Guidelines for the Monitoring and Assessment of Transboundary and International Lakes

Part A: Strategy document

UN/ECE Working Group on Monitoring & Assessment (WGMA)

Helsinki 2002

FOREWORD

Between 1996 and 2000, the UN/ECE Working Group on Monitoring and Assessment (WGMA) prepared two separate publications: Guidelines for Transboundary Rivers (1996, new edition 2000), and Guidelines for Transboundary Groundwaters (2000). Both sets of guidelines were largely strategic, and technical details were not fully elaborated. These Guidelines for the Monitoring and Assessment of Transboundary and International Lakes have been structured differently, and are divided into two parts. Part A consists of a strategy document, while Part B contains more detailed technical guidelines. The strategy document is broadly designed to be used in the same contexts as the other technical guidelines prepared by the WGMA (for rivers, estuaries and groundwaters).

These guidelines for lakes have been prepared by a Core Group from Finland, assisted by experts from several other European countries.

- **Part A, the Strategy document,** is primarily based on existing monitoring obligations under the Convention on the Protection and Use of Transboundary Watercourses and International Lakes (signed in Helsinki, 17 March 1992; enforced by the UN in 1994), and the Protocol on Water and Health in the 1992 Convention on the Protection and Use of Transboundary Watercourses and International Lakes (London, 17 June 1999; UN enforcement 1999). The scope of the strategy document is limited to strategic issues. It is intended that this document could also be suitably modified to form the basis for future common UN/ECE strategy documents covering the monitoring and assessment of transboundary watercourses, international lakes, and transboundary groundwaters. However, such documents would have be carefully drafted to ensure they also fully incorporate the mandates and programmes of other institutions. It is intended that this strategy will remain valid for a longer period than previous strategies, e.g. for ten years.
- **Part B, Technical guidelines**, contains the necessary practical guidelines for the monitoring and assessment of lakes and reservoirs. These guidelines are based on widely-accepted hydrological and limnological lake monitoring practices. There is clearly a need to harmonise monitoring programmes in Europe, for both economical and practical reasons. The economic reality is that individual countries do not have sufficient resources to maintain simultaneous monitoring programmes with differing contents. Moreover, data handling and reporting practices must be as near identical as possible for various user-organisations (EU, EEA, UN/ECE, EUROSTAT, etc.). The recommendations of the EEA's Eurowaternet and the requirements of various EU water directives, especially the Water Framework Directive (Dec. 2000), have therefore been followed as closely as possible here. Specific technical guidelines should be tested in special pilot projects, while consideration must also be given to draft guidelines on monitoring currently being prepared by the EU expert group (chaired by Italy; deadline end 2002).

The strategy document is divided into six chapters. Chapter 1 sets out the background for the monitoring and assessment work, including the relevant EU legislation. Chapter 2 specifies the types of information that must be obtained through the monitoring work, underlining the importance of detailed information on entire drainage basins and river basin management issues. Chapter 3 presents more specific monitoring and assessment strategies. Data and quality management issues are discussed in Chapter 4; while Chapter 5 covers reporting procedures, and Chapter 6 outlines co-ordination and institutional issues.

The structure of the strategy document is similar to the format of the previously published UN/ECE monitoring and assessment guidelines prepared by the WGMA. It has indeed been possible to adopt some key sections of this document from the recent Guidelines for Transboundary Rivers (2000) with very few alterations. Most of the diagrams included here were similarly presented in the earlier guidelines. These guidelines for lakes differ most significantly from those for rivers and groundwaters in that the more detailed technical guidelines are set out separately in Part B.

This strategy is based on the ecosystem approach to water management. Consequently, the strategy concerns the entire hydrological systems of catchment areas, including the various components of the aquatic and riparian ecosystems they support.

A very wide range of factors are involved in the complex interrelationships between the economic uses and ecological functioning of any body of water. The state of a water body and its related ecosystem must therefore be assessed in an integrated manner, based on criteria including the quantity and quality of the water with regard to different uses, and the presence of different organisms. Reliable information on flow regimes, water levels, mass balance derivations, the sources and fate of pollutants, water quality, habitats and biological communities should all be systematically analysed and assessed.

A background paper containing monitoring data from 21 transboundary or international lakes has been prepared in conjunction with the drafting of these Guidelines for the Monitoring and Assessment of Transboundary and International Lakes.

Both the guidelines and the background paper were approved at a meeting of the UN/ECE Working Group on Monitoring and Assessment in Vääksy, Finland, September 5 – 8, 2001.

The Finnish Core Group:

- Pertti Heinonen, Finnish Environment Institute (pertti.heinonen@ymparisto.fi)
- Sirpa Herve, Central Finland Regional Environment Centre (sirpa.herve@ymparisto.fi)
- Olli-Pekka Pietiläinen, Finnish Environment Institute (olli-pekka.pietilainen@ymparisto.fi)
- Markku Puupponen, Finnish Environment Institute (markku.puupponen@ymparisto.fi)
- Olavi Sandman, Etelä-Savo Regional Environment Centre (olavi.sandman@ymparisto.fi)
- Markku Viljanen, University of Joensuu (markku.viljanen@joensuu.fi)

Assisted by:

- Tiina Noges, Estonia (tnoges@zbi.ee)
- Miklós Pannonhalmi, Hungary (pannonhalmi.miklos@eduvizig.hu)
- Rui Rodrigues, Portugal (rrr@inag.pt)
- Hanna Soszka, Poland (hasoszka@ios.edu.pl)
- Ülo Sults, Estonia (Ylo@tkku.ee)

Contents of Part A

1 BACKGROUND

1.1 The ECE Water Convention

The Convention on the Protection and Use of Transboundary Watercourses and International Lakes was drawn up under the auspices of the Economic Commission for Europe, and adopted at Helsinki on 17 March 1992 (United Nations, 1992). This Convention is the most essential legal instrument covering the monitoring and assessment of transboundary waters and international lakes. Several bilateral or multilateral agreements between different European countries are based on the Convention.

The Convention is intended to strengthen local, national and regional measures concerned with the protection and ecologically sustainable use of transboundary surface waters and groundwaters. All parties are particularly obliged to prevent, control and reduce the pollution of transboundary waters with hazardous substances, nutrients, bacteria and viruses. The precautionary principle and the polluter-pays principle have been recognised as guiding principles in the implementation of such measures, together with the requirement that water management should meet the needs of the present generation without compromising the ability of future generations to meet their own needs.

To prevent, control and reduce transboundary impacts, emission limits for discharges from point sources are to be based on the best available technology. Parties to the Convention are also required to control waste-water discharges, to adopt water-quality objectives and to meet certain standards for the treatment of municipal waste-water using biological or other suitable equivalent processes. Parties must also develop and implement best environmental practices to reduce inputs of nutrients and hazardous substances from agriculture and other diffuse sources.

Parties bordering the same transboundary waters are obliged to conclude specific bilateral or multilateral agreements providing for the establishment of joint bodies. They are also required to consult each other on any measures to be carried out under the Convention, to jointly set water-quality objectives, to develop concerted action programmes, and to provide mutual assistance in critical situations.

The Convention therefore addresses issues such as monitoring, assessment, warning systems, and the exchange and presentation of information. Parties bordering the same transboundary waters must set up joint or co-ordinated systems for monitoring, as well as joint or co-ordinated communication, warning and alarm systems. A primary objective of monitoring and assessment systems is to check that changes in the conditions of transboundary waters caused by human activity do not lead to any significant adverse effects on flora and fauna, human health and safety, soils, climatic conditions, heritage landscapes or physical structures, or the interaction between any of these factors.

As stated in Article 9 of the Convention, joint bodies are to be responsible for carrying out the following major tasks:

1. Joint bodies shall collect, compile and evaluate data in order to identify pollution sources likely to cause transboundary impact (paragraph 2a).
2. Joint bodies shall elaborate joint monitoring programmes concerning water quality and quantity (paragraph 2b).
3. Joint bodies shall draw up inventories and exchange information on the pollution sources (paragraph 2c).
4. Joint bodies shall elaborate emission limits for waste-water (paragraph 2d).
5. Joint bodies shall evaluate the effectiveness of control programmes (paragraph 2d).
6. Joint bodies shall elaborate joint water-quality objectives and criteria, and propose relevant measures for maintaining and, where necessary, improving the existing water quality (paragraph 2e).
7. Joint bodies shall develop concerted action programmes for the reduction of pollution loads from both point sources (e.g. municipal and industrial sources) and diffuse sources (particularly from agriculture) (paragraph 2f).
8. Joint bodies shall establish warning and alarm procedures (paragraph 2g).

9. Joint bodies shall serve as a forum for the exchange of information on existing and planned uses of water and related installations that are likely to cause transboundary impact (paragraph 2h).
10. Joint bodies shall promote cooperation and exchange of information on the best available technology and encourage cooperation in scientific research programmes (paragraph 2i).
11. Joint bodies shall participate in the implementation of environmental impact assessments relating to transboundary waters, in accordance with appropriate international regulations (paragraph 2j).
12. Joint bodies shall invite joint bodies, established by coastal States for the protection of the marine environment directly affected by transboundary impact, to cooperate in order to harmonise their work and to prevent, control and reduce the transboundary impact (paragraph 4).
13. Where two or more joint bodies exist in the same catchment area, they shall endeavour to co-ordinate their activities in order to strengthen the prevention, control and reduction of transboundary impact within that catchment area (paragraph 5).

The Convention includes a number of provisions on monitoring and assessment which call for joint action. These provisions cover consultations between Riparian Parties (Article 10), joint monitoring and assessment (Article 11), the exchange of information between Riparian Parties (Article 13), warning and alarm systems (Article 14), and public information (Article 16).

1.2 The UN Protocol on Water and Health

Another essential basis for monitoring and assessment activity related to transboundary waters and international lakes is the Protocol on Water and Health (United Nations, 1999). This Protocol aims to establish effective systems for monitoring and assessing situations likely to result in outbreaks or incidents of water-related disease, along with suitable response and prevention procedures. This will include inventories of pollution sources, high-risk area surveys regarding microbiological contamination and toxic substances, and reporting on water-related diseases. Parties to the Protocol will also develop integrated information systems covering long-term trends in water and health, focusing on both current concerns and past problems and their successful solutions, also ensuring that such information is provided to the relevant authorities. Moreover, comprehensive national and local early-warning systems are to be established, improved or maintained.

