring and other operational functions, may undermine the qualification levels if training and education are not given proper consideration. Research institutions have an important function in the training system, and have a central position in innovation of methodology.

As a rule, data from monitoring networks should be easily accessible, both by the public and research institutions. The basic data should be free of charge or subject only to handling fees. This important principle should in general apply to all types of environmental monitoring data.

3. Legislation and monitoring

3.1 To what extent does legislation influence monitoring?

Although the level and detail of legislation concerning monitoring activities vary greatly from country to country, it certainly strongly influences the design and operation of monitoring networks.

Conclusions:

- The level and detail of legislation varies greatly from country to country;
- In several countries general monitoring is not directly addressed or covered by legislation, but designed and operated on the discretion of the responsible institutions;
- International agreements can have a strong impact on national monitoring activities.

Recommendations:

None

3.2 To what degree should legislation give specification of monitoring activities?

Conclusions:

- Technical detail and specifications stated in law can hamper innovation and development;
- Monitoring activities, especially national networks on background environmental information that are not mandatory by legislation, are vulnerable to financial cutbacks.

Recommendations:

a) Legislation should cover the need for general monitoring networks;

b) Legislation (at "Act" level)should not be too specific on technical aspects, but give a framework for monitoring activities;

c) Standards and specifications can be given as directives on Ministerial level;

d) The government should seek expert advice, nationally and internationally, before deciding on legislation on these matters;

e) The aforementioned points do also apply to EU Directives and other international agreements.

3.3 Licensees and monitoring

The workshop did not discuss issues that concern licensing procedures, but observed:

- There is precedence in some of the member countries for instructing licensees to contribute to ambient monitoring;
- As pollution adds to the need for and complexity of general monitoring, it can be considered fair that licensees contribute to ambient monitoring;
- This contribution can be direct, through running parts of the (local) network, or direct, through fees or financial contributions to the general network.

Recommendations:

a) It can be an acceptable situation that licensees/polluters contribute to general ambient monitoring;

b) Such arrangements should not adversely influence the design and structure of the general network;

c) The institution responsible for monitoring should have full access to all relevant data.

4. Institutional aspects

4.1 Should monitoring and licensing be carried out by the same institution?

It may be practical that the same institution is responsible for monitoring and licensing, but it can also easily cause bias in the priorities for data collection.

Recommendation:

If the same institution is responsible for monitoring and licensing, the responsibilities for these activities should belong to different departments.

4.2 Should water quality and water quantity be handled by the same institution?

It is advantageous, but not always possible, to have these activities within one organisation.

Recommendation:

If responsibilities for water quality and quantity are allocated to separate institutions, then it is imperative that the co-operation is a close as possible.

4.3 Regional/central organisation

It is often practical and efficient to have a decentralised, regional system for monitoring, data collection, and data dissemination.

Recommendation:

If monitoring and data collection is decentralised, it is necessary to have some central organisation responsible for:

- methodology
- standards
- compatibility of data storage and data exchange formats

and similar functions. There must be an obligation for all parties to follow these guidelines/directives.

4.4 International reporting

Today a lack of co-ordination is evident in the request for data from international organisations.

Recommendation:

International organisations are advised to:

- scrutinise their need for own data storage;
- co-ordinate their data collection;
- standardise their data collection formats.

4.5 Standards/quality assurance/training

The workshop discussed this topic in light of the need for international exchange of data, the tendency to subcontract monitoring, and other relevant issues.

Recommendations:

d) The institution responsible for monitoring is also responsible for implementing QA and training schemes;

e) QA should be implemented on the whole data collection system, not only on laboratory work;

f) Research institutes have an important role in developing standards, methodology, etc.

5. Access to monitoring data; pricing

The workshop discussed the access to monitoring data, and concluded that easy and free access to such data is vital for efficient use of the data in an operational context and in research. It is also a very important factor for ensuring the confidence in monitoring institutions by the public.

Recommendations:

g) As a general principle, data from monitoring networks, both on ambient and effluent monitoring, should be freely accessible to the public;

h) There may be exceptions to this rule caused by competative considerations for licensees, privacy legislation, endangered species situations etc.;

i) Handling fees may be charged;

j) The rule (of free access) applies to basic data, not necessarily "added value" data;

k) The rule should be applied not only to water data, but to all environmental monitoring networks.

The *EurAqua* position - research priorities

Within the plenary discussions the results of all workshops have been outlined as summarized in the preceeding pages. After the presentation of the results of each workshop by the Rapporteurs, the discussion has been conveyed.

The group adopted the following issues to be of high importance for the requirements of the design of hydrological networks:

* Inventory of relevant pilot areas in Europe, including a classification of the type of area combined with an index of the representativeness of existing pilot areas for Europe, and defining area types that are not covered by the existing pilot areas.

* Decision Support Systems (DSS) as analytical tools for assisting the operational management of network systems were named to be of high significance.

* Considerable concern should be directed to the coordination between water quantity and quality monitoring programmes.

* The realization of the Pulluter-Pays-Principle (PPP) would have an intense impact on the design of water-quality networks. However, even if considerable concepts do exist in various countries the transformation to the EU-level might be difficult.

* The creation of new data bases (observation points) was not thought of being attainable as this could lead to a reduction of information. However, a feasibility study for a structure of data exchange and developing a set-up for such a structure was recommended.