The provisions of the Protocol on Water and Health that most affect monitoring are:

- Adequate supplies of wholesome drinking water which is free from any micro-organisms, parasites and substances which, owing to their numbers or concentration, constitute a potential danger to human health: this shall include the protection of water resources which are used as sources of drinking water, treatment of water and the establishment, improvement and maintenance of collective systems.
- Adequate sanitation of a standard which sufficiently protects human health and the environment: this shall in particular be done through the establishment, improvement and maintenance of collective systems.
- Effective protection of water resources used as sources of drinking water, and their related water ecosystems, from pollution from other causes, including agriculture, industry and other discharges and emissions of hazardous substances: this shall aim at the effective reduction and elimination of discharges and emissions of substances judged to be hazardous to human health and water ecosystems.
- Sufficient safeguards for human health against water-related disease arising from the use of water for recreational purposes, from the use of water for aquaculture, from the water in which shellfish are produced or from which they are harvested, from the use of waste-water for irrigation or from the use of sewage sludge in agriculture or aquaculture.

1.3 EU legislation

European Union legislation provides a major tool for defining how European waters should be used, protected and restored in the 21st century. EU member states are solely responsible for the implementation of the requirements set in water-related directives. The two main approaches for combating water pollution are the Water Quality Objective approach and the Emission Limits Value approach – the former setting the minimum quality requirements for waters, and the latter specifying the maximum permissible quantities of pollutants that can be discharged into watercourses.

The protection of European surface waters is currently governed by various EU directives such as the Urban Waste Water Treatment Directive, the IPPC Directive, the Nitrates (from Agricultural Sources) Directive, the Drinking Water Directive, and the Bathing Water Quality Directive. In future, the most important water-related directive where monitoring is concerned will be the EU Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy – widely referred to as the Water Framework Directive, or WFD.

The WFD will establish a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwaters in the EU. The main aims of the WFD are to prevent further deterioration in aquatic ecosystems while protecting and enhancing their status, to promote sustainable water use, and to mitigate the effects of floods and droughts. The environmental objective of the WFD is to ensure that the ecological and chemical status of all waters within the EU is at least good by 2015 at the latest.

The WFD specifies the following bases for protection:

- Within a river basin where use of water may have transboundary effects, the requirements for the achievement of the environmental objectives established under this Directive, and in particular all programmes of measures, should be co-ordinated for the whole of the river basin district. For river basins extending beyond the boundaries of the Community, Member States should endeavour to ensure the appropriate co-ordination with the relevant non-member States. This Directive is to contribute to the implementation of Community obligations under international conventions on water protection and management, notably the United Nations Convention on the protection and use of transboundary water courses and international lakes, approved by Council Decision 95/308/EC(15) and any succeeding agreements on its application.
- It is necessary to undertake analyses of the characteristics of a river basin and the impacts of human activity as well as an economical analysis of water use. The development in water status should be monitored by Member States on a systematic and comparable basis throughout the Community. This information is necessary in order to provide a sound basis for Member States to develop programmes of measures aimed at achieving the objectives established under this Directive.

The ultimate goal of a harmonised system is further elaborated by the EU Commission in the WFD as follows:

- Technical specifications should be laid down to ensure a coherent approach in the Community as part of this Directive. Criteria for evaluation of water status are an important step forward. Adaptation of certain technical elements to technical development and the standardisation of monitoring, sampling and analysis methods should be adopted by committee procedure. To promote a thorough understanding and consistent application of the criteria for characterisation of the river basin districts and evaluation of water status, the Commission may adopt guidelines on the application of these criteria.

Instructions for monitoring are included in Article 8 of the WFD:

- Member States shall ensure the establishment of programmes for the monitoring of water status in order to establish a coherent and comprehensive overview of water status within each river basin district.
- For surface waters such programmes shall cover:
  (i) the volume and level or rate of flow to the extent relevant for ecological and chemical status and ecological potential, and
  (ii) the ecological and chemical status and ecological potential.
- These programmes shall be operational at the latest six years after the date of entry into force of this Directive (December 2006) .
- Detailed requirements of the monitoring programmes are presented in the Annex V (of the WFD).

Networks for monitoring the ecological and chemical status of surface waters are to be designed and established to provide coherent and comprehensive overviews of ecological and chemical status within each river basin, and will enable water bodies to be classified into five categories. Member States must provide maps showing surface water monitoring networks for river basin management plans.

On the basis of characterisation and impact assessment, Member States must establish surveillance monitoring programmes and operational monitoring programmes for each period of a river basin management plan. Member States may also need in some cases to establish investigative monitoring programmes.

Member States must monitor variables indicating the status of each relevant quality element. Estimates of the level of confidence and precision of the results obtained in the monitoring programmes are to be included in plans.

The WFD will inevitably affect monitoring practices in the EU, and lead to significant changes. Progress with the implementation of the WFD, and especially in the development of monitoring programmes and classification systems, should therefore be closely followed by the UN/ECE WGMA.

1.4 Other related programmes

Other international agreements and practices also affect monitoring activities in Europe. One of the most important programmes is the EUROWATERNET set up by the European Environment Agency (EEA). During the period 1994–2000, Eurowaternet was set up for five areas: Eurowaternet/Rivers, Eurowaternet/Lakes and Eurowaternet/Groundwater being the most developed of these areas, while Eurowaternet/Emissions and Eurowaternet/Quantity are still largely experimental. Eurowaternet has also been developed in the Phare Countries through close co-operation between the European Topic Centre on Inland Waters ETC/IW and its counterpart, the Phare Topic Link on Inland Waters. Data from Eurowaternet is stored in the Waterbase database (Boschet, Nixon and Lack, 2001).

Eurostat, the Luxembourg-based Statistical Office of European Communities, provides the European Union with statistics at European level enabling comparisons between countries and regions. Inland waters are a priority area for Eurostat – currently the only provider of statistics at European level. Data on water resources, water abstraction and use, and waste-water treatment and discharges will be provided through the Eurostat/OECD Joint Questionnaire. This data is collected in Member States by national statistical authorities, who also verify and analyse national data before submitting it to Eurostat. Eurostat's role is to consolidate data, and ensure it is comparable by using harmonised methodology. Data is then validated by both Eurostat and OECD. Eurostat data is highly relevant to the EU/Water Framework Directive and EU/Urban Waste Water Treatment Directive. The questionnaire data is to be published as part of the Eurostat NewCronos (THEME8/Environment and Energy) environmental statistics yearbook.

The United Nations Environment Programme's GEMS/WATER (Global Environment Monitoring System, Freshwater Quality Programme) aims to improve the understanding of fresh water quality issues around the world. Monitoring, assessment, and capacity building activities are a major element of the programme. The implementation of the GEMS/WATER Programme involves several UN agencies active in the water sector, as well as various authorities, institutions and organisations around the world.

2 INFORMATION NEEDS

2.1 The role of information

The availability of information accessible to the public is a vital pre-condition for the protection and sustainable use of transboundary waters, and for the implementation and enforcement of the Convention. Another primary goal of monitoring is to provide information to support decision-making. The most critical step in developing a successful and cost-effective monitoring programme is therefore the detailed definition of information needs to provide criteria to facilitate the design of a suitable monitoring and assessment system.

Institutions responsible for the protection and sustainable use of transboundary water bodies should be directly involved in the specification of information needs. Information users and information producers must first be identified. Information needs should be specified primarily according to an analysis of the water management of a river basin, and the subsequent identification of relevant issues. A distinction should be made between information used for policy preparation or evaluation, and information to be used in operational water management. Information users and producers should closely co-operate on specifying information needs.

The information required for the assessment of sustainable water uses and ecological functioning should be structured on the basis of issues, pressure factors and water management measures. In order to identify information needs properly, the concerns and decision-making processes of information users must be defined in advance. Inventories and preliminary surveys can help significantly both in identifying problems and issues, and subsequently during the specification of information needs.

2.2 River basin characteristics

Monitoring programmes for lakes should be based on the significant characteristics of the whole drainage basin, considering the whole hydrological cycle (Figure 1).

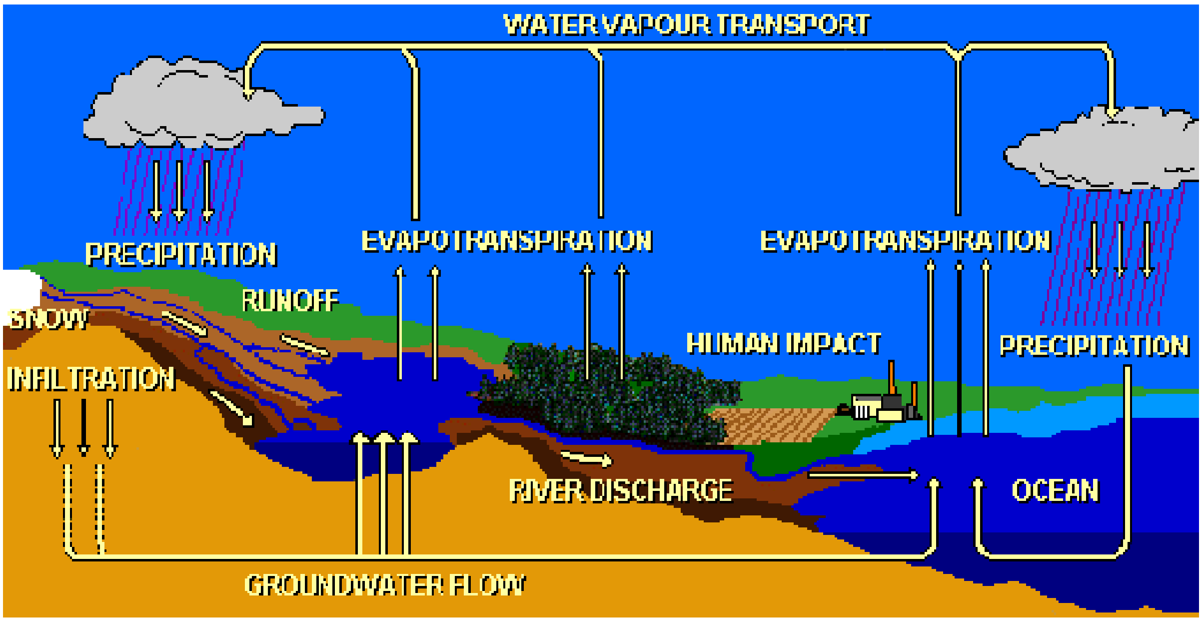

Figure 1. The hydrological cycle.

Lakes form only one element of the water cycle. To carry out a reliable monitoring programme, the interactions between lakes and other water bodies should be clearly understood. Accurate long-term monitoring of the entire hydrological cycle is essential. Reliable assessments of ecological or chemical trends in any water body cannot be conducted without hydrological data.

To obtain reliable quantitative and qualitative monitoring data on lakes or rivers, information is needed on both natural conditions in drainage basins, and pressure factors. Where monitoring and assessment are concerned, the necessary background information on entire drainage basins can be divided into the following categories:

- Climate and hydrology
- Land use
- Population density

- Waste-water loads
- Non-point-source loads (agriculture, forestry, etc.)

This basic information is already of great importance in the planning stage of monitoring programmes. The continuous monitoring of these factors must be also well organised, so that data from lake monitoring can be accurately processed and assessed.

2.3 River basin management

The various functions and uses of water bodies - both ecological and human - must be identified. Uses may compete or even conflict, in particular if water is scarce or its quality is deteriorating. A multi-functional approach tries to strike a balance between all desired uses, including ecosystem functioning. This allows the introduction of a hierarchy of uses, providing flexibility for the different levels of water resource management policy development, and for prioritisation in scheduling.

Water management always involves conflicts of interest. Most issues in a river basin are more or less closely linked with these conflicts. The three basic sources of conflicts are:

- competition for water (consumption v non-consumption uses such as navigation and waste-water disposal)
- conflicts between human interventions and nature (e.g. restoration of watercourses)
- conflicting interests of riparian countries upstream or downstream

Political priorities should be clearly defined in the analysis of water management issues. Possible sources of conflicts should be fully analysed before priorities are set.

The preparation of harmonised or joint water management plans for transboundary river basins falls within the scope of the Convention. These plans are currently based on the results of existing monitoring programmes. The basic requirements for more developed monitoring and assessment programmes should be derived from these water management plans.

Management plans also consider various land use issues, including deforestation, erosion and the diffuse pollution of water. They should preferably also include an analysis of other information needs, as well as strategies for tailor-made monitoring and assessment, the sharing of information among the riparian countries, and assessment of the effectiveness of the measures within them.

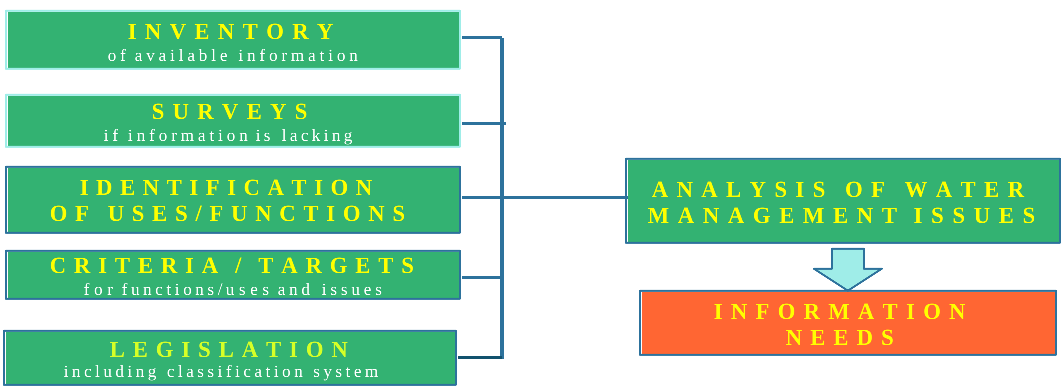

Figure 2. Water management analysis.

Several processes must be worked through before issues and priorities for the protection and use of a transboundary water body can be identified. These processes include the identification of functions and uses of the river basin; inventories on the basis of currently available information; surveys where information is lacking; the identification of criteria and targets; and an evaluation of water legislation in riparian countries (Figure 2). Well developed international river-basin management plans include all these activities.

Information needs should be based on the core elements in the management of an entire river basin, and on how information will be actively used in decision-making. Core elements can be defined as the functions and uses of the various water bodies; the issues (where criteria for use and functioning cannot be met); measures to be taken, including specific targets; and impacts on the overall functioning of the river basin. An issue can be defined as an existing or future problem or threat. Issues may also involve positive impacts where certain aspects of the environment are concerned, as is partly the case with eutrophication and fish productivity. The core elements and their interactions are shown in Figure 3.

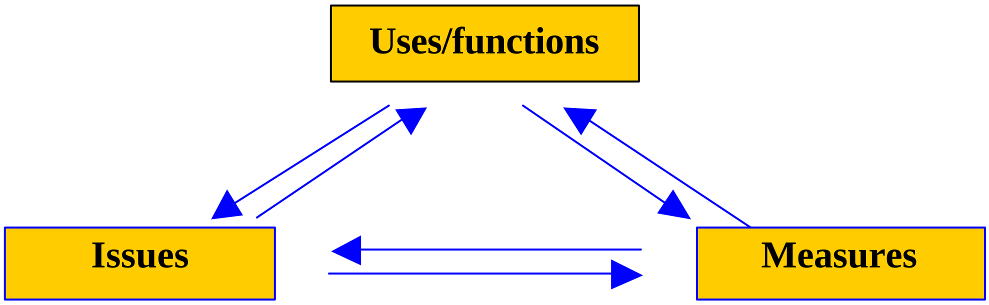

Figure 3. Core elements in water management.

Riparian countries must each identify, and then collectively agree upon the following factors:

- the specific human uses and ecological functions of a river basin
- issues with an impact on the human uses and ecological functioning of water bodies
- the existing and future pressure factors constituting these issues
- the relationship between the state of the river basin and the functioning of recipient waters
- criteria for uses and functions (e.g. water-quality objectives, design standards for flood protection, definitions of good ecological quality)
- quantitative management targets (e.g. pollution reduction targets, flood risk reduction), to be implemented within specified time periods

Each country should take into account current or envisaged measures, policies and action plans in water management. In specifying human uses and the ecological functioning of water bodies and in identifying pressure factors, issues and targets, the full range of qualitative and quantitative factors in river-basin management should be considered (Table 1).

As the Convention focuses on the river-basin approach, riparian countries should identify specific issues that are relevant to each of their transboundary water bodies, and set priorities. These priority issues and targets to a large extent determine information needs in the context of transboundary cooperation. Issues, targets and information needs identified at different levels (global, ECE region, river basin and local) should be clearly distinguished.

Criteria for uses or functions should be specific requirements following on from risk assessment considerations. Quantified management targets for transboundary water bodies should be based on water management policies agreed by the riparian countries. Targets can be criteria, standards or other resolutions.

USES/FUNCTIONS → ISSUES ↓	Human health	Ecosystem functioning	Fisheries	Recreation	Drinking water	Irrigation	Industrial use	Hydro power	Transport medium[1]	Navigation
Flooding	x	x		x					x	x
Scarcity	x	x	x	x	x	x	x	x	x	x
Erosion / sedimentation	x	x			x			x	x	x
Biodiversity		x	x	x						
River continuity		x	x	x				x	x	x
Salinisation		x			x	x	x			
Acidification[2]		x	x		x					
Organic pollution[3]	x	x	x	x	x					
Eutrophication	x	x	x	x	x	x	x			
Pollution (hazardous substances[4])	x	x	x	x	x	x	x			

Table 1. Examples of the relationships between uses or functions and issues in a river basin.

x Major impacts on functions/uses (problematic issues).
[1] Transport of water, ice, sediments and waste-water.
[2] Dry/wet acid deposition
[3] Organic matter and bacteriological pollution in waste-water discharges
[4] Hazardous substances, including radio-nuclides, heavy metals, harmful organic compounds and pesticides.

2.4 Pressure inventories and surveys

Preliminary investigations such as inventories and surveys are needed before any monitoring programme is started, so that issues, problems and risk factors can be clearly identified and evaluated.

Inventories should bring together all the available data, even where data which may be only indirectly comparable is scattered around different agencies or institutions and their various departments. This can involve the registering of historical data, licenses, etc. in administrative databases, as well as a general screening and interpretation of all the relevant information. For inventories of pollution sources, this will involve examining information at the source of pollution such as figures concerning production processes and the usage of raw materials, as well as the investigation of suspect incidents through additional questioning.

Inventories should cover major factors relevant to the identification of issues including: water uses and water needs in the river basin; run-off characteristics; the probability of sudden floods and ice drifts in the river basin; water quality (in physical-chemical, biological, ecological, hygienic and ecotoxicological terms); major point sources of pollution from industrial and municipal waste (considering the origin, composition and load of discharges); land uses and diffuse pollution sources from land use (with inventories of the use of agricultural fertilisers and pesticides); other sources of diffuse pollution (such as traffic, pipelines and airborne pollution); and potential sources of accidental pollution.

Water quality surveys give a preliminary insight into the functioning of the aquatic ecosystem, and the occurrence of pollution and toxicity in the water. The ecological status of a river, lake or estuary can be assessed by investigating the qualitative and quantitative structures of the biotic components of ecosystems (phytoplankton, macrophytes, the macro-invertebrate community, fish populations). Chemical screening of surface water, sediment and effluents at hot spots and key locations can be performed with the relevant supporting analyses. Any specific target compounds that inventories suggest might be expected to occur can also be analysed. Toxic effects in surface water, sediments and effluents can also be investigated at such locations.

Hot spots in surface waters, effluents and sediments should be identified through preliminary investigations. Inventories of the available monitoring data and information on effluent discharges will give a preliminary indication of where combinations of toxic effects may be expected.

2.5 Cause-effect relationships

When focusing on a specific water management issue, information is needed on the causes and effects of the problem, and any measures taken. Causality chains such as the DPSIR (Figure 4) set out the different aspects of issues. Information needs can be specified for one or more of these aspects.

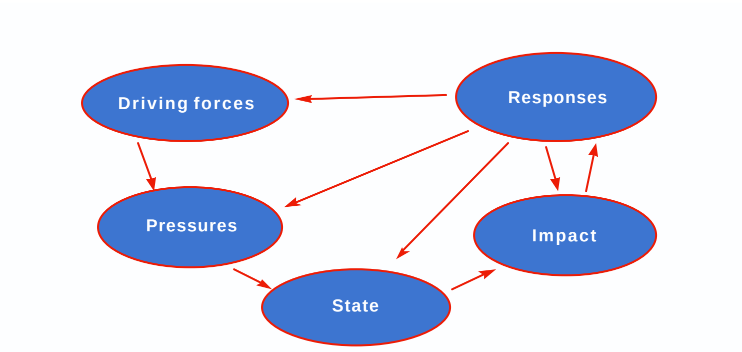

Figure 4: The Driving Forces-Pressures-State-Impact-Responses (DPSIR) framework (EEA).

Driving forces include human activities like urbanisation and agriculture which are often the main sources of problems and threats. Pressures include the stress such problems put on the functions and uses of a river basin. The state of a river basin is described in terms of concentrations of certain substances, and the hydrological or ecological characteristics of the basin. The impact element describes any loss of function or use, which might for instance be due to toxicity or unpleasant drinking water. Responses include policies and measures designed to deal with problems.

Information needs should be further specified to enable the design of an effective monitoring and assessment system. Specifications of information needs should include:

- the selection of appropriate variables or indicators to adequately fulfil specific information needs
- definitions of criteria for assessment, e.g. standard conditions for the application of early-warning systems for floods or accidental pollution
- requirements for the reporting and presentation of information (e.g. visuals, degree of aggregation, indices)
- definitions of suitable margins for each monitoring variable with regard to information users' concerns, including the degree of detail relevant for decision-making
- response times – for early-warning procedures information will be needed within hours, whereas for trend detection information may only be needed weeks or months after sampling
- levels of confidence required in data – it is normally either impossible or prohibitively expensive to obtain data that is 100% reliable, and confidence levels can vary, depending on the seriousness of any consequences. This is also a determining factor when locations, frequencies and methodologies are selected for monitoring programmes.

2.6 Identification of indicators

Information should preferably be presented in a comprehensive and condensed form. Data should be comparable between different places and situations, and should be linked to specific issues related to specific management needs. Indicators may be suitable for these purposes, and may also facilitate the specification of information needs. To identify suitable indicators, appropriate characteristics have to be selected. Variables should either sufficiently represent functions and uses of water bodies, express water quantity or quality, characterise an effect on a function or use, evaluate pollutant discharges, or be of value for testing the effectiveness of measures.

Riparian countries should agree on the choice of indicators. Important criteria for selecting indicators include:

- Communication: indicators should be suitable for users in all riparian countries
- Simplification: indicators should provide insight, without giving too much unnecessary detail
- Availability of data: enough data must be available to formulate reliable indicators

The Indicators for Sustainable Development devised by the United Nations (United Nations 2001) and the list of indicators in the EEA's Environmental Signals 2001 (EEA 2001) report are of great assistance in selecting suitable indicators.

2.7 Information objectives

Various information objectives can be defined, specifying the intended use of the information (purpose) and the management concern (e.g. protection of a specific use). The main information objectives for both effluents and water bodies are:

- to assess the current status of a river basin through regular testing for compliance with standards defined for various human uses, and targets for the ecological functioning of river basins.
- to test for compliance with permits for water withdrawal or waste-water discharges; or to set environmental charges
- to verify the effective implementation of policy measures, by detecting long-term trends in water levels, concentrations and loads, to assess progress in reaching targets
- to provide early-warning for water users in the event of flooding or accidental pollution
- to identify and understand water-quantity and water-quality issues through surveys examining such aspects as erosion patterns or the presence of toxic substances.

Since information needs are derived from issues, the prioritisation of issues leads on to a prioritisation of information needs. Information needs evolve as water management develops, as targets are attained, or as policies are changed. This means monitoring strategies often need to be modified over time. Changing information needs mean that regular revisions of information strategies may be necessary in order to update the whole concept. But the need for continuity in terms of the variables, locations and analytical methods used in time series measurements to detect significant trends in river-basin characteristics should not be neglected.

2.8 Evaluation of legislation

In transboundary river basins each riparian country generally has its own assessment criteria, water management targets and water-quality classification system. These often form part of the respective national water legislation, along with legal monitoring obligations. In transboundary contexts, riparian countries have to agree on common assessment criteria and management targets.

Riparian countries should compare and evaluate their own national water legislation and any other monitoring and assessment obligations arising from conventions, EU environmental legislation, or other agreements. They should jointly agree on criteria and targets in the context of transboundary co-operation (e.g. water classification criteria, flood risk criteria, and water extraction policy).

It is recommended that optimal use should be made of international standards and internationally recognised risk assessment criteria based on experimental data and current knowledge. The recent achievements and experiences of international organisations and river commissions can also be helpful.

A harmonised system of water classification should be developed with close regard to international systems and especially EU practice. This should not conflict with any national legislation in riparian countries, and must also be in line with international assessment practices. The following procedure may be useful in evaluating existing legislation (UN/ECE, 1998):

- Make an inventory of water-related environmental legislation and water classification methods in countries. Inventory existing regulations for data exchange between countries.
- Identify function-related international standards for the quality of surface waters.
- Identify recent developments in EU environmental legislation on surface waters.
- Identify significant experiences with the development of water-quality objectives in European river commissions (e.g. International Rhine Commission).
- Compare water legislation and classification methods of riparian countries and compare with international standards and EU legislation.
- Compare applied standards (related to their objectives) with internationally recognised risk assessment criteria.
- Propose a harmonised system of water classification that does not conflict with the existing national legislation systems.

3 MONITORING AND ASSESSMENT STRATEGIES

3.1 General strategy

The information needed to assess transboundary water bodies or to address problems linked to these waters can be derived from monitoring and other investigations. This can be demonstrated with the help of the policy life cycle (Figure 5). The problem recognition phase will involve different procedures than the policy formulation, policy implementation and results evaluation phases.

The first phase involves research. Thereafter, inventories and surveys are more important. It will be necessary to set criteria and targets, then to start monitoring temporal trends and spatial distribution, and finally to focus on compliance monitoring.

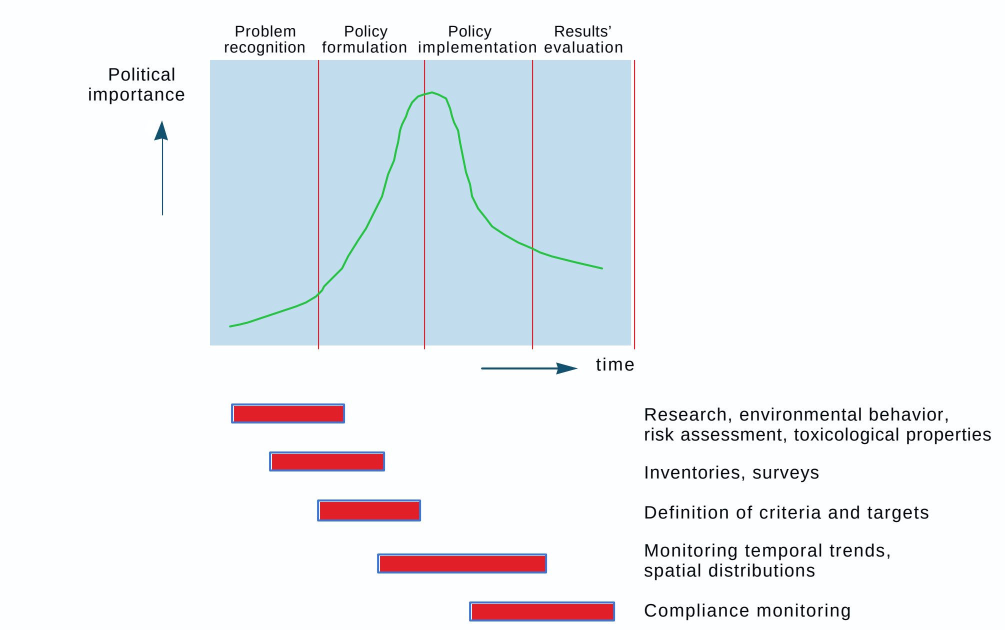

Figure 5. Policy life cycle.

The process of monitoring and assessment should principally be seen as a sequence of related activities starting with the definition of information needs, and ending with the use of the information product (Figure 6).

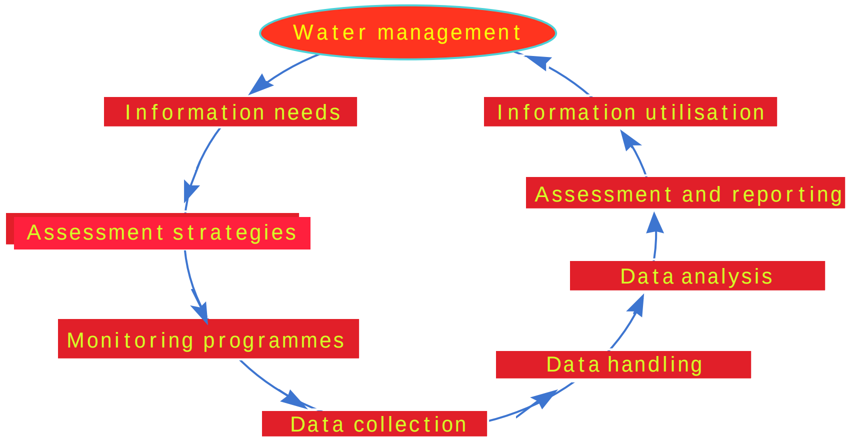

Figure 6. The monitoring cycle

Successive activities in this monitoring cycle should be specified and designed according to the required information product, as well as the preceding part of the chain. In drawing up programmes for the monitoring and assessment of river basins, riparian countries should jointly consider all stages of the monitoring process.

Information for river-basin management can be obtained from primary sources such as monitoring programmes, model-based computations and predictions, expert pronouncements, and databases and other sources of statistical or administrative information. The results of national monitoring programmes carried out under the responsibility of national or local governments will always form the basic information sources under the Convention.

After the specification of the information needs, assessment strategies must be drawn up so that monitoring programmes can be designed and operated to ensure the desired information is obtained. Strategies define the approach and the criteria needed for the proper design of the monitoring programme, ensuring that information needs are incorporated into monitoring networks.

The design of a monitoring programme includes the choice of locations for the sampling network; the selection of chemical, biological and micro-biological variables; the definition of sampling procedures (sample collection, frequencies, pre-treatment, method of storage and transport); and the planning of field measurements, laboratory analyses, data collection, data quality controls, data processing and data services. In large programmes involving several parties, institutional issues are very important.

Ten basic rules can be defined for successful monitoring and assessment programmes:

1. The information needs must be defined first and the programme adapted to them, and not vice versa. Adequate financial support must then be obtained.
2. The type and nature of the water body must be fully understood (most frequently through preliminary surveys), particularly the spatial and temporal variability within the whole water body as well as the relation between natural (morphometric, hydrologic and watershed) features and lake water status.
3. The appropriate media (water, particulate matter, biota, sediment) must be chosen.
4. The variables, type of samples, sampling frequency and station location must be chosen carefully with respect to the information needs.
5. The field equipment and laboratory facilities must be selected in relation to the information needs, and standardised methods or, in the lack of these, well documented methods must be used.
6. A complete and operational data treatment scheme must be established.

7. The monitoring of the quality of the aquatic environment must be coupled with the appropriate hydrological monitoring.
8. The quality of data must be regularly checked through internal and external control.
9. The data should be given to decision makers not merely as a list of variables and their values, but interpreted and assessed by experts with relevant recommendations for management action.
10. The programme must be evaluated periodically, especially if the general situation or any particular influence on the environment is changed, either naturally or by measures taken in the catchment area.

In European countries, the implementation of EU legislation is an important strategic aspect which must be taken into account. The EU Water Framework Directive will in particular be highly influential, especially in determining information needs in river basins. Monitoring activity will play a very important role in the implementation process. The WFD divides monitoring activities into the following three categories:

- surveillance monitoring
- operational monitoring
- investigative monitoring

Surveillance monitoring programmes are designed to provide information on the water body concerned for:

- supplementing and validating the impact assessment procedure,
- the efficient and effective design of future monitoring programmes,
- the assessment of long-term changes in natural conditions, and
- the assessment of long-term changes resulting from widespread anthropogenic activity.

The results of such monitoring shall be reviewed and used, in combination with the impact assessment procedure, to determine requirements for monitoring programmes in the current and subsequent river basin management plans.

Operational monitoring shall be undertaken in order to:

- establish the status of those bodies identified as being at risk of failing to meet their environmental objectives, and
- assess any changes in the status of such bodies resulting from the programmes of measures.

Investigative monitoring shall be carried out:

- where the reason for any exceeding is unknown,
- where surveillance monitoring indicates that the objectives set out in Article 4 for a body of water are not likely to be achieved and operational monitoring has not already been established,
- in order to ascertain the causes of a water body or water bodies failing to achieve the environmental objectives, or
- to ascertain the magnitude and impacts of accidental pollution, and shall inform the establishment of a programme of measures for the achievement of the environmental objectives and specific measures necessary to remedy the effects of accidental pollution.

3.2 The need for integrated assessment

Water management implies that water resources are managed in an integrated manner on the basis of catchment areas, with the aims of linking social and economical development to the protection of natural ecosystems, and relating water resource management to regulatory measures for other environmental factors. Such an integrated approach will influence the way in which monitoring programmes are designed and assessments made.

Aquatic ecosystems are not closed ecological systems, since they exchange materials and energy with their surroundings. The scope of assessments must therefore be broadened to explore linkages and interactions within ecosystems. The challenge lies in discovering the abiotic and biotic factors and the key linkages that provide for ecosystem integrity while maintaining balances in energy, chemical, physical and biological terms between interlocking ecosystems. The movements of chemical substances into and out of catchment areas should be studied as well as their internal dynamics. Transfers of pollutants between environmental media should also be assessed.

An integrated approach is also a departure from the earlier focus on localised pollution and the management of separate components of ecosystems in isolation. The profound influences of land use on hydrology and water quality have to be accounted for. Changes in human activities and any consequent habitat changes or other changes alongside water bodies that may effect their aquatic ecosystems should therefore also be assessed.

An integrated approach includes people as a central element in the well-being of the system. This involves the recognition of social, economical, technical and political factors that affect the ways people use nature. These factors should be assessed because of their ultimate effect on the integrity of the ecosystem.

Assessments should consequently be based as far as possible on integrated criteria in terms of water quality and quantity, as well as flora and fauna. To provide the basis for such assessments, water quality, flow regimes and water levels, habitats, biological communities, mass balances, and the sources and fate of pollutants should all be systematically analysed.

Water pollution control policies aiming to predict, detect and control waste loads entering river basins, and to assess water quality and ecological functioning in aquatic ecosystems must integrate the following elements:

a) physical-chemical analysis of water, suspended matter, sediments and organisms
b) biological surveys
c) ecotoxicological assessments

The combined use of biological surveys, bio-assays and chemical analyses improves the prospects for determining cause and effect relationships. This approach also leads to a more cost-effective assessment strategy, compared with approaches dominated by the monitoring of a rapidly increasing number of individual chemicals.

Assessments of environmental quality serve many aims (e.g. providing warnings, controls or predictions), and since the related information needs vary from broad indications to fine-tuned diagnostic figures, the choice of variables and methods will also vary. Stepwise testing strategies, generally leading from rough to more precise assessments, are recommended. Each step should conclude with an evaluation of the adequacy of the information obtained. Stepwise approaches can help reduce the information needs for future monitoring programmes (Figure 7).

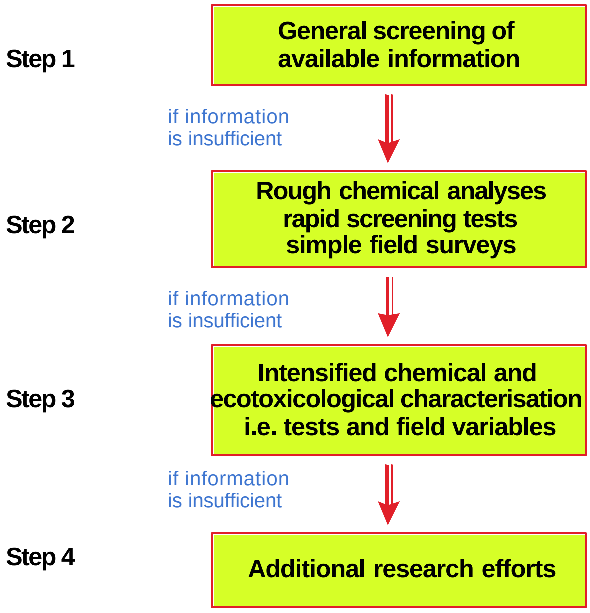

Figure 7. Stepwise testing strategies.

A phased approach to implementing monitoring efforts, going from broad to fine and from simple to more advanced, is usually advisable for reasons of cost-effectiveness.

Risk assessment can help considerably in prioritising monitoring activities. Risk assessment is recommended for the selection of variables in the monitoring programme. Predictions can be made regarding the environmental concentrations of chemicals produced and emitted into watercourses. Based on the ratio between predicted concentration levels and expected harmful effects, these chemicals might be included as variables in water-quality monitoring programmes. Risk assessment can be used to prioritise specific pollutants, based on their physical-chemical properties and toxicity.

Risk assessment, regarding both biological agents and chemical substances, will also help in setting priorities for establishing health-related monitoring systems or early-warning systems, and in selecting appropriate variables for monitoring.

Models (numerical, analytical or statistical) may play several roles in the monitoring and assessment of transboundary water bodies. They can assist in the integrated assessment of the transboundary area, in screening alternative policies, in optimising monitoring network design, in assessing the effectiveness of implemented measures, and in determining the impact on surface water systems and related risks to human health and the ecosystem. Models also play an important role in early-warning systems in the event of accidental pollution.

Models should be carefully calibrated and validated to avoid unreliable results. Successful mathematical modelling is possible only if the methodology is properly harmonised and integrated with data collection, data processing and other methods for the evaluation of surface water system characteristics.

3.3 Cost-effectiveness

The effectiveness and efficiency of monitoring and assessment can be improved by:

- specifying information needs and setting up accountable monitoring programmes
- using a combination of monitoring and models where beneficial (e.g. correlation models in water-quality assessment, rating curves for river flow, flood forecasting)
- selecting policy indicators and using aggregate characteristics, mixture toxicity variables, etc.
- integrating chemical and biological monitoring systems (including bio-assays) which can increase the effectiveness of monitoring (by determining cause and effect relations) as well as efficiency. Where appropriate, biological methods may be more economical to apply than chemical analyses. But the advantages of biological methods in indicating problems do not eliminate the need for chemical analysis for diagnostic purposes or for tracing pollution sources.
- using stepwise approaches for the screening of water, sediments and biota to gain more information at lower cost

Inventoried and specified information needs will probably require different monitoring networks to fulfil different monitoring objectives. The integration of monitoring activities for reasons of cost-effectiveness in an early stage of the monitoring cycle may result in the over-sizing or under-sizing of monitoring networks. It is therefore recommended that an information strategy should firstly be developed for each monitoring objective or information need. The integration of monitoring efforts may be considered during the implementation phase.

Riparian countries should provide sufficient funding for the implementation of monitoring and assessment in a transboundary context. This funding should be part of normal national budgets, or the regular budget of a joint body funded appropriately by the parties involved. External funding should only be sought only for specific purposes (e.g. surveys or training).

3.4 Hydrological data

Monitoring and mapping: Knowledge of various hydrological phenomena is of the utmost importance for the management of a river basin. Hydrological characteristics play a role in all functions and uses of any water body, but are especially important for such aspects as water supply, water quality, ecological functions, lake regulation, navigation, and protection against flooding. In many situations, information on hydrological variability and extremes is essential.

Hydrological monitoring programmes should be designed systematically through close co-operation between countries in or affected by the lake basin. The geographical coverage of these programmes should be the entire basin. Institutional aspects, such as the role of all main actors, should be carefully considered.

All basic components of the hydrological cycle should be measured, taking into account temporal and spatial aspects of hydrological processes. Most crucially, the factors controlling the water balance of a lake should be either measured directly or calculated by means of regional assessment or the water balance equation.

From the point of view of lake water balance, the key hydrological variables are typically regional precipitation, lake inflow, lake water level, lake evaporation, and lake outflow. Snow cover and ground water storage are also important factors in many cases. Important physical hydrological phenomena such as sediment transport, erosion, water temperature and ice phenomena can also affect chemical and biological processes in lakes.

A considerable part of the hydrological data should be collected in real-time or almost real-time to allow efficient lake management. Where data is collected in order to analyse basic hydrological variability, the requirement for real-time data collection is not relevant.

Monitoring programmes can include short-term measurements and campaigns as well as longer-term observations, and may be supported by various types of research programmes involving more intensive measurements.

All hydrological monitoring programmes should be evaluated regularly. There should be close co-ordination between hydrological monitoring and other monitoring programmes, considering modelling and assessment routines as well as reporting procedures.

Land use and other basin characteristics control the run-off process, so the management of a lake can greatly benefit from the use of geographical information systems (GIS). Basic GIS databases include the borders of main river basins and their sub-basins, as well as certain land use and geological classifications. Geographical information on the actual water bodies – rivers, lakes and shoreline - is also important.

The morphological characteristics of the lake itself are of key importance. A bathymetric map – preferably in a data system format – can be used for the definition of the morphological features, as well as for various physical, chemical and biological studies.

Hydrological modelling and forecasting: Modelling the hydrological cycle of a river system is a relatively straightforward process. Operational simulation and forecasting models have proven very efficient in drainage basin management, and in the case of international lakes they can play a very important role. Hydrological monitoring and modelling can form supplementary elements for linking with decision-support systems as well as ecological modelling and assessment.

Water level and flow forecasts should be provided daily for many functions and uses, including water supply, navigation, ecological functions, river channelling work, the operation of reservoirs, and flood prevention and protection. As the speed of movement of accidental pollution in a river system mainly depends on flow characteristics, provision should be made to use hydrological forecasts when accident or emergency warnings are to be issued. Forecasting is also particularly important during periods of drought, when river flows are low and the supply of water is inadequate to satisfy all the different water uses.

Flood forecasting is more intensive, and requires more frequent observations and data transmission. More observation sites and a wider range of information (e.g. on reservoir operation, dike failures and emergency measures) are needed. Forecasts can then be issued more frequently, and include additional characteristics such as the timing and magnitude of flood peaks.

Specific issues: Some important water-use data can be calculated by using hydrological observations. Examples include flows at industrial or municipal intakes and outlets, releases from reservoirs, and other main diversions to and from lakes. This information can be used for lake regulation or the allocation of water during extreme situations or normal operations.

Flood protection in international lakes requires agreement on flood protection criteria and acceptable flood risks. Here both economical and ecological damage are to be considered. Special attention should be paid to the comparability of flood forecasts, if more than one forecasting system is being used. Terminology and the structuring of messages should also be agreed. The risk of serious local flooding when rivers are blocked by ice may be an important factor in places.

Low-flow conditions can disrupt the use or consumption of water and the ecological status of a water body. Long-term series of data on hydrological parameters and the corresponding climatic factors are needed for the statistically reliable estimation of drought conditions. During droughts, more frequent exchange of information and data on reservoir operation, diversions and water uses may be necessary in addition to hydrological and meteorological data.

Riparian countries should jointly agree on the exchange of hydrological data, including time-scales and transmission procedures. Information should be comprehensive enough to attain the required reliability for hydrological forecasts, hydrological evaluations, water resources management and water-quality management. It is important to ensure that the roles of various actors in each country are clear. These arrangements should also cover operations in extreme situations.

3.5 Ecological functioning

The management of the aquatic environment should aim at sustaining or restoring the good ecological quality of river basins, so that substances or structural components from human activities have no significant detrimental effects on the ecosystem. More ambitious goals such as the preservation or possible restoration of aquatic ecosystems to a high ecological status should also be considered.

The EU Water Framework Directive (WFD) similarly describes good ecological status as: “The values of the biological quality elements for the surface water body type show low levels of distortion resulting from human activity, but deviate only slightly from those normally associated with the surface water body type under undisturbed conditions.”

The functioning of ecosystems should be considered in the whole catchment area. Different ecological regions can be distinguished on a smaller scale as well as world wide. The ecological region to which the river basin belongs should be clearly identified. River and lake types should also be distinguished, since this is an important factor in their assessment.

Basic elements in the ecological assessment of a river basin include biodiversity factors and the identification and description of comparable reference situations. Assessment should be closely linked to problems and detrimental aspects, and be based on representative indicators.

Biological assessment tools should be carefully chosen with respect to the intrinsic - actual or potential - ecological value and the designated functional uses of the ecosystem, as well as the character and size of the watercourse. The biological status of a water body can usually be assessed through the structure and functioning of biological communities. A reference state should be introduced against which the ecological condition of a system can be assessed. Because of the importance of abiotic as well as biotic factors for the functioning of ecosystems, integrated ecological assessment methods should be applied in addition to purely biological assessments.

3.6 Water-quality requirements for human consumption

Sustainable human use of the river basin has to be based on a multi-functional approach to water management. Suitability for various uses can be evaluated through specific water-quality requirements (criteria, objectives, and targets). Threats and pressure factors should be identified in terms of their consequences related to these requirements. The information required for the assessment of water quality to ensure the sustainable use of water resources and the protection of human health and safety should be specified accordingly.

Preliminary investigations should aim to identify specific issues in river basins, and facilitate the establishment of monitoring systems as effectively and efficiently as possible. Inventories and in-depth surveys should provide relevant background information with respect to the uses of water, the possible presence of pollutants not previously monitored, toxicological factors, and the spatial and temporal variability of pollutant distributions. Water-quality criteria and targets for specific uses must be agreed by the riparian countries.

Suitable variables should be selected as indicators related to identified issues or human uses. Aggregate parameters may be included where suitable. Specific chemical variables are to be included in monitoring programmes if they are the subject of special concern in a river basin.

Pollutants may occur in several different media, including suspended matter, sediments or organisms, as well as in the water itself. The appropriate media for monitoring parameters should be identified considering the following criteria:

- the occurrence of pollutants in the various media
- existing objectives and standards for specific media
- the capability to accurately detect pollutants in the various media

It is recommended that sediment quality should be monitored and assessed if there is a risk of detrimental affects on human health or environmental quality, and wherever dredging is planned. Sediment-quality problems are particularly an issue in sedimentation zones (such as reservoirs, floodplains, harbours, the lower reaches of rivers, lakes and estuaries) in river basins with substantial pollution, and where bank filtration is carried out (e.g. for drinking water production) through polluted sediments. Any material to be dredged should be monitored beforehand.

3.7 Early-warning systems

The ability to provide early warnings is not only important for lakes. As has been stressed elsewhere, it is important to consider the whole river basin where such issues are concerned. The effects of accidents such as oil spills in one part of the river basin will inevitably spread downstream, and eventually to the sea. It is therefore recommended that early-warning systems covering accidents and other emergencies should be set up for whole river basins wherever a use of water (e.g. a water supply intake) potentially threatened by accidental pollution can be safeguarded through emergency measures. River basin early-warning systems have four main elements:

- accident emergency warning systems
- hazard identification through databases
- models to be used during emergencies
- local screening of river water

Prior to the establishment of an early-warning system, potential sources of accidental pollution and all available emission data should be inventoried to find out which accidental pollutants could be threats. Risk analysis should highlight the critical risk factors to the functions and uses of the river. Such inventories and risk analyses should specify a list of priority pollutants to be the subject of early-warning procedures.

The establishment of an accident emergency warning system is recommended as the first step in providing an early-warning system for a river basin. This should include:

- a network of international alert centres in the river basin, where emergency messages from national or regional authorities can be received and processed without delay on a 24-hour basis
- agreements on international alerting procedures
- a reliable international communications system through which emergency messages can be forwarded to alert centres in riparian countries

The initial detection of high concentrations of pollutants or toxic effects at river sites can be performed through regular (e.g. daily) analysis of river water in nearby laboratories. The establishment of *in situ* automatic measuring equipment at early-warning stations may be feasible if frequent measurements or a fast reaction time are required.

The appropriate indicative variables to be monitored for early warnings will vary, and should be selected on the basis of:

- the past history of pollution emergencies (frequently occurring local risk substances)
- issues specific to the river basin (e.g. dissolved oxygen, pH)
- any additional need to detect specific micropollutants, such as heavy metals, harmful organic compounds or pesticides, using advanced technologies

Variables should also be selected for early-warning systems according to the availability of equipment for *in situ* measurements and other cost-benefit considerations, due to the high investment, operating and maintenance costs for automatic measuring devices. Acute toxic effects may also be recognisable with the help of biological systems examining species from different trophic levels and with various functions.

Any potentially hazardous pollutants that frequently occur in a river basin in concentrations that may jeopardise water uses should be targeted by early-warning systems. Simple indicative parameters such as dissolved oxygen, pH or oil substances can routinely be measured by automatic *in situ* sensors. If specific problematic micropollutants such as pesticides need to be detected, more advanced analytical systems can be used, although investment, operating and maintenance costs are high. Toxicological effects in organisms at various trophic levels can be measured with automated biological early-warning systems.

Early warnings should provide enough time for emergency measures to be taken. The locations of early-warning stations should therefore be determined with regard to the response time (the interval between the moment of sampling and the issue of an alarm) and the time any contaminant plume in a river will take to flow from the warning station to any site downstream where the water is used, such as a water supply intake. The diffusion of contaminants may be crucially affected by high river discharges. Sampling points should also be carefully located to ensure that the presence of all the relevant pollutants will be observed.

The frequency of measurements should be determined by the expected size of contaminant plumes so that no significant pollution is missed. Plumes will inevitably disperse to some extent between their discharge source and the sampling location, according to the characteristics of the river. Furthermore, sampling frequencies should allow sufficient time for action to be taken in the event of an emergency. Additional and intensified sampling is recommended after any first indication of accidental pollution.

3.8 Effluents and loads

According to the Convention, waste-water discharges have to be licensed by the competent national authorities, and authorised discharges should be monitored and controlled in order to protect transboundary waters against pollution from point sources. Limits for discharges of hazardous substances have to be based on the best available technologies. Stricter requirements are imposed when the quality of the recipient water body or ecosystem necessitates this.

There is currently increasing interest in monitoring additional chemicals and low concentration levels, due to the following trends:

- the increase in the number of chemicals which have to be considered during environmental impact assessment or to obtain permits and other monitoring requirements
- increasing knowledge of the adverse effects of extremely low concentrations of pollutants on human health and biota
- general decreases in the concentrations of individual chemicals in effluents, due to reduced industrial pollution and improved waste-water treatment
- rapid increases in the availability of chemical and ecotoxicological analytical methods

There may be a lack of information on microbiological characteristics in certain cases, meaning that a monitoring approach based solely on ambient water quality will be inadequate. Consequently, administrative controls over discharges of hazardous substances are vital tools for risk management in water pollution control.

The objectives of effluent assessment are:

- to screen effluent during the preparation of discharge permits
- to supervise authorised discharge permits (dischargers are widely obliged to carry out such monitoring themselves)
- to test for compliance with discharge limits, and for the setting of effluent charges (carried out by the authorities to monitor enforcement and control discharges)
- to estimate loads, with regard to possible pollution reduction or remedial measures, and in studies of the responses of recipient water bodies to reduced loads
- to provide early warning of malfunctioning or accidental spills

Effluent assessment strategies depend on the identified objectives, the characteristics of discharges, the number of discharged substances, the complexity of the mixtures discharged, and any variations in discharges. Continuous monitoring is recommended for early warning of large pollution discharges or for surveys of short duration to gain an insight into the variability of effluent discharges. Automated end-of-pipe effluent early-warning systems should be installed at high-risk industrial sites if there is any serious risk of accidental pollution, or where such systems can prevent direct threats to water body functions by fast corrective action.

Pollution load estimates are used to assess the total inputs of pollutants to rivers and the pollution loads the rivers discharge into recipient waters (lakes, reservoirs, seas). Riparian countries can agree on pollution reduction targets within set time periods. Assessments will concentrate on long-term changes in pollution loads, and on the effects of any measures taken to reduce pollution loads. Pollution from all sources is to be included in these assessments, allowing an evaluation of the relative contributions of the various sources in different countries to the total loads. For this reason the total loads from both point and diffuse sources should be inventoried and estimated. Estimates of pollution loads in a river basin are based on water-quality monitoring data (concentrations of the pollutants) and hydrological observations such as river discharge.

Long-term loads are needed, including annual figures. This requires the combination and integration of water discharge records and data on concentrations for the entire period. Both pollutant concentrations and water discharges vary over time, due to the nature of the pollutants and their sources, the mechanisms of transportation in rivers, the hydrological systems of rivers, and the frequency of extreme flow conditions.

It is recommended that simple and transparent methods should be used for estimating diffuse pollution loads. Rough estimates could be fine-tuned later on as necessary. For the sake of comparability, it is of the utmost importance that riparian countries should document results carefully, making all steps transparent. The principal sources of diffuse pollution and the selected substances must firstly be defined, as well as the routes of these substances into the water body.

The selection of monitoring variables should be based on the likelihood of the occurrence of specific pollutants in effluent discharges, according to their application or occurrence in production processes, or their presence in the raw materials used. Sampling frequencies and sampling methods for effluent discharges should be based on the quantities of effluent discharged, also considering their variability. The statistical significance and accuracy required for specific objectives such as compliance testing or load calculation can provide a basis for the selection of sampling frequencies and sampling methods.

3.9 Practical implementation of monitoring programmes

Considerations of the local representativeness of sampling points are to be based on preliminary surveys, taking hydrology and morphology into account. In general, the selection of sampling sites in a river basin must be based on their representativeness with regard to the water body concerned.

In transboundary lakes, sampling should preferably be performed at or near borders. Sampling at outlets and in main tributaries upstream of a lake is important, to show their respective contributions. The section of a lake that any monitoring location and its results are intended to represent should be clearly defined.

Where quantitative and qualitative data are to be used in combination, the locations used for hydrological measurements and for water-quality sampling should be the same, as far as possible. Different locations are only permissible where the relationship between the hydrological characteristics of the two sites is completely unambiguous.

Water quantity and quality, sediment characteristics and biota vary spatially and temporally. The monitoring objectives greatly determine the time-scale selected. Sampling frequencies and methods should be selected on the basis of temporal and spatial variability as well as the monitoring objectives. Joint measurements are recommended to improve the cost-effectiveness and comparability of results.

Quality control should be performed on a national level, to ensure that institutions involved in monitoring programmes achieve acceptable standards of accuracy and precision. Inter-laboratory testing at the level of the whole river basin is vital to ensure the comparability of data where transboundary water bodies are concerned.

The choice of water quality monitoring sites within a lake is more complicated. A sampling network must be planned with the help of a bathymetric map and suitable information on prevailing currents in the lake. The precise locations of waste-water outlets and other possible sources of pressure factors must also be known. Sampling sites are usually located in the deepest parts of lakes to allow the sampling of different layers of water.

The number of sampling sites depends on the total area of the lake, and the possible existence of separate deeper waters. The general status of the lake must also be considered. Major discharges must be monitored with a sampling network so that the effects of loading can also be estimated as a function of distance. In addition to the sampling of deep waters, data from lake-bottom areas nearer the shoreline is also needed. The sampling of phytoplankton, macrophytes, lake-bottom fauna and fish must be planned to support observations of physical and chemical characteristics as well as simultaneous hydrological observations.

Monitoring frequencies should be selected to take account of variability in parameters resulting from both natural and anthropogenic conditions. The timing of monitoring should be determined to minimise the impact of seasonal variation on the results, thus ensuring that results reflect changes in the water body due to anthropogenic pressure factors.

In general, variables are selected for monitoring according to their usefulness as indicators, their occurrence, and any harmful characteristics. Variables should be indicative of functions and issues in river basins. For reasons of efficiency, the number of variables should be limited by only adopting variables with explicitly identified uses. The additional value of any further variables under consideration should be assessed for cost-effectiveness.

The need to obtain information which is integrated or differentiated over time and space should govern the selection of methods for the measurement and sampling of water, sediment and biota. Various alternative methods may be chosen, including grab sampling, depth integrated sampling, time proportional composite sampling, and space composite sampling. Protocols to ensure the comparability of results and to prevent sample contamination should be established for all sampling methods.

To avoid changes in the samples during transportation and storage before analysis, sufficient attention should be paid to careful handling and rapid analysis. Analytical and biological methods and ecotoxicological tests should all be well validated, described and standardised, and be sufficiently selective and thorough. The required sensitivity, accuracy and precision of analytical methods will depend on the margins defined for the use of the information.

3.10 Special aspects of lakes

The geographical distribution of lakes in Europe is very uneven. Some countries or regions have hundreds of thousands of lakes or ponds, and dozens of lakes larger than 100 km^2 – notably Russia (particularly Karelia and Kola in the north-west), Norway, Sweden and Finland – while other countries only have a few smaller lakes and no larger lakes at all.

In some countries reservoirs are the most common type of water body. Artificial reservoirs can resemble natural lakes in many ways, but one crucial difference is that reservoirs are always built with a particular use in mind. The most common purposes for the construction of reservoirs are water supply, irrigation and hydropower generation. The main idea is usually to store water, delaying its flow from a wet period to a dry period, when the demand for water is higher. In southern Europe, where droughts can last many years, some reservoirs have been designed store up to three or four times the average annual flow.

The total volumes and residence times of the water in lakes vary greatly. Usually the average depth of lakes is quite low, except in certain mountainous areas where maximum depths can reach several hundred metres. In many European countries, the total fresh water resources contained in lakes are extremely limited, especially compared to the total populations of the drainage basins concerned. External pressures from different sources on the quantity and especially the quality of lake water are extremely serious in such areas.

Lakes differ from rivers as ecosystems in many respects, such as their hydrological circumstances, thermal properties, production/decomposition relations, sedimentation rates and composition, and the stability of certain phenomena. Lakes are almost closed systems. Substances introduced into a lake may become permanently incorporated into its cyclical processes, with only a proportion of the total load being removed, according to the rate of replenishment. Rivers are open systems, where substances are more or less constantly transported downstream. These factors should all be carefully considered in the planning and implementation of monitoring programmes for lakes.

In many rapidly flowing stretches of rivers, water quality is quite homogenous, and wastes discharged into rivers may be diluted very quickly by the natural river water. But in lakes, waste-water can proceed through deeper waters during stratification periods for considerable distances without any real mixing. Heavier industrial waste-water effluents can destroy large areas of bottom sediments and their biota in this way. The concentrations of many pollutants may differ by factors of tens or even a hundred between the surface water level and bottom levels.

Temperatures in rivers quite closely follow changes in air temperature. In deeper lakes, seasonal vertical temperature distributions must be taken into account in sampling. Many northern European lakes are dimictic, i.e. the whole water mass only mixes twice a year, in spring and in autumn. During the summer, thermal stratification is clearly evident in all deeper lakes. In the upper water layer, the temperature is higher, and may equal water temperatures in local rivers at the same time. This warm layer is known as the epilimnion. The temperatures in the deeper layer of the lake can remain much colder (5 – 10 ^{o}C) during the entire stratification period. This cold bottom layer is known as the hypolimnion, and is very important from the monitoring point of view, since in many cases the earliest indications of pollution problems are most detectable in the hypolimnion.

The dominant biological process in rivers is the decomposition of organic matter, and primary production is much less important. In contrast, in deeper lakes with clear thermal stratification, the dominant biological phenomenon in the epilimnion during summer time is primary production. In the hypolimnion primary production cannot normally be detected, and the dominant process is the decomposition of organic matter by bacteria.

Sedimentation is also a very important process in lakes, and has a dominant role in nutrient cycles, and thus also in the eutrophication process. Sedimentation zones must be identified before monitoring programmes are implemented.

Residence times also have a considerable effect on both eutrophication and the rate of recovery of polluted lakes.

The status of European lakes varies greatly. In more remote areas with very low population densities, including many parts of the Nordic Countries, the status of lakes and the usability of lake water can still be excellent. Any differences from the natural state are so marginal that they cannot be detected through routine monitoring methods. Other regions, however, have such a long history of water pollution that all the original natural structures and features of biotopes have been totally destroyed. In these cases there is little hope that the original characteristics of such lakes can ever be restored.

The major problems that have widely affected lakes and their ecological status and usability for different human purposes have been listed by Premazzi and Chiaudani (1992):

- excessive inputs of nutrients and organic matter, leading to eutrophication
- hydrological and physical changes, such as water-level stabilisation
- increased siltation, due to inadequate erosion control in farmland
- acidification from atmospheric sources
- contamination by metals and organic micro-pollutants
- the introduction of exotic species

Particularly in northern Europe, relatively high concentrations of humic substances in lake water can cause special problems, which should be accounted for in the preparation of monitoring programmes for humic lakes, and especially in the assessment of monitoring data. High humic concentrations in such lakes affect both the intensity of primary production in the epilimnion, and particularly the oxygen balance.

4 DATA AND QUALITY MANAGEMENT

Data produced by monitoring programmes should be validated, archived and made accessible. The goal of data management is to convert data into information that will meet the specified information needs and the associated monitoring objectives. The combined use of data from multiple sources places high demands on data exchange systems and data management systems.

To safeguard the productive future use of the data collected, four data management steps are required before the information can be properly used:

- Data should be analysed, interpreted and converted into defined forms of information using the appropriate data analysis techniques.
- Data should be validated or approved before it is made accessible to users or entered into archives.
- Information should be reported to users for decision-making, management evaluation or in-depth investigation. Information should also be made accessible to the public, and presented in tailor-made formats for different target groups.
- Data needed for future use should be stored, and the exchange of data should be facilitated at all other appropriate levels (international, ECE regional, river basin, etc.) as well as within the monitoring body itself.

The first archiving of monitoring data generally takes place at the monitoring agency. According to the Convention, transboundary co-operation has to involve the exchange of data. To facilitate the comparability of data, clear and precise agreements should be made on the coding of data and meta-information. Standardised software packages for data management should be applied where data is to be stored, with data storage formats used to increase the opportunities for data exchange. Framework agreements regarding the availability and distribution of data can further facilitate data exchange. The relevant data terminology should be jointly compiled and agreed, including definitions of terms used during the exchange of information or data.

In addition to the quality control carried out on separate procedures, such as sampling, measurements and analyses, data validation should be an intrinsic part of data handling. Regular controls over newly produced data should include the detection of outliers, missing values and other obvious mistakes. Only when data has been thoroughly checked, and the necessary corrections and additions made, can it be approved and made accessible. To be available for future use, data should be stored in such a manner that it is accessible and complete, with respect to all the conditions and qualifiers covering data collection and analysis.

Furthermore, a sufficient amount of the secondary data, or 'meta-data', needed to interpret the data, must also be stored. Details of the times and places of sampling, the type of sample, and any preconditioning and analytical techniques used are commonly stored for these purposes. If monitoring is performed in any media other than water (e.g. in suspended solids or biota), relevant meta-data such as the total amounts of substances in different media and particle size distributions should be recorded.

The data needed for such purposes as the assessment of the ecological state of a water body or for load calculations is often produced by separate monitoring programmes run by various laboratories or agencies. Data from other sources is often indispensable for assessment purposes, in addition to the monitoring data itself. Special attention should be paid to the validation and quality control of the process of data collection from these multiple sources. The use of software for the integration of data is unavoidable.

Geographical information systems (GIS) are among the important tools for the integrated interpretation of data together with any other information (e.g. maps, satellite images, land use data etc.) that may be needed to assess water quality and quantity, or in the event of accidental pollution, flooding, etc. This allows external models to be used, with controlled access to the system given to a broad range of information users, and reports adapted to suit the recipients.

Integrating data originating from different agencies or sources into a single system is not easy. Data-bases should be suitably harmonised. Standardised interfaces should be used to interconnect databases and provide for integration with a GIS. Relational databases should preferably be used to facilitate integration with GIS and models. Data processing based on jointly accepted, compatible standards will make assessment and reporting comparable, even when the software used in the various riparian countries differs.

Converting data into information involves data analysis and interpretation. Data analysis should be embedded in a data analysis protocol (DAP) that clearly defines a data analysis strategy, taking into account the specific characteristics of the data concerned, such as missing data, detection limits, censored data, data outliers, non-normality and serial correlation. The adoption of DAPs gives the data-gathering organisation or country a certain flexibility in its data analysis procedures, but requires that these procedures should be documented. Data will generally be stored on computers, and the largely statistical process of data analysis can make use of generic software packages. The use of tailor-made software is recommended, in order to achieve standardised automated data analysis.

For international data storage purposes, a central system may be considered. This task could be given to joint bodies including representatives of the national authorities of the riparian countries concerned. Guidelines and tools developed within the framework of EUROWATERNET may support such activities.

The goals of quality management in monitoring and assessment can be expressed in the terms effectiveness and efficiency. Effectiveness is the extent to which the information obtained from the monitoring and assessment system meets the information needs. Efficiency is concerned with obtaining the information as economically as possible in financial and human resource terms. Traceability as a further goal of quality management is concerned with defining and documenting the processes and activities that lead to the information, and how results are achieved.

Quality policy defines the level of quality to be reached. Joint bodies should define quality policy, and thus set the prerequisites for quality management. It is imperative that all the organisations involved in performing quality management are fully committed. Striving for quality involves investments in quality systems and staff training. Quality management can therefore only be put into practice when the management of the responsible monitoring organisations are committed, and provide sufficient funds.

Where transboundary co-operation is concerned, arrangements for producing and sharing information are particularly important. Quality management supports such arrangements, because it describes the procedures to be implemented, and forms a basis for cooperation between riparian countries. Quality management systems should therefore be adopted by joint bodies, although such quality systems should be limited to activities not yet covered by existing quality systems within the riparian countries.

Quality systems should document the relevant activities, interactions between these activities, and the relevant products in the form of procedures and protocols, dealing with every element of the monitoring cycle. Additionally, quality systems should allocate responsibilities with regard to the procedures defined. In drawing up procedures, special emphasis should be placed on responsibilities where decisions are made, such as the approval of monitoring and assessment strategies, or the acceptance of samples at a laboratory. Procedures and protocols should define what documentation should be produced about the monitoring process, such as the loss of any sample trays or weather conditions during sampling. Adherence to procedures should be checked periodically, while evaluation of the usefulness of procedures is also essential.

Protocols for the specification of information needs, defining monitoring and assessment strategies, monitoring programmes, *in situ* measurement and sampling, sample transport, sample storage, laboratory analysis, data handling (including validation and storage), data analysis, data exchange and reporting should be drawn up and agreed by riparian countries. These protocols define the operational steps in a process where insufficient quality control may result in unreliable data. By following such protocols, mistakes can be traced and minimised.

For *in situ* measurements and samplings (e.g. water level, river flow, transparency, temperature), special emphasis should be put on protocols describing procedures in the field, since such measurements cannot be reproduced. It is essential to document sampling and measurement conditions in these protocols.

Requirements for all relevant products should be specified and documented. Quality systems describe how requirements are integrated into processes, and how deviations from requirements are dealt with. Standard requirements on recurrent products are set out in the quality system. Monitoring data should only be used as input for models and GIS presentations where it is fully suitable for this purpose.

Standards for methods and techniques should be defined for procedures including measurements and sampling, the transport and storage of samples, laboratory analysis, data processing, data handling (including validation and storage) and data exchange, calculations and statistical work. International standards should preferably be used. If international standards are not available, or are inadequate for some reason, national standards should be applied or developed. The standards used by riparian countries need not be the same, but must provide comparable data for exchange purposes. Joint bodies should agree on the standards to be used by riparian countries.

5 REPORTING

Reporting is the final step in the gathering of information, and links this process to the information users. The main issue here is to present the interpreted data in an accessible way. How this information is to be presented depends greatly on the audience to be addressed.

Reports should be prepared on a regular basis. They need not necessarily be printed, but can take other forms, such as oral reports or digital representations. The content of reports, which may involve transferring data analyses or merely giving a brief overview of conclusions, and their frequency and level of detail will depend on how the information is to be used. Technical staff will need detailed reports more frequently than policy makers, for instance.

Reporting has to be tailored to meet the needs of those who request the information. Public authorities, including joint bodies, usually request information in a formalised manner. In such cases, the content and frequency of reports are defined in reporting protocols. Such reports are usually presented in writing to ensure results are clearly understood.

Public authorities may also receive ad hoc requests for information which is not routinely included in reporting protocols, but which may be related to specific current water management issues. This kind of reporting has to meet strict requirements concerning response time and flexibility.

Reports prepared for individuals or environmentalist groups or organisations are usually the result of ad hoc requests for information, and cannot be predefined in reporting protocols. The Aarhus Convention and Guidelines on Public Participation in Water Management may facilitate such reporting. Public access to relevant information is also stressed in the provisions of the Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters (1998). Raising the awareness of progress in water management will increase governmental and public support for measures.

Quality status reports or environmental indicator reports should provide concise information to support decision-making in water management. Quality status reports typically provide information on the functions of water bodies, describe problems and the pressures they lead to, and give insight into the intended impacts of corrective measures. Quality status reports are much more useful for decision-making purposes where simplifying indicators and visuals are used.

Standardisation of reports is encouraged within river basins and at the international level (e.g. the ECE region). Joint river-basin quality status reports should preferably also be produced. To produce reliable reports on the state of river basins as regards safe human uses and ecological functioning, countries party to the Convention will need to improve data comparability (e.g. by standardising laboratory analyses), and develop DAPs.

DAPs should be extended to provide reporting formats for the resulting information, and should set out formats for reports, publication frequencies, stipulating the intended audience, distribution procedures, and the types of conclusions to be drawn and represented. Information should always be supplied according to the information needs and the related monitoring objectives.

It is recommended that annual status reports for each river basin should be provided to focus on the link between policy measure responses and the status of the water body concerned. A Convention-wide reporting system which would cover all catchment areas within countries party to the Convention is also recommended to encourage the regular evaluation of progress made under the

Convention (e.g. for three-year periods), to stimulate commitment, and to make results more available to the public.

National and international reporting obligations should be inventoried to ensure all reporting requirements laid down in water management legislation are fulfilled. The European Environment Agency's Reporting Obligations Database includes an overview of many international reporting obligations. This database may be complemented with reporting obligations under national, bilateral or multilateral legislation.

The Internet is a powerful tool for sharing and communicating information, and can be used to inform and involve the public. Officials are often wary about presenting environmental information and data to the public, since there is a danger that it might be misinterpreted by those with less special expertise; but involving non-governmental organisations and individuals in transboundary water management can help to promote truly sustainable international co-operation.

6 CO-ORDINATION AND INSTITUTIONAL ISSUES

According to the Convention, riparian countries are to draw up bilateral and multilateral agreements or other arrangements on the relevant issues, including arrangements for monitoring and assessment. The Convention also foresees the establishment of joint bodies as one of the main vehicles for transboundary cooperation.

One critical obligation is that information on the issues covered by the Convention must be exchanged as widely and as early as possible. This obligation covers both the sharing of monitoring data and information on the status of transboundary waters, and the provision of public information. It also involves sharing data and information generated through other activities, such as preliminary investigations, surveys and literature searches (e.g. regarding water-related laws and regulations).

The recommendations in the previous chapters and sections show that improving the monitoring and assessment of transboundary waters is a complex process involving much more than technological and technical improvements. Better procedures for specifying information needs and improved assessment strategies are also required, together with modifications to existing legislation in some cases. Other important factors may have positive or negative effects on monitoring and assessment processes. These factors include the drafting and implementation of policy plans; the sharing out of responsibilities between institutions; the achievement of agreements on transboundary waters; progress on access to information; and the building up of confidence between partners. While improvements in these areas can contribute greatly to the monitoring and assessment of transboundary waters, it is also true that suitably conducted monitoring and assessment work will lead to progress with these important environmental policy and management issues.

References

Boschet, A.-F., Nixon S. C. and T. J. Lack, 2001. Topic report 2/2001, European Topic Centre on Inland Waters, Annual topic update 2000.

Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters (Aarhus, Denmark, 25.6.1998), E/ECE/1366; United Nations, New York and Geneva, 1998.

Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Helsinki, 17.3.1992); United Nations, New York and Geneva. 1994.

EEA. 2001. Environment signals 2001. European Environment Agency regular indicator report. . Environmental assessment report No 8.

EUROWATERNET. The European Environment Agency's Monitoring and Information Network for Inland Water Resources, Technical Guidelines for Implementation, Technical Report No. 7. Copenhagen, 1998.

Guidelines on Monitoring and Assessment of Transboundary Groundwaters, UN/ECE Task Force on Monitoring and Assessment (Lelystad, Netherlands), March 2000.

Guidelines on Water-quality Monitoring and Assessment of Transboundary Rivers, UN/ECE Task force on Monitoring and Assessment, RIZA report 96.034 (Lelystad, Netherlands), 1996 (second edition in 2000).

Premazzi, G. and Chiaudani, G., 1992. Ecological Quality of Surface Waters. Quality Assessment Schemes for European Community Lakes. European Communities Commission, EUR 14563, Ecological Quality of Surface Quarters, Environmental Quality of Life Series. Environmental Institute, University of Milan, Milan, Italy.

Protocol on Water and Health to the 1992 Convention on the Protection and Use of Transboundary Watercourses and International Lakes (London, 17.6.1999), MP.WAT/2000/1 - EUR/ICP/EHCO020205/8Fin ; United Nations. Geneva and Copenhagen.

UN, 2001. Indicators of Sustainable Development: Guidelines and Methodologies, New York.